DoD EPA DOE

SERDP

Strategic Environmental Research and Development Program

ANNUAL REPORT TO CONGRESS

Fiscal Year 2002

March 2003

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Strategic Environmental Research and Development Program

ANNUAL REPORT TO CONGRESS— FISCAL YEAR 2002

FROM THE STRATEGIC ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAM

March 2003

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EXECUTIVE SUMMARY

The Strategic Environmental Research and Development Program (SERDP) is the Department of Defense's corporate environmental science and technology program. To fulfill its mission to address environmental problems through innovative research and share that information across federal and private organizations, SERDP executes the program in partnership with the Department of Energy and the Environmental Protection Agency. Further, SERDP fully leverages complementary programs within the Department of Defense and solicits interest from other public and private research organizations.

The organization and management of SERDP is described in Section I. As directed by the SERDP Council, the Executive Director and Program Office Staff implement the Program with the support of various working groups and panels to meet high priority, DoD mission-related environmental needs. The activities, achievements, and recommendations of the SERDP Council, Scientific Advisory Board, and Executive Director are detailed in this section.

SERDP conducts basic research through advanced technology development in the following five Technology Thrust Areas: Cleanup, Compliance, Conservation, Pollution Prevention, and Unexploded Ordnance (UXO). Section II describes significant accomplishments achieved during FY 2002 within each of the Thrust Areas. Highlights of these accomplishments include: (1) new technologies to remediate and/or contain groundwater contaminated with explosives and ammonium perchlorate; (2) new technologies capable of detecting UXO with high detection rates to significantly reduce the cost of DoD site characterization and cleanup; (3) advances to achieve the long-term sustainability of DoD testing and training ranges, including techniques to assess the risk posed by residues from live munitions on military ranges; (4) innovative monitoring techniques to ensure that Navy operations do not adversely impact marine mammals; and (5) new steel alloys that eliminate the need for toxic corrosion protection coatings on weapons platforms. Each of these advancements will ensure DoD maintains mission-readiness while complying with high-priority and emerging environmental requirements.

In each fiscal year cycle, SERDP must manage ongoing research within the program, solicit and select new research projects, and plan future research initiatives and funding distribution for each Thrust Area. Section III provides an overview of the SERDP Program, including the goals, environmental and operational research drivers, actual and planned funding levels, and the planned research initiatives for the Program. In FY 2002, SERDP was appropriated $62.2 million for the funding and management of 165 research projects. The FY 2003 appropriation of $52.3 million will be used for at least 133 projects, including both continuing and new start projects. Summaries of each project funded in FY 2002 and those planned for funding in FY 2003 are provided for the five Thrust Areas in Appendices A through E. Research topic areas for which proposals will be requested for projects to be funded in FY 2004 are provided in Appendix F.

This report provides a summary of SERDP's activities and its most significant accomplishments for FY 2002, its plans for FY 2003, and new research activities to be addressed in FY 2004. It responds directly to the requirements as stated in Title 10, U.S.C. section 2902, as modified. This report complies with FY 2001 amendment to the SERDP statute that repeals the requirement for an Annual Report from the SERDP Scientific Advisory Board, and includes the contents of that report in this Annual Report to Congress.

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I. PROGRAM MANAGEMENT

Background

Authorizing Legislation

In June of 1990, Senator Sam Nunn addressed the Senate to advise his colleagues about the seriousness of the environmental problems faced by this nation, and specifically by the Department of Defense (DoD) and the Department of Energy (DOE). Having recently been relieved of the strenuous efforts and financial burden of the Cold War, it became apparent to Senator Nunn and others that a significant capability existed both in the nation's Federal research infrastructure, as well as the defense industry, whose technical skills could be brought to bear on this Nation's environmental matters of concern. From this revelation, he recommended the creation of a Strategic Environmental Research Program, composed of several Agencies and Departments, that would seek to apply defense technologies for environmental benefits.

Later that year, Public Law 101-510 (Title 10, U.S.C., §§2901-2904) established the Strategic Environmental Research and Development Program (SERDP) funded by DoD and planned and executed in partnership with DOE and the Environmental Protection Agency (EPA). The immediate success of the Program led to SERDP becoming the DoD's corporate environmental Science and Technology (S&T) program. SERDP fully leverages complementary programs found within the Army, Navy, and Air Force, and those of the DOE and the EPA. Over the past decade, measures have been implemented to take full advantage of the intrinsic capabilities of the participating organizations. This feature makes SERDP unique, as it can tap the vast technical resources of the Federal research infrastructure to meet the needs of our most pressing environmental matters of concern. During the past seven years, SERDP has successfully engaged in directly funding the private sector and academia in a step that further widens the spectrum of technological capability and innovation.

This report provides a summary of SERDP's activities and most significant accomplishments during fiscal year 2002, its plans for fiscal year 2003, and new research initiatives to be addressed in fiscal year 2004. It responds directly to the reporting requirements as stated in Title 10, U.S.C. §2902. Subsection 2902(d)(3) was amended in 2000 to include subsection (D) which requires that the SERDP Annual Report contains a summary of the actions and recommendations of the SERDP Scientific Advisory Board (SAB) during the preceding year.

Mission

The purposes or mission of SERDP can be found in the statute and are paraphrased below. The clear intent of Congress was to not only address environmental problems through research efforts, but also to share information across and within Federal and private lines in order to more rapidly and effectively deal with these serious problems. Specifically, the four purposes of SERDP are to:

SERDP addresses DoD and congruent DOE environmental matters of concern through cooperative research.

- Address environmental matters of concern to the DoD and the DOE through support for basic and applied research and development of technologies that can enhance the capabilities of the Departments to meet their environmental obligations;

- Identify research, technologies, and other information developed by the DoD and the DOE for national defense purposes that would be useful to governmental and private organizations involved in the development of energy technologies and of technologies to address environmental restoration, waste minimization, hazardous waste substitution, and other environmental concerns and to share such research, technologies, and other information with such governmental and private organizations;

- Furnish other governmental organizations and private organizations with data, enhanced data collection capabilities, and enhanced analytical capabilities for use by such organizations in the conduct of environmental research; and

- Identify technologies developed by the private sector that are useful for DoD and DOE defense activities concerning environmental restoration, hazardous and solid waste minimization and prevention, and hazardous material substitution and provide for the use of such technologies in the conduct of such activities.

This mission, crafted over 12 years ago, remains highly relevant, and while significant successes have been achieved, a number of difficult technical challenges remain.

Requirements

SERDP is a "requirements-driven" program that directly responds to defense requirements generated by the Services and sanctioned by the Deputy Under Secretary of Defense for Installations and the Environment (DUSD/I&E). It is critical that the limited funds available for environmental technology R&D be focused on the highest priority requirements of the Services. Each Service develops prioritized user requirements through internal processes that include members of the technology user community. These requirements are collected, cross-referenced, and correlated at the DoD level by the DUSD (I&E).

Requirements submitted by the Services are ranked into high, medium, and low categories based on the priorities assigned by the Services. The programs to address these requirements are developed jointly by the Services and DDR&E through the Reliance Process and form the basis for all DoD Science and Technology initiatives.

DoD environmental concerns may be divided into four broad categories of concerns:

- Those dealing with the cleanup and legacy of past wastes;
- Those that impact training, testing, and readiness;
- Those that have cost and performance impacts on the supporting infrastructure; and
- Those that have a cost and performance impact on the life cycle of weapon systems and platforms.

All of these categories have a direct impact on the Department's ability to perform its primary mission of maintaining military readiness for national defense. For the ease of managing the program, SERDP places all research efforts into one of five thrust areas: Cleanup, Compliance, Conservation, Pollution Prevention, and Unexploded Ordnance (UXO).

In the course of addressing DoD's highest priority environmental needs, SERDP also has sought opportunities to help solve other significant national and international environmental problems through the application of DoD's technical capabilities, analytical systems, and information.

The SERDP Management Structure

SERDP is a multi-agency managed program funded by the Department of Defense. Pursuant to Title 10, U.S.C., SERDP receives general oversight and policy guidance from the SERDP Council which is composed of members from the DoD, DOE, and EPA. Also included in this authorizing language is a requirement for an Executive Director to lead the day-to-day Program activities, and a SAB that is charged with providing advice and recommendations to the SERDP Council on projects/proposals reviewed. Further, the SAB may advise the Council regarding other programmatic, funding, or technically related issues with respect to the Program. Other activities shown in Figure I-1 represent those that were established by the Council and Executive Director to support Program needs.

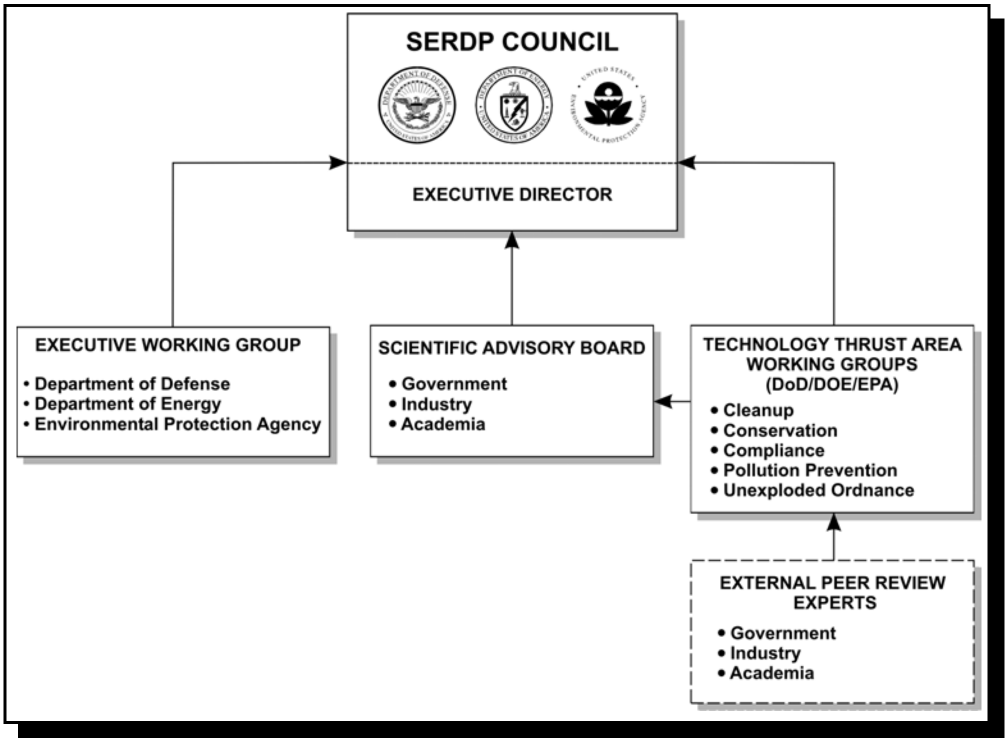

Figure I-1. SERDP Organization.

SERDP Council

Established by law, SERDP's multi-agency Council ensures integrated, non-duplicative research.

Title 10, U.S.C. §2902 established the Strategic Environmental Research and Development Program Council to oversee management of SERDP. Specifically, this Council prescribes policies and procedures to implement the Program and, uniquely, is the sole funding approval authority. As such, the Council may enter into contracts, grants, and other agreements in accordance with other applicable law to carry out the purposes of SERDP. Congress intended the Council to be a multi-agency membership body to promote maximum exchange of information and to minimize duplication of environmentally related research, development, and demonstration activities through close coordination with the military departments and Defense agencies; the Department of Energy; the Environmental Protection Agency; the National Oceanic and Atmospheric Administration; the National Aeronautics and Space Administration; other departments and agencies of the Federal, State, and local governments; and other organizations engaged in environmentally related research.

DoD and DOE Council representatives alternate as Chair.

Consistent with the SERDP statute and with facilitating multi-agency cooperation, the Secretary of Defense has designated the Director, Defense Research and Engineering (DDR&E) as chairperson for each odd-numbered fiscal year, and the Secretary of Energy has designated the Director of the Office of Science to serve as chair for each even-numbered year. Other members are assigned per guidance provided in the SERDP statute. The following are the Council members who served during a portion of, or for the entire, FY 2002.

Council Members - FY 2002

Dr. Jane Alexander
Office of Naval Research (ONR)
U.S. Navy

Dr. Everet H. Beckner
National Nuclear Security Administration
U.S. Department of Energy

Lt. Col. Jeff Cornell
Office of Deputy Assistant Secretary of the Air Force
Environment, Safety and Occupational Health
U.S. Air Force

Mr. Ray DuBois
Installations & Environment
Department of Defense

Captain Jim Evans
Research and Development
U.S. Coast Guard

Dr. Paul Gilman
Office of Research and Development (ORD)
U.S. Environmental Protection Agency

Dr. Charles J. Holland
Deputy Undersecretary of Defense, Science and Technology

Dr. Ray Orbach
Office of Science
U.S. Department of Energy

Mr. James Owendoff
Office of Science and Technology
Office of Environmental Management
U.S. Department of Energy

General Peter Pace
Joint Chiefs of Staff

Dr. John Parmentola
Research and Laboratory Management
U.S. Army

Mr. Bradley Smith *(non-voting member)*
Executive Director
Strategic Environmental Research and Development Program

Executive Working Group

The Executive Working Group (EWG) is an extension of the Council and serves as a working-level representation of the Council. This body, while not established by law, facilitates SERDP policy preparation, investment strategy considerations, and annual program plan development.

SERDP Scientific Advisory Board

SAB members focus on technical quality.

Established in accordance with the SERDP statute, the SERDP Scientific Advisory Board (SAB) assures that the Program maintains clear focus on technical quality. The SAB has the authority to make recommendations to the Council regarding technologies, research, projects, programs, activities, and, if appropriate, funding within the scope of the SERDP. The SAB is composed of no more than 14 members who are jointly appointed by the Secretary of Defense and the Secretary of Energy in consultation with the Administrator of the Environmental Protection Agency. During FY 2002, two members completed their tenure on the Board late in FY 2002 leaving the Board with a total of eleven members. SERDP has successfully identified four new candidates for membership in 2003.

To ensure that SERDP objectives are congruent with the Administration's goals, two members of the SAB are mandated in the statute - the Science Advisor to the President, or his/her designee, and the Administrator of the National Oceanic and Atmospheric Administration, or his/her designee. Similarly, to ensure that regional and global environmental issues are appropriately addressed in SERDP, at least one member should represent the interests of State governments and one member should represent environmental public interest groups. The list below reflects SAB membership in FY 2002.

Scientific Advisory Board Members - FY 2002

Dr. Braden Allenby
AT&T

Dr. Patrick R. Atkins
Aluminum Company of America

Dr. Mary Barber
The Ecological Society of America

Dr. Clifford J. Gabriel
Office of Science and Technology Policy

Dr. Ronald Heck
Cummins, Inc.

Dr. Carol Henry
American Chemistry Council

Dr. Michael Kavanaugh
Malcolm Pirnie, Inc.

Dr. Perry L. McCarty
Stanford University

Dr. William Neff
National Oceanic and Atmospheric Administration

Dr. Jean'ne M. Shreeve (Vice Chair)
University of Idaho

Dr. C. Herb Ward (Chair)
Rice University

Mr. Randolph Wood
Texas Natural Resources Conservation Commission

Dr. Lily Young
Rutgers University

The statute directs the SAB to review all projects with a value in excess of $1,000,000. Several years ago, the SERDP Council modified this direction by requesting that each new start effort and every continuing project exceeding $900,000 be reviewed by the SAB. During FY 2002, each project meeting this criteria was reviewed to ensure technical quality and fiscal responsibility. Furthermore, the SAB confirmed that multiple projects responding to the same or a similar requirement were complementary in approach and well coordinated.

Executive Director and Program Office Staff

Title 10, U.S.C. authorizes an Executive Director to direct and focus the day-to-day efforts of SERDP, and Mr. Bradley P. Smith retained the position of Executive Director. The Executive Director is a non-voting member of the SERDP Council and a voting member of the EWG. Dr. Jeffrey Marqusee, the Environmental Security Technology Certification Program (ESTCP) Director, also served as the SERDP Technical Director. Collocation of SERDP and ESTCP has served to broaden the staff's technical skills and facilitate technology transition from one program to another. The balance of the Federal staff consisted of four technical Program Managers and a Financial Officer who have been detailed from the military Services' R&D infrastructure. These individuals include:

- Dr. Anne Andrews - Program Manager for UXO technologies
- Dr. Andrea Leeson - Program Manager for Cleanup technologies
- Mr. Charles Pellerin - Program Manager for Pollution Prevention technologies
- Dr. Robert Holst - Program Manager for Compliance and Conservation technologies
- Ms. Brenda Batch - Financial Officer

Technology Thrust Area Working Groups

As evidenced by the small size of Program Office staff, the breadth of technical knowledge demanded by SERDP far exceeds the limited staff in the SERDP Program Office. Consequently, SERDP must rely on the technical skills offered by the participating Services and Agencies to assist in the technical aspects of program development, program monitoring, and technology transfer. For each of the Technology Thrust Areas, a Technology Thrust Area Working Group (TTAWG) was established to help solicit and review technical proposals, formulate and recommend the annual program plan, conduct technical reviews of the ongoing projects, and facilitate technology transfer according to the needs of their users in the field. TTAWGs offer several advantages over conventional R&D management schemes. First, their members are selected by the Services and Agencies as represented on the Council. Second, they bring not only a wealth of understanding of the needs of their organization, but also knowledge of similar completed or ongoing efforts. This knowledge helps SERDP to avoid duplication of effort and promote joint and cooperative funding of projects. TTAWG members, for the most part, are provided from their organizations as a collateral assignment, however, without their assistance, SERDP would have difficulty achieving the same level of success.

Peer Review Experts

Assisting the TTAWGs and the Program Office in their quest to select quality research proposals are the Peer Review Experts. Following the model established by the National Science Foundation, SERDP proposals must undergo an independent Peer Review prior to receipt of initial funding. The results, scores, and evaluation comments of this review are passed directly to the TTAWGs who use this information to develop their recommended list of new start projects. Further, these same results are passed to the Scientific Advisory Board for consideration during their proposal review and deliberations.

SERDP supports an electronic peer evaluation process via the Internet.

Peer Reviewers come from all walks of disciplinary life - from industry, academia, and government as well. Each reviewer is certified to be without conflict of interest, an expert in their field and profession, and credible on record. Peer Reviewers are identified and tasked under a support contract, and in FY 2002, 72 Peer Review Experts were used to evaluate 135 proposals.

SERDP Strategy

Program Goals

The SERDP Council ensures that the partnership focuses on the mission needs of the DoD and empowers the EWG with developing goals and an investment strategy that will assist SERDP to successfully satisfy these mission needs. In 1993, the EWG assembled to develop the SERDP Strategic Guidance that served as a framework within which to develop the annual SERDP program plan. This Strategic Guidance continues to provide the overarching guidelines to Program Managers and participants in the Program. Included in this document are the SERDP goals which are to:

- Resolve environmental concerns in ways that enhance military operations, improve military systems effectiveness, and help ensure the safety of personnel; and

- Support technology and process development that reduce operational and life cycle costs, including those associated with environmental cleanup and costs of full compliance with environmental laws and regulations.

SERDP achieves its goals by promoting cooperative environmental technology development and a strong effort in information dissemination. Specifically, SERDP succeeds by:

- Identifying and supporting programs of basic and applied research and development to:
  - Accelerate cost-effective cleanup of contaminated defense sites.
  - Facilitate full compliance with environmental laws and regulations at reduced cost.
  - Enhance training, testing, and operational readiness through prudent land management and conservation measures.
  - Reduce or eliminate defense industrial and operational waste streams through aggressive pollution prevention programs that strongly encourage use of non-hazardous, non-toxic, non-polluting, and other environmentally sound materials, substances, and processes.
- Promoting the effective exchange of information regarding environmentally related research and development activities.
- Ensuring that SERDP research and development (R&D) activities complement, but do not duplicate, Tri-Service R&D programs and other ongoing activities.

SERDP promotes cooperative environmental technology development and information transfer.

- Providing appropriate access to data under the control of, or otherwise available to, the Departments of Defense and Energy that is relevant to environmental matters.
- Facilitating the transfer of unclassified DoD and DOE environmental information and technology to other sectors of society that might be able to use them to advance national environmental objectives.
- Emphasizing multi-service, inter-departmental research and development projects and using the unique capabilities of the partnering Federal agencies, private industry, and academia to solve the Departments' environmental problems.

Key Metrics for SERDP Success

The following four key metrics are used to maintain Program quality and enhance the success of the Program:

1. Address the highest-priority, defense mission-relevant environmental requirements with emphasis on multi-service issues.

The Executive Director and his staff worked hand-in-hand with ODUSD(I&E) to establish clear lines of communication, address effectively the Department's highest priority environmental requirements, and foster transition of technical efforts to field demonstration or implementation. Through the use of focused Statements of Need, the Executive Director solicited cooperatively funded and executed projects to address high-priority multi-service needs. The TTAWGs facilitated this process by communicating effectively and applying their knowledge of the needs and capabilities of the Federal R&D infrastructure.

SERDP often holds workshops to explore the state-of-science, technology gaps, and opportunities for research in need areas where it may be difficult to interpret this need. From these workshops, several key Statements of Need can be identified. In FY 2002, one such workshop was held on Sustainable Range Management.

2. Pursue/achieve universal, world-class technical excellence.

World-class research is considered the cornerstone of SERDP projects. Continuing the successful solicitations of the past few years, SERDP solicited proposals from all sources including the non-Federal sector. SERDP continued to use external Peer Review Experts in addition to the comprehensive multi-agency review procedures to ensure that technically sound proposals performed by world-class researchers are selected for funding. Technical experts representing universities, industry, and government participate in the Peer Review process. Additionally, the SAB, TTAWGs, and the Program Office staff all emphasize the need for each research team to demonstrate superior technical merit and perform according to world-class research standards.

3. Emphasize and promote technology transfer.

Transfer of technology, from research to the DoD environmental user community, is one of the key objectives of SERDP. This objective is achieved by supporting applied research and technology demonstrations that respond directly to high-priority, DoD mission-related, environmental needs. With FY 2002 marking its eleventh year of technology development, SERDP is aggressively pursuing technology transfer mechanisms. The co-location of ESTCP with SERDP has already helped to facilitate project transitions, both between Programs and into other Agencies' certification programs as well. Many of the SERDP projects initiated in the earlier years have been, or are being completed and are now ready for field demonstration, implementation, or transition to the next step of development.

Significant focus on technology transfer has been placed on the Principal Investigators (PI) of all SERDP projects at both briefings to the SAB as well as at the In-Progress Reviews (IPR). At these IPRs, PIs are required to demonstrate their interaction with the user community or those who will sponsor further development. Members of the multi-agency TTAWGs, Joint Engineers Management Panel (JEMP) members, and key representatives from ODUSD(I&E) attended the IPRs in FY 2002 and provided various potential technology transfer opportunities to the PIs.

4. Ensure sound fiscal management.

Timely and complete financial reporting is one of the principal keys to SERDP's success. The SERDP Executive Director has continued to ensure that the Program complies with the DoD fiscal guidance. Effective controls include periodic fiscal review of projects, implementing aggressive corrective actions to promote effective use of limited R&D resources, and implementation of various information management/monitoring tools which fully utilize state-of-the-art Internet capabilities.

Research Framework and Technical Strategy

SERDP has the flexibility to fund basic and applied research, or advanced technology development projects as needed.

Within the Services' Environmental Quality Programs, Program Elements exist to provide funding specifically focused on either basic research, applied research, or advanced technology development. The authors of SERDP's statute understood the need to easily and judiciously allocate funds against the highest priorities and most intractable problems faced by DoD. Accordingly, SERDP has the flexibility to perform under all of these research categories. Figure I-2 illustrates SERDP's role in the DoD environmental technology development process.

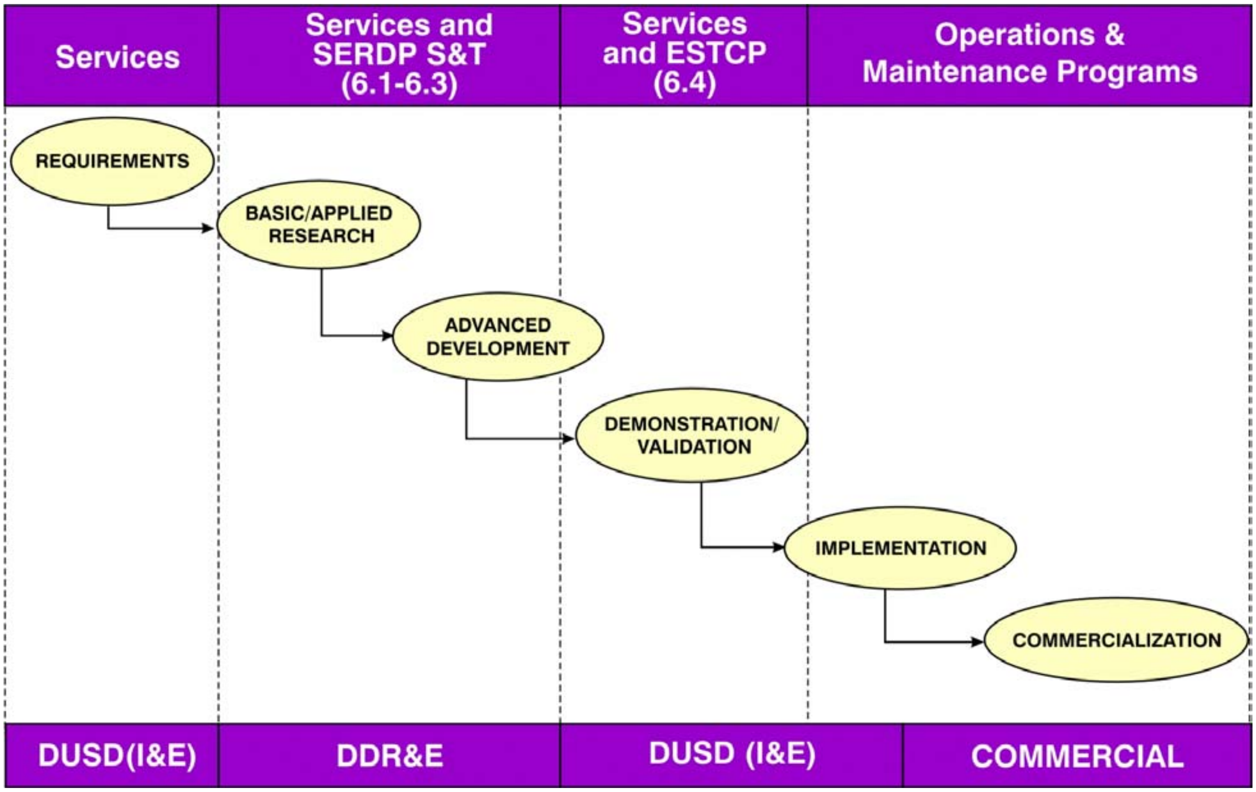

Figure I-2. Environmental Technology Development Process.

Figure I-3 represents the research taxonomy that defines the SERDP Program. The primary areas of emphasis were developed in response to user community needs for science and technology required to accomplish the military mission in an environmentally compliant manner. This taxonomy follows the four pillar structure that is consistent with the focus of the Office of the Deputy Under Secretary of Defense for Environment and Installations [ODUSD(I&E)], that corresponds to those identified in the National Environmental Technology Strategy. The research taxonomy reflects the current areas of emphasis under each of the four pillars, plus an added fifth pillar that reflects the increases in funding and need for research in UXO technologies.

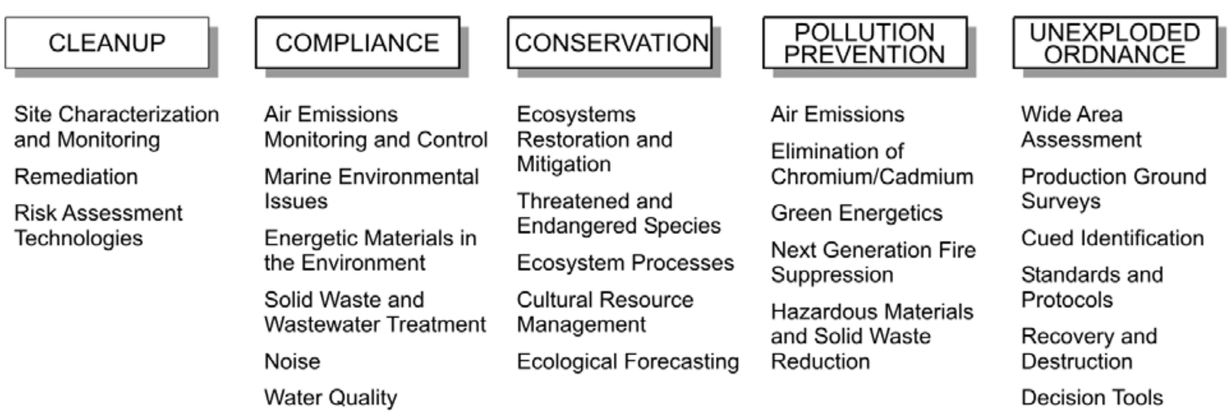

Figure I-3. SERDP Research Taxonomy.

Technical Strategy

For FY 2002, the SERDP Council directed the continuing pursuit of seven avenues in planning and executing defense mission-relevant environmental research and development:

- ✔ Identify and fund major-impact, multi-agency environmental R&D programs to solve high- priority, mission readiness related concerns of DoD;
- ✔ Identify opportunities to accelerate existing DoD environmental quality R&D programs and fund those that address the highest priority concerns of the Department;
- ✔ Advance and use applicable state-of-the-art modeling and simulation capabilities to accomplish SERDP goals;
- ✔ Use the technical and research capabilities of the SERDP partners, including their unique data collection and analysis capabilities, as appropriate;
- ✔ Plan for a transition of successfully proven technologies to demonstration and validation or to commercialization and implementation; and
- ✔ Encourage high-risk, high-payoff novel approaches to resolve environmental problems through the use of low-cost, short-term, exploratory R&D efforts.

Search for Innovation

With respect to the last strategic element, SERDP continues to seek innovative ideas with commensurate technical risk. The SERDP Exploratory Development Program, or SEED, that was initiated in FY 1999, has succeeded in soliciting novel ideas that were demonstrated under a low-cost ($100,000 or less), short-term (one year), proof-of-concept study. SEED projects and the larger, longer-term "Core" efforts both respond to the highest priority needs as defined in published Statements of Need (SON). These SONs are released annually with a Federal Call for Proposals and a non-Federal Broad Agency Announcement. In search of world-class research, SERDP promotes direct participation from the private sector, including small and large businesses and academic institutions. In FY 2002, five of these SEED efforts (two in Conservation, two in Pollution Prevention, and one in UXO) were successful in their study phase and are expected to propose follow-on work for FY 2003. The accomplishments of these efforts are described in Section III entitled, "Program Description" and Appendices C, D, and E.

Investment Strategy

Each year the SERDP Council annually determines the distribution of funding to the Thrust Areas. The Council seeks the advice and recommendations of the SERDP Scientific Advisory Board and the Executive Working Group to best position SERDP to respond to both pressing needs as well as environmental problems that loom in the future. For FY 2002, the Council had approved shifting the allocation of resources among the pillars in recognition of the growing impact that environmental issues are having on training and testing ranges as well as the enormity of the future liability for the remediation of lands contaminated with UXO. These funds were directed by the issues of UXO remediation and environmental issues impacting the sustainability of military training and testing ranges.

The FY 2003 President's Budget Request for SERDP was $60.5 million, a decrease of $2.4 million from the FY 2002 appropriation. Congress further reduced the amount appropriated for SERDP in FY 2003 to $54.6 million. The investment allocation among the five thrust areas in FY 2003 has changed in response to this reduction, with the largest percentages going to Cleanup and UXO, followed by Pollution Prevention, Compliance and Conservation. Within these thrust areas, SERDP will focus its allocation of resources to address high-priority requirements that cut across thrust areas, such as understanding and minimizing the environmental impacts of training and testing and reducing DoD's future liability for the cleanup of UXO and recalcitrant contaminants.

Actions of the SERDP Scientific Advisory Board

In accordance with Section 2904, Title 10, U.S.C., the Scientific Advisory Board (SAB) is required to meet a minimum of four times during the Fiscal Year. In FY 2002, the SAB met five times. Four meetings were held in Arlington, VA and a fifth was held in North Falmouth, MA. Consistent with the statute, the Board made recommendations to the SERDP Council through the Executive Director regarding the projects reviewed. They also assisted and advised the Council in identifying environmental opportunities and provided advice on other environmental issues within the scope of SERDP.

Figure I-4 provides a list of dates and locations of all SAB meetings held during FY 2002. In accordance with the Federal Advisory Committee Act, all meetings were open to the public and detailed records of events are maintained. Further, all records, reports, working papers, and agendas were made available to the public for review. In FY 2002, no requests were made to review this information.

SAB Meeting No.	Dates	Location	Projects Briefed		
			Ongoing	New Starts	Total
1	October 16-18, 2001	Arlington, VA	6	13	19
2	March 5-7, 2002	Arlington, VA	1	20	21
3	June 11-12, 2002	Arlington, VA	5	7	12
4	August 7-8, 2002	Arlington, VA	1	8	9
5	September 17-18, 2002	North Falmouth, MA	-	7	7

Figure I-4. Summary of FY 2002 SAB Meetings.

During FY 2002, the SAB continued to be committed to enhancing three processes within SERDP: research initiation, quality control, and technology transfer.

Commitment to Enhancing the Research Initiation Process

Consistent with the SAB's desire to define and fulfill its role within SERDP's statutory requirements, in a manner that most effectively utilizes the collective expertise and experience of the Board, the SAB reaffirmed its commitment to ensure that SERDP complies with the statute by soliciting and funding projects that are sharply focused on the environmental needs of the DoD and those congruent needs of the DOE. The Board reviewed and contributed to the process of preparing and issuing Statements of Need (SON). In the course of review, the SAB was instrumental in identifying opportunities to enhance the expected research product. Additionally, their final quality control review ensured that the SONs clearly articulated the objective of each and every need. This process was instrumental to fostering properly focused research proposals and minimizing irrelevant submissions in response to the broad solicitation.

The Board continued its proactive strategic role in identifying and defining environmental research gaps and associated technology development opportunities. The Board continued to support strongly the concept of focused technical workshops to provide an assessment of the state of the science and identify and prioritize research needs specific in areas of interest to SERDP. As a result of workshops held in the past, numerous SONs were generated that resulted in many proposals. A number of SONs to address high-priority DoD needs resulted from the workshop on Range Sustainability held in FY 2002.

During their review and evaluation of proposals, the SAB conscientiously scrutinized each effort to understand and enhance the research partnerships that were proposed. Considered to be a major strength of the Program, cooperative research efforts have demonstrated a higher quality of effort by ensuring that each facet of the project is afforded a second look and chance to ensure that it is conducted with the highest standards. Where appropriate, the SAB suggested improvements or additions to the research team - from inclusion of a Co-PI having specific disciplinarian credentials that would enhance the research effort, to offering suggestions of organizations that might shed additional light and enhance the standards and procedures proposed in the effort. The SAB also strongly encouraged inclusion of graduate students in research teams to promote training and foster development of technical expertise in cutting edge technologies.

Commitment to Ensuring Quality Research

The Board continued its key focus on assisting SERDP to ensure that SERDP-supported projects meet the highest standard of technical and scientific quality. The SAB addressed this issue from three avenues.

- First, the members strongly endorsed the established proposal review process. The SAB firmly supports SERDP's procedure to have each and every proposal reviewed by at least three Peer Reviewers that are experts in the discipline most closely related to the proposal's technical approach. All Peer Review comments are forwarded to the SAB prior to their meetings and are used extensively by the members during proposal discussions with the Principal Investigator. These review comments complement the Board members' already diverse and deep technical expertise.

- Second, the members encouraged close coordination between projects that address related problems. In this sense, the Board evaluated projects on more than just the basis of their individual scientific merit and DoD relevance, putting increasing emphasis on coordination and leveraging between projects to ensure that related efforts indeed complement each other. As demonstration of this emphasis, the Board voiced its support for the use of a Technical Advisory Committee for "umbrella"-type projects, i.e., those that are a conglomeration of subprojects and centrally managed by a laboratory or agency representative. Projects in this category include Next Generation Fire Suppression Technology Program, the SERDP Ecosystem Management Program, and the Green Medium Caliber Ammunition Program.

Technical Quality Control is a recurring theme for the Scientific Advisory Board.

- Third, the Board fully supported the mid-year In-Progress Review of each project by the Technical Thrust Area Working Groups (TTAWG). While the SAB's primary function is to assess the technical aspects of SERDP projects, the Board has insufficient time to conduct a thorough technical evaluation of each ongoing project. The TTAWG is the appropriate group to perform this assessment. However, often times SAB members did attend and participate in some of the mid-year review meetings.

Commitment to Technology Transfer

The SAB continued to emphasize technology transfer potential as an important criterion for evaluating proposals. Technology transfer is one of the SERDP Keys to Success, and the Board members continued their keen interest in the role of the military Services and eventual users of the technologies being developed.

Complete technical reporting, including publications in the peer-reviewed literature as well as SERDP-required interim and final technical reports, was a metric used to determine project technical achievement and management acumen. The SAB fully supported SERDP's requirement for annual/interim technical reports and a final technical report upon completion of the project. These reports constitute technical progress to date, whether successful or not, on each project's technical approach. According to the Board, the value of "negative results" cannot be overstated, and SERDP projects should clearly state their progress and publish these results to facilitate further research.

The SAB continued its participation in the planning and execution of the annual *Partners in Environmental Technology Technical Symposium and Workshop* sponsored by SERDP. During strategy discussions at SAB meetings, the members offered comments on the overall theme of the Symposium and suggestions for technical session topics and plenary and session speakers. SAB members continued the tradition of active involvement in the planning and execution of breakout sessions. At the November 2001 event, three members served as technical session Chairs, Dr. Herb Ward, Dr. Perry McCarty, and Dr. Braden Allenby. Dr. Allenby also served as Keynote speaker in the technical session on Environmental Design for Maintainability. Drs. Ward and McCarty and Dr. Lily Young, each gave technical presentations in three separate technical sessions. The Board continued to demonstrate its commitment to involvement at the latest Symposium held in December 2002, with Dr. Herb Ward presenting the SERDP FY 2002 Project of the Year Awards. The active involvement of the SAB was a significant contributing factor to the overall success of each Symposium.

Areas of Opportunity

In the past the SAB has suggested areas of opportunity for SERDP investment. Often, these areas prove to become the focus of a national or world-wide research effort. An example of research that commenced at the suggestion of the Board is the remediation of groundwater contaminated with ammonium perchlorate. Due to their proactive thinking, SERDP was able to get a head start on understanding this phenomenon and initiating research to resolve associated issues.

Consistent with past practice, the Executive Director solicited the advice of the membership regarding his proposed allocation of funds among the five Thrust Areas for FY 2002. The Board was fully supportive of the proposed profile and general trends of investment within each of the five Thrust Areas.

Project and Program Recommendations

During FY 2002, the SAB reviewed 66 proposals/projects, 55 of which were new start efforts and 11 of which were continuing projects. Of these 66 efforts, 45 requested FY 2002 funds totaling $14,719,000. A total of 22 projects requested $12,855,000 in FY 2003 funds. The Board recommended against funding three proposals. A summary of all projects reviewed and the results of their deliberations may be found in Figure I-5.

At the September 2002 SERDP Council meeting, Dr. C. Herbert Ward, Chair of the Scientific Advisory Board advised the Council of how the SAB ensures that quality research is focused on high-priority DoD needs and that technology transfer is fostered to the users in the field. Dr. Ward called SERDP a 'high-impact program' that encourages partnering and multi-institutional collaborative projects. He praised the

Project No.	Recommendation				FY02 Meeting Date					New Starts	Continu -ing Projects
	Fund		Not Fund		1	2	3	4	5		
	FY02	FY03	FY02	FY03	Oct-01	Mar-02	Jun-02	Aug-02	Sep-02		
CU-1165	$ 906						Jun-02				●
CU-1166	$ 448				Oct-01						●
CU-1205	$ 252				Oct-01						●
CU-1209	$ 685				Oct-01						●
CU-1210	$ 432				Oct-01						●
CU-1228	$ 300						Jun-02			●	
CU-1235*	$ 835						Jun-02			●	
CU-1289	$ 312				Oct-01					●	
CU-1291	$ 257				Oct-01					●	
CU-1292	$ 246				Oct-01					●	
CU-1293	$ 299				Oct-01					●	
CU-1294	$ 179				Oct-01					●	
CU-1295	$ 318				Oct-01		Jun-02			●	
CU-1317	$ 189					Mar-02				●	
CU-1318	$ 218					Mar-02				●	
CU-1319	$ 201					Mar-02				●	
CU-1347		$ 125						Aug-02		●	
CU-1348		$ 126							Sep-02	●	
CU-1349		$ 420						Aug-02		●	
CU-1350		$ 502						Aug-02		●	
CU-1351		$ 307						Aug-02		●	
CS-1257	$ 400				Oct-01					●	
CS-1259	$ 427				Oct-01					●	
CS-1260	$ 316				Oct-01					●	
CS-1261	$ 180				Oct-01					●	
CS-1263	$ 326					Mar-02				●	
CS-1303	$ 127					Mar-02				●	
CS-1302	$ 216					Mar-02				●	
CS-1332		$ 400							Sep-02	●	
CS-1334		$ 330							Sep-02	●	
CS-1335		$ 245							Sep-02	●	
CP-819*				$ 2,476			Jun-02			●	
CP-1155		$ 1,021					Jun-02				●
CP-1197		$ 736					Jun-02				●
CP-1247	$ 555				Oct-01					●	
CP-1304	$ 277					Mar-02				●	
CP-1305	$ 241					Mar-02				●	
CP-1330		$ 129				Mar-02				●	
CP-1336		$ 923							Sep-02	●	
CP-1339		$ 390							Sep-02	●	
CP-1340		$ 379							Sep-02	●	
PP-1059		$ 1,000					Jun-02				●
PP-1148		$ 500			Oct-01						●
PP-1179	$ 976				Oct-01						●
PP-1237	$ 1,220	$ 1,190				Mar-02		Aug-02			●
PP-1269			$ 321		Oct-01					●	
PP-1271	$ 460				Oct-01					●	
PP-1341		$ 346						Aug-02		●	
PP-1342		$ 380						Aug-02		●	
PP-1343		$ 410						Aug-02		●	
PP-1344				$ 520				Aug-02		●	
UX-1309	$ 171					Mar-02				●	
UX-1310	$ 368					Mar-02				●	
UX-1311	$ 150					Mar-02				●	
UX-1312	$ 191					Mar-02				●	
UX-1313	$ 132					Mar-02				●	
UX-1314	$ 172					Mar-02				●	
UX-1315	$ 387					Mar-02				●	
UX-1316	$ 331					Mar-02				●	
UX-1321	$ 175					Mar-02				●	
UX-1322	$ 351					Mar-02				●	
UX-1323	$ 145					Mar-02				●	
UX-1326	$ 243						Jun-02			●	
UX-1327	$ 353						Jun-02			●	
UX-1328	$ 186						Jun-02			●	
UX-1329	$ 151						Jun-02			●	
TOTALS	**$14,398**	**$ 9,859**	**$ 321**	**$ 2,996**						**55**	**11**

* Congressional Earmark

Figure I-5. Summary of Proposals Reviewed by SAB in FY 2002 by Thrust Area (Funding in Thousands).

quality of the SAB membership and reiterated that the Board conducts critical reviews of the technical aspects of the projects and proposals. His encouragement reassured Council members that the Program is continuing to take the correct measures and is proceeding appropriately.

Other Management Actions

Council

Multi-agency management and oversight of SERDP continues to be one of the clear strengths of SERDP. Active participation by the members of the SERDP Council, their designated representatives on the Executive Working Group (EWG), and participation on the Technology Thrust Area Working Groups (TTAWG) precludes duplication of effort, ensures quality Program content, and facilitates information transfer. This tri-parte arrangement, composed of executive, programmatic and technical individuals who represent the three primary participating organizations, yields a depth and breadth of knowledge and experience at several levels of management and technical expertise lending significant credibility to the Program.

On September 26, 2001, the SERDP Council approved the FY 2002 Program Plan and the FY 2003 Investment Plan. For FY 2002, SERDP was appropriated $62.9 million, which included funding for two additional congressional interest projects.

Multi-Agency participation is a clear strength of the Program.

The Council met one year later on September 26, 2002 to approve the FY 2003 Program. The President's Budget Request for SERDP for FY 2003 represented a decrease of $2.4 million from the FY 2002 appropriation. The Congressional appropriation for FY 2003 further reduced SERDP's budget to $54.6 million, which included two Congressional interest projects. The Council approved the FY 2003 Core program as presented. The Council further granted the Executive Director the authority to execute any Congressional interest projects that may be added to the appropriation to ensure they appropriately focused on defense issues. The Council reviewed and approved the FY 2004 investment guidance.

Executive Director and Program Office

Continued Emphasis on Unexploded Ordnance and Range Sustainability

In FY 2002, the Executive Director continued managing UXO as a separate Thrust Area. This is due to the significant technical challenges and potentially large liability for the DoD, its associated increase in the President's Defense budget to address UXO detection, and the fact that the technologies involved in UXO detection are discretely different than those used in conventional cleanup. SERDP will continue to coordinate its UXO research efforts with the DoD's Joint UXO Center of Excellence and keep abreast of new initiatives developed with the Counter Mine efforts, such as found within the Multiple University Research Initiative, or MURI. Furthermore, the UXO Program plan undergoes a thorough peer review to ensure that it properly characterizes the broad problem, establishes clear and logical goals, and identifies specific, relevant, near-term technical objectives.

During FY 2002, SERDP convened a workshop devoted to Range Sustainability. Held during the summer of FY 2002, this event was similar to previous SERDP workshops, in that it identified gaps in technical knowledge, and identified strategic investment opportunities for DoD/SERDP. The workshop was unique in that it brought together for the first time a wide range of DoD installation managers from all levels to articulate and prioritize environmental challenges they currently face as well as those they anticipate could impact range operations in the near term. The results of this workshop included the development of several Statements of Need that were issued in the FY 2004 solicitation, including three on monitoring and assessing the impacts of noise, one on developing emission factors for PM, two on threatened and endangered species, and one on invasive species.

Proposal Solicitation and Selection

SERDP takes pride in the fact that funds for new starts are available to industry, academia and Federal researcher alike, and the Council continues to be pleased with SERDP's ability to reach out to a broader pool of researchers through a Broad Agency Announcement. SERDP again extended two solicitations – a "Core" solicitation that has traditionally been used to develop the annual program and a SEED solicitation.

The SEED Program is designed to provide initial funding for high-risk, high-payoff proof-of-concept projects. Funding is limited to a maximum of $100,000 for up to one year. Successful efforts may compete for additional funds in the following years.

Technology Transfer

Successful technology transfer is used as a metric to measure the success of the Program. SERDP has funded over 400 individual projects. Several avenues are taken to ensure that the successful efforts of the research teams are transitioned to either higher development programs, such as ESTCP, or implemented directly into field use.

Technology transfer and transition continued to be a primary area of focus during annual project reviews by both the SAB and the TTAWGs. Principal investigators were tasked to prepare Annual Technical Reports that serve as a fundamental baseline of technical progress. At the end of each project, a Final Technical Report is required for each effort. These reports are maintained in a SERDP library and referenced on the SERDP website. Additionally, they are entered into the Defense Technical Information Center (DTIC) in both a hard copy and electronic version. DTIC provides all researchers with copies of these reports upon request. SERDP continues to partner with the EnviroScience Electronic Print (e-Print) Service, a joint project of DOE's Environmental Management Science Program (EMSP), the EPA Office of Research and Development (ORD), the DoD's Environmental Security Technology Certification Program (ESTCP), and SERDP. e-Print uses EPA's Environmental Information Management System to collect, store and access published and unpublished manuscripts, conference papers, presentations and posters. This joint effort should have the result of enhancing scientific collaboration; speeding the dissemination of research findings; providing effective access to relevant research across the agencies.

SERDP has posted Fact Sheets on the website for every SERDP funded project. These Fact Sheets include summaries of the technical accomplishments and potential benefits of each project. The SERDP website also provides links to websites maintained by SERDP researchers that provide additional information about technologies developed under SERDP.

Each year, SERDP, in cooperation with ESTCP, hosts the *Partners in Environmental Technology Technical Symposium and Workshop*. This event has, for the past eight years, attracted hundreds of researchers, technology developers and users, and regulators to meet in a collegial and informative setting. In December 2002, the annual Symposium once again succeeded in providing an excellent technology transfer and networking forum for researchers, scientists, and engineers from both the Federal laboratory system and the non-Federal sector alike. Our venue focused on "Meeting DoD's Environmental Challenges" in recognition of the fact that while significant advances have been made in addressing environmental issues, additional challenges are expected over the course of the next decade. This event brought more than 750 technology developers and implementers together, as well representatives from the policy, programmatic, regulatory, academic, and industrial sectors. The SAB Chairman issued the annual SERDP Project of the Year Awards, which were given to the best projects in each of the four Thrust Areas for FY 2002. These awards have successfully attracted the attention of the scientific and engineering community around the globe and have measurably helped to either transition this technology into higher development programs, or implement its use in field applications. This conference, which has received numerous accolades, will continue to be enhanced to serve as a significant technical, educational and technology transfer event.

Plans for FY 2003

In FY 2003 SERDP will aggressively respond to the increasing challenges of environmental issues impacting training and testing activities as well as the remediation of lands contaminated with UXO. Specifically, in response to the President's FY 2003 budget request and subsequent Congressional changes, SERDP issued SONs to address the following issues:

- Source zone delineation, characterization, and remediation of chlorinated solvents and evaluation of the sequestration and bioavailability of metals.

- Non-point source surface water runoff from military lands and air emissions from off-road diesel vehicles.

- Impacts of military activities on Threatened or Endangered Species (TES), characterization of benthic species communities, and estuarine ecosystem management and restoration.

- Environmentally acceptable alternatives to chrome coating systems, nickel electroplating, metal parts cleaning, and liquid spray paint components. Environmentally acceptable techniques for the removal of Radar Absorbing Material (RAM) coatings, energetic synthesis techniques, and components of medium caliber munitions.

- Given the overwhelming response to the UXO SONs issued for the annual and supplemental solicitations in FY 2002 and the large number of projects funded, only one SEED SON was issued in FY 2003 in UXO for innovative approaches for UXO detection and cleanup.

In developing the FY 2003 program, 20 SONs were prepared, three of which were specifically for the SEED program. All 17 Core SONs, were made available to the private sector via a Broad Agency Announcement. The Core solicitation resulted in 189 pre-proposals that were submitted by non-Federal participants. Of the 62 full proposals that were requested, 12 were selected for funding resulting in a 19 percent selection rate. This figure approaches the Council's target of 20 percent and was much greater than that experienced in other programs, such as those funded by the National Science Foundation. The Federal sector submitted 77 full proposals of which seven were selected for a 9 percent selection rate. Figure I-6 depicts the distribution of Core proposals selected during the FY 2003 program development process.

CORE PROPOSALS

Thrust Area	No. of Statements of Need	No. of Proposals Selected	SOURCE: Federal	SOURCE: Academia	SOURCE: Private	Approximate Value (Thrust Total)
Cleanup	4	6	1	4	1	$4.6 million
Compliance	2	5	2	3	--	$1.2 million
Conservation	3	4	1	3	--	$1.3 million
Pollution Prevention	8	6	2	2	2	$1.4 million
UXO	--	--	--	--	--	$0
Total	17	21	6	12	3	$8.5 million

Figure I-6. FY 2003 Core New Start Proposal Distribution by Thrust Area.

The solicitation for FY 2003 SEED proposals resulted in the submission of 41 proposals. Thirty-two percent were received from industry, 36 percent were from academia, and 32 percent came from Federal sources. While only seven proposals were selected for funding, each exhibited the prerequisite characteristics of innovativeness, high risk and potentially high payoff. Figure I-7 depicts the distribution of all SEED proposals selected during the FY 2003 program development process.

SEED PROPOSALS						
			SOURCE			
Thrust Area	No. of Statements of Need	No. of Proposals Selected	Federal	Academia	Private	Approximate Value (Thrust Total)
Cleanup	--	--	--	--	--	$0
Compliance	--	--	--	--	--	$0
Conservation	--	--	--	--	--	$0
Pollution Prevention	2	3	1	1	1	$0.3 million
UXO	1	6	2	--	4	$0.6 million
Total	3	9	3	1	5	$0.9 million

Figure I-7. FY 2003 SEED New Start Proposal Distribution by Thrust Area.

Other activities that SERDP plans to actively pursue in FY 2003 include:

- In early FY 2003, SERDP issued SONs for projects to be funded in FY 2004 (see Appendix F for full listing of SONs). Areas of interest for funding in FY 2004 include:

  - Cleanup - Innovative methods for measuring hydraulic conductivity; abiotic attenuation processes for chlorinated solvents; and remedial technologies for contaminated sediments, heavy metals in groundwater, and nitroaromatic compounds in soil and groundwater.

  - Compliance - characterizing, monitoring, and evaluating the impacts of aircraft noise and impulse noise; nitrogen oxides (NO_x), particulate matter (PM), and air toxic emissions from aircraft; and developing PM emission factors for DoD activities.

  - Conservation - control of invasive plant species, monitoring high-priority TES and quantifying physiological stress in TES; characterization of marine mammal behavior; and measuring terrestrial productivity and carbon budgets at Ft. Benning.

  - Pollution Prevention - Eliminating redwater from Trinitrotoluene (TNT) manufacturing and developing environmentally acceptable alternatives to: cadmium plating on high-strength steels, solvents containing Class II ozone depleting substances, ammonium perchlorate in missile fuels, and incendiary compositions for medium caliber munitions.

  - UXO - Advanced approaches for detecting and discriminating UXO, identifying filler material in recovered UXO, and characterizing and remediating underwater UXO sites.

- SERDP will further evaluate the outcome of the FY 2002 Sustainable Range workshop to identify the need for future, more specific range-related workshops, as well as identify opportunities for research to address increasing constraints on military testing and training activities on military ranges.

- SERDP will continue conducting special studies and gap analyses to identify future opportunities for research and potential opportunities for integration/collaboration to address unmet high-priority research needs.

II. SIGNIFICANT ACCOMPLISHMENTS

Introduction

SERDP continues to be a leader in the field of environmental research and development by providing solutions to both new and persistent priority environmental matters of concern to the Department of Defense (DoD) and the Department of Energy (DOE). With an effective outreach program that includes technology gap analysis studies, SERDP strives to remain ahead of the curve on identifying high-priority and emerging environmental technology requirements. SERDP has supported hundreds of science and technology projects since the Program's inception in 1991 in the areas of cleanup, compliance, conservation, pollution prevention, and unexploded ordnance. These projects have enabled DoD installations to meet their environmental responsibilities using cost-effective and innovative methods. During FY 2002, SERDP continued to play a critical role in the development of science and technology that supports the DoD's environmental security mission.

A selection of SERDP's most significant accomplishments during FY 2002 are described in this section. While these projects represent but a small slice of the many innovative projects supported by SERDP, they demonstrate the breadth and depth of the program and highlight the types of major technical advances resulting from focused research and development. Moreover, many of these accomplishments illustrate potential cost savings resulting from full implementation of new technologies while simultaneously maintaining military mission readiness. Appendices A through F provide a summary of each SERDP project funded in FY 2002, new projects funded for FY 2003, and new initiatives planned for FY 2004.

Cleanup Accomplishments

Energetics

Figure II-1. Munitions on Ranges are a Potential Source of Contaminant Releases.

Past, present, and future activities involving munitions at testing and training ranges have been and will continue to be a critical element in maintaining military operational readiness. However, environmental contamination may result from the use of munitions in weapons development, testing, and training (Figure II-1). There are over 200 chemicals identified with munitions' components and their degradation and combustion products. Many of these compounds have been of environmental concern to DoD for more than 15 years. These compounds may be found in the soil and groundwater at former and current ammunition manufacturing and load, assemble, and pack plants and have been investigated in ongoing remediation activities at these sites. More recently, munitions compounds have been detected in soils and groundwater at active and former training and testing ranges. The predominant energetic chemicals of environmental concern include 2,4,6-trinitrotoluene (TNT) and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), which were often used in combination, and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX). The amino reduction products of TNT, such as dinitrotoluene (DNT), are also toxic and have been detected in soil and groundwater.

To address these concerns, SERDP is funding research to improve the fundamental understanding of the microbial processes that degrade these contaminants and to search for ways to improve on these natural processes to remediate these contaminants.

The SERDP project, **Bacterial Degradation of DNT and TNT Mixtures, (CU-1212)**, was funded to improve the fundamental understanding of microbial processes involved in the degradation of mixtures of TNT and DNT. Researchers from the University of Iowa have demonstrated that bacteria grow on molecules of DNT, and that these same bacteria should also be able to degrade TNT. The key to this approach was to identify enzymes, and engineer bacteria that can detoxify TNT and/or amino dinitrotoluenes (ADNT), and develop a conceptual model of the degradation of mixtures of nitroaromatic compounds. The researchers demonstrated, for the first time, that bacterial enzymes catalyze the oxidation of ADNT. This new insight about the degradation of mixtures of energetic compounds will be directly applicable to future cleanup efforts at TNT manufacturing and DoD sites. The information from this work also will be used in follow-on studies to identify microbes that can generate organisms to degrade nitroarene compounds, a related group of toxic by-products of energetics degradation.

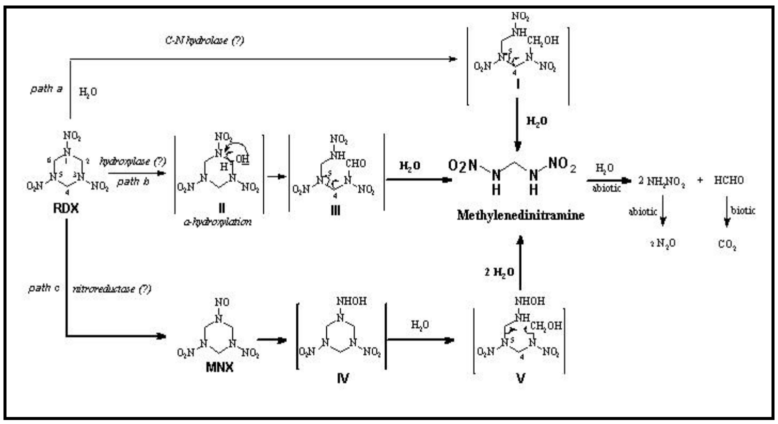

Figure II-2. Degradation Pathways for RDX and HMX.

A second SERDP energetics project focused on the degradation of non-aromatic energetics such as RDX and HMX. **Microbial Degradation of RDX and HMX, (CU-1213)**, was funded to research the enzymatic and microbial processes that rapidly degrade RDX and HMX. The research team characterized and confirmed degradation of RDX/HMX, under both aerobic and anaerobic conditions, allowing the identification of key intermediate degradation steps and final end products (Figure II-2). The team initiated experiments that identified and isolated from sludge and soil samples microbial species that degrade RDX and HMX, and identified microbial genes that are coded for RDX degradation enzymes. During FY 2002, researchers integrated these known chemical and enzymatic processes to establish the biochemical pathway for degradation of the RDX and conducted microcosm studies to monitor the degradation of RDX and HMX. The results of this project provide a solid foundation for pilot-scale work to develop engineering parameters for the remediation of RDX and HMX in the field.

In a third project, **Novel Pathways of Nitroaromatic Metabolism: Hydroxylamine Formation, Reactivity and Potential for Ring Fission for Destruction of TNT, (CU-1214)**, researchers from Rice University are investigating the biochemical mechanism of TNT ring fission. The goal is to harness this activity to remediate TNT contamination in soil and groundwater. The research team has identified a novel TNT transformation pathway that results in non-aromatic compounds. The characterization of these transformation products has demonstrated that when aromaticity is lost, the product is considerably different than the last known aromatic intermediate. The research team also determined the mechanism of ring fission and identified the enzymes that were responsible. The final step of the project in FY 2002 was to validate the destruction of TNT in a lab-scale microcosm test using soils from the Volunteer Army Ammunition Plant. This information will be transitioned to aid in the development of effective strategies to remediate TNT contamination in soils and groundwater.

To expedite the prioritization and cleanup of DoD sites contaminated with explosives compounds, scientifically-based, ecological soil screening levels (Eco-SSLs) are needed to identify contaminant levels in soil that present an unacceptable ecological risk. Responding to this requirement, SERDP funded **Development of Ecological Toxicity and Biomagnification Data for Explosives Contaminants in Soil, (CU-1221)**. Researchers at the Army Edgewood Chemical Biological Center have conducted experiments to establish Eco-SSL values for a variety of different soil conditions. For the first time, researchers developed Eco-SSL values for soil invertebrates and terrestrial plants using exposures of explosives in soils (Figure II-3). The methods developed in this project will aid in the development of Eco-SSL values for other contaminants and receptors and in the determination of the bioaccumulation potential for explosives contamination at DoD and DOE sites. These scientifically-based, Eco-SSLs will be used to identify sites with soil contaminant levels that present an acceptable ecological risk, thereby potentially reducing the number of sites requiring cleanup. Identifying sites with contaminant concentrations below these Eco-SSLs early in the ecological risk assessment process can generate significant cost savings for remediation efforts while protecting human health and the environment.

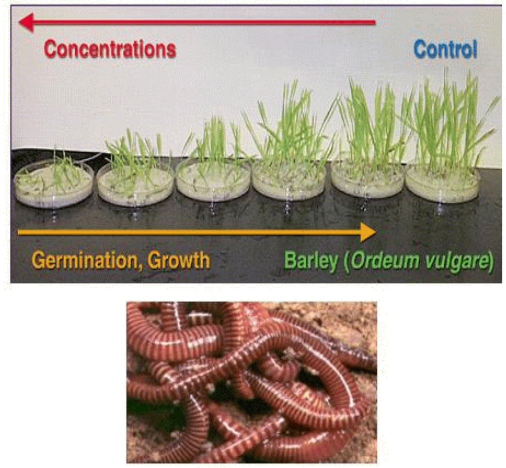

Figure II-3. Soil Invertebrates and Plants Used in Toxicity Testing.

The collective results of these SERDP projects will facilitate the establishment of more cost-effective and efficient remedial action plans that are protective of human health and the environment. The degradation processes characterized through this research will improve the reliability of energetic contaminant treatment processes and expedite the cleanup/closure of energetics-contaminated DoD sites.

In-Situ Bioremediation of Perchlorate Impacted Groundwater

Figure II-4. Rockets that Use Perchlorate-Based Propellants.

Perchlorate (ClO_4^-) is a salt that is used as the primary oxidizer in solid rockets such as the Titan, Minuteman, Peacekeeper, Hawk, Polaris, and Space Shuttle (Figure II-4). Perchlorate is very stable and mobile in the subsurface, therefore groundwater contamination related to the production, handling, and use of rocket propellants has been identified as a widespread problem at DoD, DOE, National Space & Aeronautics Administration (NASA), and defense contractor facilities. In California, Arizona, and Nevada, it is estimated that perchlorate has been detected in the drinking water supplies of more than 18 million people. The concern surrounding perchlorate in groundwater and drinking water supplies relates to its ability to adversely affect thyroid function.

SERDP funded three research teams to develop the basic science and understanding needed to develop cost effective, in-situ treatment technologies for groundwater contaminated with perchlorate. These research teams worked closely with one another, and the technologies now have transitioned to large scale demonstrations.

Under the SERDP-funded project **In-Situ Bioreduction and Removal of Ammonium Perchlorate, (CU-1162)**, researchers from Southern Illinois University (SIU) investigated the microorganisms that degrade perchlorate. Researchers isolated and characterized more than 30 perchlorate-reducing bacteria that were collected from a broad diversity of subsurface environments. These studies demonstrated that microbial perchlorate reduction is ubiquitous in the environment. The SIU team successfully developed a universal probe that is able to rapidly determine if perchlorate-reducing bacteria found in the soils contain an enzyme that is essential for the reduction of perchlorate. This enzyme catalyzes the dismutation of toxic chlorite (ClO3-) into harmless chloride (ClO2-) and oxygen (Figure II-5).

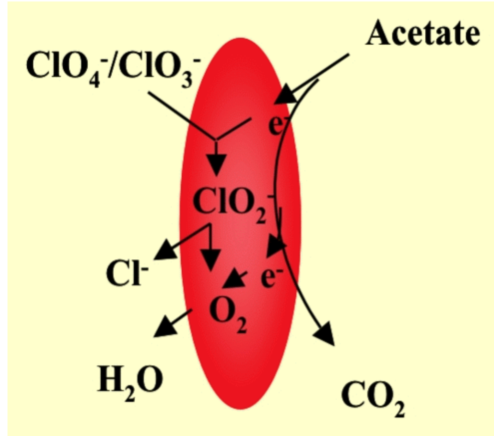

Figure II-5. The Chlorite Dismutase Enzyme Found in Bacteria Can Reduce Perchlorate to Harmless Compounds.

Researchers at Envirogen, Inc., conducted laboratory studies under the SERDP project **In-Situ Bioremediation of Perchlorate, (CU-1163)** to develop the fundamental knowledge required for designing and implementing in-situ bioremediation technologies at perchlorate-contaminated sites. Envirogen researchers determined: (1) the most effective nutrients or substrates for stimulating perchlorate reduction by naturally-occurring bacteria; (2) the role of alternate electron acceptors, such as nitrate, ferric iron, and sulfate on perchlorate reduction; and (3) the impact of co-contaminants and environmental factors on perchlorate biodegradation. Laboratory studies revealed that with the addition of an appropriate substrate, microorganisms in most cases can be stimulated to degrade perchlorate to below detection limits. Using soil column studies, researchers developed kinetic models of perchlorate biodegradation that describe the degradation of perchlorate in the presence of compounds that would impede its degradation. This model was incorporated into an existing reactive contaminant transport model and is being used as a tool for predicting perchlorate transport and degradation in the field.

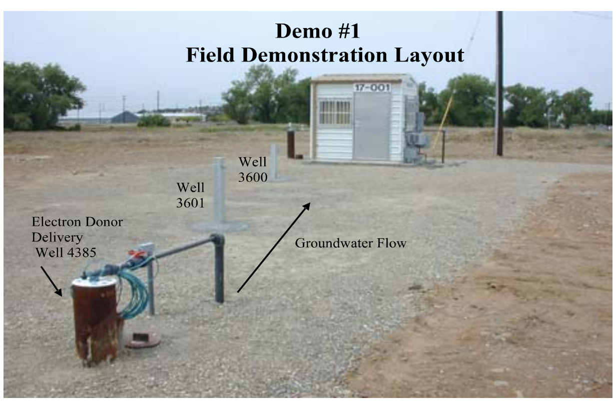

Figure II-6. Small Pilot-Scale Demonstration of the Biobarrier Used to Remediate Perchlorate-Contaminated Groundwater.

Using the information obtained in the two SERDP projects described above, researchers from GeoSyntec Consultants, Inc., have completed a field pilot test that demonstrated the in-situ bioremediation of perchlorate. Under the project **In-Situ Bioremediation of Perchlorate-Impacted Groundwater, (CU-1164)**, researchers used an innovative approach in which perchlorate-contaminated groundwater was captured, extracted and then combined with ethanol and acetate, compounds that are known to promote biodegradation of perchlorate in groundwater. This mixture was then re-injected via recharge wells into the ground to the appropriate depth interval of the aquifer. Using this innovative technique, the capture and recharge wells formed a zone of perchlorate degrading bacteria, also known as a "biobarrier," in the groundwater that prevented further migration of the perchlorate plume (Figure II-6). This novel approach has been transitioned for demonstration and validation under the ESTCP program, and shows promise for significantly reducing the costs of remediating perchlorate-contaminated groundwater.

These collaborative SERDP efforts have answered some of the basic science questions and indicate that biodegradation of perchlorate contaminated groundwater is easier to achieve then first thought. These successful technologies are now ready to transition to the Environmental Security Technology Certification

Program (ESTCP) to conduct pilot-scale, field evaluations to determine the costs and performance of these technologies at a larger scale.

Metals

Thousands of sites at Department of Defense (DoD) installations contain soils contaminated with the metals lead (Pb), arsenic (As), chromium (Cr), and cadmium (Cd). SERDP researchers have been investigating methods to facilitate better cleanup decisions at these sites. To evaluate a site contaminated with metals, risk assessors estimate the human health risks from a number of different potential contaminant exposure pathways. For future residential or recreational land-use scenarios, the ingestion of soil by children is almost always the critical human health exposure pathway. The default risk assessment guidelines for most metals assume that, when children ingest metal-contaminated soil, all of the metal is completely absorbed by the body (i.e., the metal is 100 percent bioavailable). Soils, however, often tightly bind metals, potentially reducing their bioavailability. Therefore, implicitly assuming that metals in soil are 100 percent bioavailable may overstate the risks posed. In fact, a previously-funded SERDP technology, known as phosphate-induced metal stabilization (PIMS), stabilizes metals in soil using a natural and benign additive, Apatite II, to chemically bind metals into stable, insoluble minerals. PIMS has been successfully transitioned to the field and is being use to remediate metals-contaminated soil at DoD facilities.

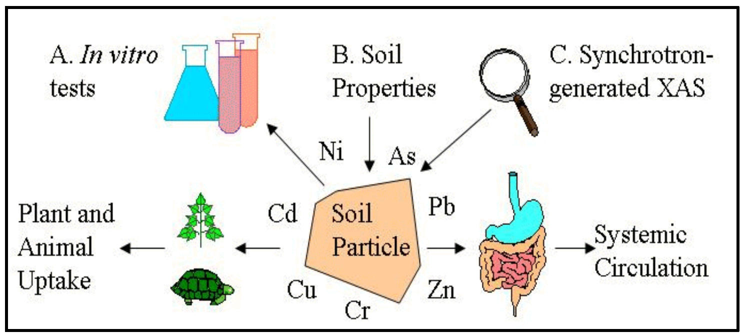

Figure II-7. Researchers Developed a Model to Predict the Bioavailability of Metals Based on Soil Properties.

To better assess the risks associated with metals in soil at DoD sites, SERDP funded the project, **Quantifying the Bioavailability of Toxic Metals in Soils, (CU-1166)**. Researchers from Oak Ridge National Laboratory measured changes in the relative bioavailability of metals over time in a wide range of soil types at DoD sites, and developed a predictive model to quantify toxic metal bioavailability on the basis of soil properties (Figure II-7). The results of this SERDP project indicate that soil-metal interactions significantly reduce the bioavailability of Cr and As in soils. For example, naturally-occurring organic matter in soil can reduce chromium(VI) to chromium(III), significantly reducing its bioavailability. In FY 2002, researchers used this model to successfully predict the bioavailability of As in soils (as measured in swine feeding studies) to within an average of 10 percent, based on the soil's pH and iron oxide content. This improved fundamental understanding of the processes that control the long-term sequestration and bioavailability of metals, along with a new predictive model, will allow DoD site managers and risk assessors to make better initial estimates of the human health risks posed by metals. These estimates of risk can then be used to prioritize high-risk sites and to better determine when costly, site-specific bioavailability studies are needed.

Chlorinated Solvents

Chlorinated solvents have migrated through the subsurface and entered the groundwater at many DoD/DOE sites and account for a significant portion of environmental contamination requiring cleanup action (Figure II-8). Dense non aqueous phase liquids (DNAPLs) consisting of chlorinated solvents pose the most widespread obstacle to cleanup at DoD/DOE facilities, with annual costs greater than $500,000 for containment and monitoring of a single DNAPL plume. The technology for remediation at more than 90 percent of the sites with DNAPL contaminated groundwater is pump and treat. While this method can be

Figure II-8. Past Disposal Practices Lead to the Release of DNAPL and Other Hazardous Waste into the Groundwater at Many DoD Facilities.

effective in controlling the migration of DNAPL contaminated groundwater, in-situ alternative treatment technologies are required to more effectively and more cheaply remediate DNAPL contamination.

The degradation of the chlorinated solvents tetrachloroethene (PCE) and trichloroethene (TCE) is well understood. However, there is great uncertainty about the environmental fate of the PCE and TCE breakdown products cis-1,2 dichloroethene (cis-DCE) and vinyl chloride (VC), which are more carcinogenic than PCE and TCE. Microorganisms at some contaminated sites seem unable to completely dechlorinate PCE and TCE into non-carcinogenic ethene. Therefore, cis-DCE and VC often accumulate, posing significant environmental concerns.

To provide insight into the factors that control the bioremediation of cis-DCE and VC, SERDP funded three projects beginning in FY 2000. In a project entitled **Aerobic and Anaerobic Transformation of cis-DCE and VC: Steps for Reliable Remediation, (CU-1167)**, researchers at Michigan State University characterized microbiological dechlorination processes and evaluated their potential applicability to groundwater remediation. Results from this study indicate that the microbial populations that exist at most contaminated sites are able to degrade these compounds, but are missing key components that are required to completely dechlorinate cis-DCE and VC. Researchers compiled geochemical and contaminant data from 17 sites, performed microcosm studies using soil samples from each site, and identified the conditions required to stimulate microorganisms that fully degrade cis-DCE and VC to ethene. The results of this research provide a protocol to select the best strategies to achieve cleanup goals at sites where chlorinated solvents are contaminants of concern in groundwater.

In the project, **Characterization of the Aerobic Oxidation of cis-DCE and VC in Support of Bioremediation of Chloroethene-Contaminated Sites, (CU-1168)**, researchers from Cornell University studied the distribution and metabolic capabilities of aerobic microorganisms that degrade cis-DCE and VC (Figure II-9). The results indicated that most of the organisms are capable of using VC as a growth substrate, enabling them to degrade VC to ethene. A small portion of the microbes were able to use cis-DCE as a growth substrate. The team isolated and characterized the VC-degrading bacteria and found that most are from the mycobacterium family. The information developed with this project significantly enhances our understanding of the role of aerobic processes in degrading these highly toxic, lesser-chlorinated compounds.

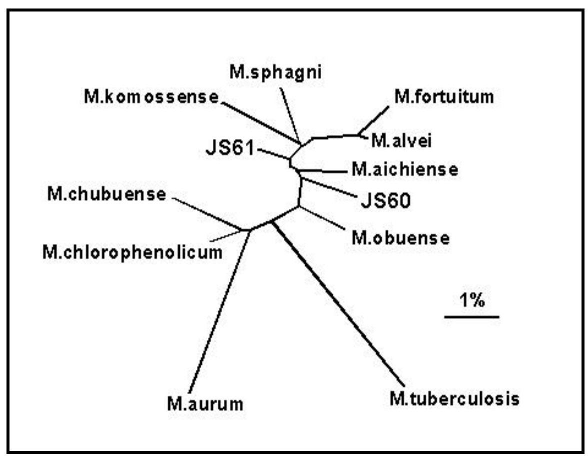

Figure II-9. SERDP Researchers Isolated Two Mycobacterium Species from Groundwater (JS60) and Sludge (JS61) Which Degrade Toxic VC.

The collective results of these SERDP projects will aid in the development of robust, cost-effective, in-situ strategies to remediate chlorinated solvents in groundwater, a persistent and costly problem at DoD facilities nationwide.

Compliance Accomplishments

Range Sustainability

Figure II-10. The Firing of Live Munitions May Leave Residues of Explosives Compounds on Soils.

Testing and training ranges are essential to maintaining the readiness of the Armed Forces of the United States. Concerns have arisen over the potential environmental contamination from residues of explosive materials, also known as "energetics". The current state of knowledge concerning the nature, extent, and fate of contamination is inadequate to ensure sound management of ranges as sustainable resources. Sustainable ranges enable military training under realistic combat conditions, while minimizing environmental impacts on the ranges and surrounding communities. The SERDP project, **Distribution and Fate of Energetics on DoD Test and Training Ranges, (CP-1155)**, is identifying range activities that result in explosives residues that may have the potential to contaminate groundwater (Figure II-10). Researchers from the Department of the Army's Engineer Research and Development Center have devised a novel approach to assess the potential for groundwater contamination from residues of the explosives compounds TNT, RDX, and HMX, by determining the concentration of post-blast residues and identifying major sources of explosives contamination.

SERDP-funded researchers have estimated explosives contaminant source terms for high- and low-order detonations and weapon firing points for a variety of munitions. They have also developed a protocol that can be used to accurately characterize explosives contamination in soils on military ranges across the United States. Fate and transport process descriptors have been developed to better predict the risks of explosives residues in the environment. Furthermore, a comparison of samples found at the Massachusetts Military Reservation (MMR) with data collected for this project confirmed suspicions that low order rounds and cracked unexploded munitions were the primary sources of contamination.

Researchers also conducted range characterization studies at 17 locations, including four Canadian sites and a site in Hawaii. The composition, distribution, and concentrations of explosives residues vary with range use, and the distribution of residues can be extremely heterogeneous. At artillery ranges, the data indicate surface contamination, in general, ranges from nondetectable to extremely low-levels. However, there are "hot-spots" of significantly higher concentrations around targets and low-order detonations. Results of the characterization of four hand-grenade ranges reveal that the residues are distributed more evenly at concentrations that require remediation of the entire grenade range.

Understanding the migration of these energetic materials from the soil surface into soil pore water is critical for defining the impact of energetic residues on groundwater contamination. The SERDP project, **Measurement and Modeling of Energetic Material Mass Transfer to Pore Water, (CP-1227)**, has developed a source release function that predicts the mass transfer of solid energetic materials to soil pore water. In FY 2002, this information was used in a transport model that links the release of energetic compounds to weather cycles that control the transport process. Experimental observations indicate that low-order detonation residues are a significant pollution source, and that weather cycles drive the impact to groundwater. The inclusion of an energetic material source release function in soil transport computer models has created a new predictive ability to assess the migration potential of energetic materials left by military testing and training operations. This tool will enable range managers to make decisions that mitigate the impacts of munitions training activities on groundwater.

Figure II-11. Corrosion of Intact, Unexploded Ordnance May Pose a Risk at U.S. Military Testing and Training Ranges.

In addition to the risks posed by energetic residues, it is estimated that 1,500 different sites, encompassing 15 million acres of land, contain unexploded ordinance (UXO). These intact munitions corrode at vastly varying rates in soil (Figure II-11). Understanding the relative rates of corrosion can greatly enhance the assessment of risks to humans and the environment posed by the toxic energetic and constituent materials. In FY 2002, the SERDP Project, **Corrosion of Unexploded Ordnance in Soil Environments, (CP-1226)**, collected and analyzed soil and UXO scrap metal samples from several ranges across the country. By sampling UXO under various environmental conditions, the data generated by this work have been used to develop a robust UXO corrosion model for evaluating the environmental risks of UXO corrosion at U.S. military installations.

The advances in basic science and the tools developed by these three innovative SERDP projects will foster cost effective sustainable range management strategies that will ensure the long-term viability of active military ranges.

Dust Emissions and Air Quality

Fugitive dust is a relatively new term for an old problem. It consists mainly of small airborne particulate matter (PM), and especially PM less than 2.5 microns in size ($PM_{2.5}$), that does not originate from a specific point such as a smoke stack. Human activity coupled with unfavorable weather conditions, can dramatically increase fugitive dust levels in the atmosphere. Fugitive dust contributes to local and regional air pollution, and recent research indicates that there are significant health risks associated with PM. New and more stringent air quality regulations set strict standards for allowable levels of PM. As municipalities develop air quality plans to meet these standards, fugitive dust is likely to be scrutinized more closely as a component of overall air quality conditions.

Figure II-12. Tank Training Activities Are a Source of Fugitive Dust.

Military activities on Department of Defense (DoD) installations in the southwest U.S. are potentially large contributors of wind-blown fugitive dust due to the presence of large expanses of fragile desert soils and the disruptive nature of these activities (Figure II-12). PM emitted by testing and training activities impacts vehicle performance, and threatens the health and safety of military personnel due to inhalation of PM and loss of visibility. The SERDP-funded project, **Characterizing and Quantifying Local and Regional Particulate Matter Emissions from DoD Installations, (CP-1191),** employs a systematic, empirically-based approach that combines environmental monitoring and field experimentation to quantify and characterize PM emissions from testing and training. The contributions from dust and other sources to PM emissions were measured during a one-year, ambient air quality monitoring program at upwind and downwind sites, combined with intensive monitoring during periods of active training. Progress in FY 2002 included the development of a PM emission factor database using upwind-downwind monitoring methods to measure vehicle-generated emissions with fast-response instrumentation. The long-range transport of the emitted PM and the potential visibility degradation downwind from the military base was accurately determined with an intensive field measurement campaign.

These dust emission factors will be used by another SERDP-funded project, **Development of a GIS-Based Complex Terrain Model for Atmospheric Dust Dispersion, (CP-1195)**, for testing in a GIS-based, dust emission model. The objective of this four-year project is to develop a fully tested and documented atmospheric dust dispersion modeling system for use by military staff to assess training/testing range contributions to local and regional air quality, to manage dust-generating activities, and to help develop dust mitigation strategies. A primary focus of the proposed research is to develop an EPA-approved, GIS-based air quality model that will be compatible with available military land management and operational models and will incorporate the effects of complex terrain on dispersion. In FY 2002, researchers incorporated two EPA-approved atmospheric models (CALPUFF and CALGRID) into a modeling system with the existing PGEMS atmospheric model to provide the most accurate predictions of atmospheric conditions that affect dust transport. The research team also formulated a new dust emission module for military vehicles, and produced a preliminary version of the modeling system for review and use at military training facilities.

Additional collaborative efforts on dust emissions research included the SERDP project, **Characterization of $PM_{2.5}$ Dust Emissions from Training/Testing Range Operations, (CP-1190)**. The goal of this study is to provide installation environmental staff with scientifically validated information for developing dust emissions inventories, environmental assessments, and cost-effective dust control measures that are compatible with mission readiness. The major components of this project include: real-time air samples, laboratory analysis of these samples, advanced real-time sample analysis techniques, theoretical modeling, and measurement of PM emissions in the field and at receptor sites. The study is based on two hypotheses developed from previous studies of dust emissions in arid climates. First, only a small fraction of the dust that is initially emitted by DoD activities is actually transported long distances. Second, dust emissions from various sources potentially contain marker species that are present at higher concentrations than the regional background species. These markers can provide accurate methods for quantifying the contribution of various sources to the PM collected at receptor sites (Figure II-13). This project's experimental program tested these hypotheses during FY 2002, with an integrated program of dust sampling at multiple locations and elevations above grade during selected troop operations on unpaved roads or cross-country trails.

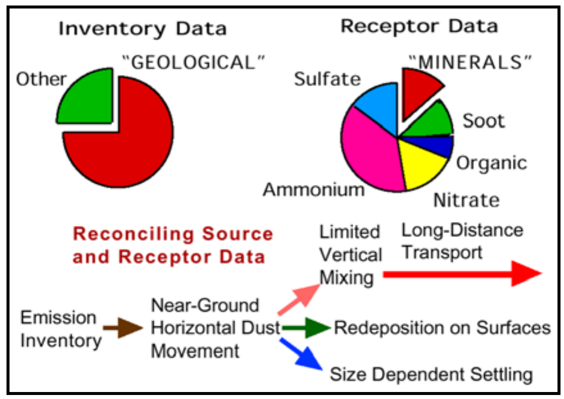

Figure II-13. Partitioning of Dust Between Transport and Redeposition May Explain the Difference Between Source Inventory and Receptor Site Estimates of $PM_{2.5}$ Emissions.

The products of these collaborative SERDP projects include a critical evaluation and review of the characterization of dust sources, a dust emission inventory, and a transport modeling technology to assess the impacts of training/testing operations. The collective results of this partnership of researchers is a set of innovative tools that can accurately assess the contribution and help mitigate the impacts of fugitive dust from military activities.

Engine Emissions and Air Quality

The Department of Defense (DoD) needs new, cost-effective technologies to comply with the more stringent National Ambient Air Quality Standards (NAAQS) for particulate matter below 2.5 microns ($PM_{2.5}$). In addition, Title III of the CAA Amendments (CAAA) of 1990 requires the promulgation of National Emission

Standards for Hazardous Air Pollutants (NESHAP) that will establish emission standards for sources such as engine test facilities, including jet engine test cells (JETCs). Therefore, air emissions from both stationery and mobile air pollutant sources are a concern for military environmental managers. Characterization of the health risks of air pollutants of various particle size ranges would allow for the most effective design of pollution control devices for military sources.

The SERDP project, **Characterization of Particulate Emission: Size Characterization and Chemical Speciation, (CP-1106)**, is developing advanced methods for the measurement of the size distribution and composition of PM emissions and will provide the DoD with the tools needed to characterize and control these emissions from DoD facilities. The data obtained from the evaluation of these instruments provide a measure of the relative importance of different DoD PM emission sources, and will guide strategies to control these emissions. Two innovative techniques for rapid measurement of fine PM were used in combination with a dilution sampler. The first is an aerosol time of flight mass spectrometer (ATOFMS) that measures the size and composition of individual articles. The second is a photoelectric aerosol sampler (PAS) that provides rapid measurement of PM that contains hazardous polycyclic aromatic hydrocarbon (PAH) particles, which dominate the PM emissions from combustion sources. The value of ATOFMS for providing rapid diagnostic information on diesel operations has been demonstrated and has provided important new data on the different classes of compounds emitted by diesel and spark ignition engines, as well as coal-fired facilities. The PAS has successfully demonstrated its potential for measuring jet engine emissions under actual operating conditions from off-runway measurements. In FY 2002, researchers developed assessments of the relative cost, reliability, and speed of these alternative air emissions measurement strategies, their ease of use, and potential use for feedback control to improve engine efficiency. The results indicate that these new instruments can provide PM composition information much more quickly, accurately, and cost-effectively than traditional measurement instruments.

Figure II-14. The Annular After-Reactor Reduces Emissions of Particulate Matter from Jet Engine Test Cells.

The SERDP project, **Reduction of Particulate Emissions from Jet Engine Test Cells Using an Annular After-Reactor, (CP-1126)**, has developed an approach that will allow the Jet Engine Test Cells (JETCs) used by all components of the DoD (Navy, Air Force, and Army) to become compliant with anticipated regulatory requirements in a cost-effective manner. This project developed a prototype Annular After Reactor (AAR) to reduce particle emissions from JETCs (Figure II-14). The AAR, positioned in the flow path of the jet engine exhaust tube, is simply a hollow pipe that delays the mixing of exhaust gases with the surrounding air stream for a sufficiently long residence time, promoting the incineration of up to 90% of PM. With a slight modification, the system may also be adapted for the removal of nitrogen oxides (NOx), carbon monoxide (CO), and unburned hydrocarbons. The results of tests conducted in FY 2002 are promising, with significant PM reduction at lower than anticipated temperatures, suggesting that PM reduction and NOx reduction could be achieved simultaneously. A side benefit of this technology is its ability to reduce the noise of the jet exhaust, which is a significant concern for facilities located near communities. In addition to JETCs, this technology has the potential to be transitioned to other stationary and mobile sources of combustion emissions.

The treatment of volatile organic compound (VOC) air pollution releases, during the application or removal of paints on military aircraft, is necessary to maintain compliance with regulations developed under the Clean

Air Act Amendments of 1990. Currently available VOC emissions control technologies are costly at the high volumetric flow rates and low contaminant concentrations associated with the ventilation of hangars used for the painting of military aircraft. Biofiltration of paint off-gas streams is limited, not because of insurmountable technical problems, but because current systems have not been designed to handle the operating conditions typical at these facilities. The SERDP project, **Optimization of an Innovative Biofiltration System as a VOC Control Technology for Aircraft Painting Facilities, (CP-1104)**, developed an innovative, high flow-rate biofiltration method for treating VOC-laden air emissions from aircraft painting facilities (Figure II-15). In FY 2002, SERDP researchers investigated, tested, and applied innovative design features and biofilter configurations to an actual Air Force paint spray booth. A series of experiments have been conducted using a bioreactor packed with hydrophobic foam and inoculated with a consortium of VOC-degrading bacteria. These experiments compared the performance of biofilters operated as conventional, continuous-flow systems versus those operated using sequenced batch operations. The results indicated that the sequentially-fed bioreactor achieved a pollutant elimination capacity nearly double that of the continuously-fed biofilter column. This innovative system has the added advantage of operating at ambient temperatures and minimizing the generation of secondary wastes.

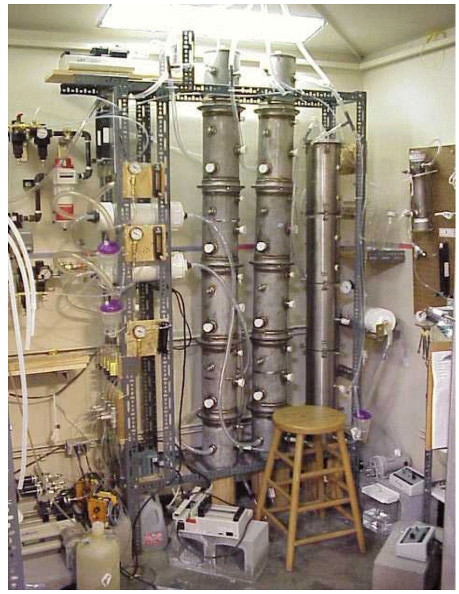

Figure II-15. An Innovative Biofiltration System Successfully Treats VOC-Laden Emissions from Aircraft Paint Spray Booths.

The collective results of these advanced air emissions monitoring technologies combined with innovative air emissions treatment technologies will help ensure that DoD will continue to maintain military readiness while complying with stringent air pollution regulations.

Conservation Accomplishments

Threatened, Endangered and At-Risk Species—Monitoring of Marine Mammals

There is increasing concern that man-made sounds may have detrimental effects on marine mammals. Anthropogenic ocean noise is associated predominantly with commercial shipping, but a wide variety of other noises such as explosive sources, sonar, and seismic exploration, may also affect marine mammals. These noise sources, especially shipping, have contributed to a dramatic increase in the ambient sound field in the world's oceans.

Marine mammals are protected under the Marine Mammal Protection Act (MMPA), the Endangered Species Act (ESA), and National Environmental Protection Act (NEPA). The MMPA prohibits harassment of marine mammals. Some concern exists that Navy sonar activities may constitute harassment to marine mammals, especially to deep-diving whales. If so, this harassment may be subject to regulation under MMPA. The Navy has a high priority requirement for data on marine mammal locations and seasonal population densities within areas of frequent naval operations to ensure that Navy operations do not constitute harassment. Two SERDP funded projects are addressing the Navy's concerns by developing advanced techniques for predicting the location and monitoring the behavior of marine mammals.

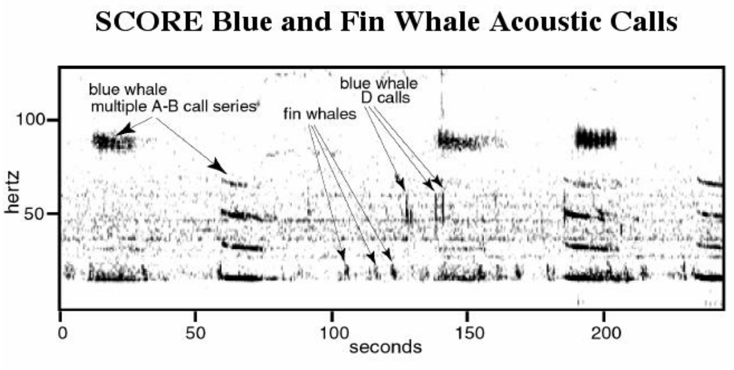

Figure II-16. Recordings of Whale Vocalizations off the Coast of California.

Under the direction of Dr. John Hildebrand from the Scripps Institution of Oceanography of the University of California, San Diego, the SERDP project, **Acoustic and Visual Monitoring for Marine Mammals at the Navy's Southern California Off-Shore Range, (CS-1189)**, is leading the Navy's efforts to compare methods for actively monitoring marine mammals within the Southern California Off-Shore Range (SCORE), a region where naval operations are frequently conducted and where marine mammals are known to be abundant. The project uses aerial visual surveys, ship-based transects, sonobuoy-based mobile acoustic surveys, and continuous fixed-site acoustic surveys (Figure II-16) for real-time marine mammal detection and classification. Research conducted in FY 2002 has resulted in a comprehensive database of seasonal marine mammal movements within SCORE. This information supports a model that can be used to accurately predict the presence of marine mammals with a given set of environmental conditions, thereby allowing Navy to minimize the impacts of their training activities on marine mammals.

Figure II-17. The Digital Acoustic Recording Tag Developed by Woods Hole Oceanographic Institute (NMFS Permit #981-1578-0).

Dr. Peter Tyack, a senior scientist at the Woods Hole Oceanographic Institution (WHOI) under the SERDP project **Acoustic Response and Detection of Marine Mammals Using an Advanced Digital Acoustic Recording Tag, (CS-1188)**, is investigating the interrelationships between military noise in the ocean and the behavior of deep-diving whales. Dr. Tyack has worked with Dr. Mark Johnson, a research engineer at WHOI, to develop a compact electronic tag (Figure II-17) that can be temporarily attached to whales to record their exposure to acoustic signals and their vocal or behavioral responses to these exposures. This tag records whale vocalizations and ambient ocean sounds, along with the depth and orientations of whales in three dimensions, to correlate their reactions to controlled exposures of man-made noise. The recorded responses of the whales are analyzed to understand the reactions of marine mammals to various noise sources in the ocean. In FY 2002, Dr. Tyack and his team of researchers processed the data collected on whale movements and developed sets of whale response indices that can help the Navy establish safe exposure levels for these marine mammals during naval operations. Collectively, the results of these two projects provide advanced tools and predictive capabilities to ensure that Navy operations do not adversely impact marine mammals.

Ecosystem Restoration

The DoD recognizes the critical importance of riparian ecosystems as essential habitat areas, as well as for their beneficial effects on adjacent aquatic ecosystems, including the maintenance of water quality of streams and rivers on military installations. To address DoD's need to manage valuable riparian habitat, SERDP is funding the project, **Riparian Ecosystem Management at Military Installations: Determination of Impacts and Restoration and Enhancement Strategies, (CS-1186).** This project is identifying the impacts to riparian ecosystems of upland and riparian disturbances resulting from military training and prescribed

Figure II-18. A Riparian Zone at Fort Benning, Georgia Illustrating Heavy Erosion and Sedimentation.

fire (Figure II-18). Two riparian restoration strategies, woody debris addition and revegetation are also being evaluated.

Researchers measured key riparian parameters (e.g., vegetation, soil) and stream ecosystem parameters (e.g., water chemistry, metabolism, algal/macroinvertebrate communities) across a "disturbance gradient" (an area where military activities have disrupted the habitat) before and after riparian restoration. In FY 2002 (Year 2 of a six-year study plan), researchers completed the first phase of the project, which included the assessment of the impacts on riparian ecosystem functions resulting from a variety of upland and riparian disturbances. The initial two years of measurements provide the necessary data to quantify disturbance impacts to riparian ecosystem functions. A key accomplishment during these first two years was the development of mapped disturbance indices based on aerial photos and remote imagery. Phase II, a three-month restoration program, will commence in FY 2003, followed by a three-year period of data collection, providing the data needed to evaluate the effects of riparian restoration strategies. The results of this research will provide land managers at military installations with the information needed to make decisions concerning training intensity and the use of prescribed fire to more effectively protect the functioning of riparian ecosystems.

Maintaining military readiness requires extensive training maneuvers that can be highly damaging to vegetation and soil. Tracked and wheeled vehicles can damage plants and compress soils, compromising soil cover needed for sediment control (Figure II-19). The SERDP-funded project, **Identify Resilient Plant Characteristics and Develop Wear Resistant Plant Cultivars for Use on Military Training Lands, (CS-1103),** has been extremely successful in responding to the Department of Defense (DoD) land restoration needs by developing hardier grass varieties and seed mixtures and providing a better understanding of the effects of training on soil compaction, plant injury, and regrowth. Through the leadership of the Cold Regions Research and Engineering Laboratory (CRREL) of the U.S. Army Corps of Engineers Engineering Research and Development Center, and with the assistance of the U.S. Department of Agricultural's Agriculture Research Service, three new plant germplasms have been developed: two crested wheatgrasses and one wildrye. The grasses resulting from these germplasms are more resilient to military training activities and severe environmental conditions, because of their resistance to drought and cold temperatures, low maintenance requirements, and improved seedling vigor.

Figure II-19. Tanks and Other Tracked Vehicles Can Damage Plant Cover and Lead to Erosion.

Another component of this project in FY 2002 used seed mixtures that combine naturalized species from the new germplasms with native species indigenous to military lands. This combination helped to foster the biodiversity of plant species on military lands while providing soil cover and animal habitats. The research team also performed tank traffic studies which demonstrated that introduced species are more tolerant and recover more rapidly under repeated tracking than native plants. However, two of the native species being improved, western wheatgrass and Snake River wheatgrass, showed promise as stabilization species because they are able to spread into damaged areas. The greater yields by the natives in the control plots indicate that they can be used successfully in combination with introduced species to obtain native plant swards.

These new germplasms, seed mixtures, and compaction studies are providing a far-reaching return on the military investment in land repair and maintenance. With the guidance developed under this project, military, as well as other federal, State and local land managers now have access to better information on which plants are best suited to rehabilitate their lands and the effects of seeding naturalized species on the biodiversity of an ecosystem. This guidance is assisting land managers and trainers in arranging training schedules and in estimating cost and time requirements for maintaining military training sites.

Figure II-20. Garlic Mustard, an Invasive Plant Species on Military Lands Can Be Managed with Biological Controls.

Executive Order 13112 directs all federal agencies to develop a coordinated nationwide management plan to address the problem of invasive plant and animal species. Garlic mustard *(Alliaria petiolata)*, an introduced European plant species, is one of the most invasive weed species in the Northeast, Southeast, and Midwest, replacing native spring wildflowers in forest communities (Figure II-20). Physical, mechanical, and chemical means have failed to provide long-term control of garlic mustard. However, the development of biological controls appears to be an option for the ecologically-sound management of garlic mustard and the restoration of native species and their habitats.

The SERDP-funded project, **Developing Biological Control of Garlic Mustard, (CS-1146)**, has identified four insect species *(Ceutorhynchus alliariae, C. roberti, C. scrobicollis* and *C. constrictus)* that show promise as biological control agents for garlic mustard in North America. Personnel at the CABI Bioscience Center in Switzerland, under the auspices of Dr. Bernd Blossey of Cornell University, have studied the ecology, life history, and impact of these specialized insect herbivores in Europe to develop and implement a biological weed control program for garlic mustard in the United States. To assess the impact of the release of biocontrol agents on garlic mustard and native plant communities, a standardized monitoring protocol was developed in FY 2002 using long-term monitoring sites on DoD installations. Data collected on garlic mustard performance (height and seed production) and abundance (presence/absence, number of stems, cover, and biomass) were recorded to evaluate the influence of habitat types on the control success. A formal petition to the Technical Advisory Group on Introduction of Biological Control Agents (within US Department of Agriculture Animal and Plant Health Inspection Service) for the use of these insects in biological control is forthcoming.

The standardized protocols developed by this project can now be used by researchers and natural resource managers at military installations and other agencies to monitor the success of biological control agents on garlic mustard. Workshops and manuals have been designed to better educate resource managers on the application of biological weed controls and to the use of the protocols to closely monitor the success of garlic mustard control programs.

Pollution Prevention Accomplishments

Green Energetics

Military munitions are an essential part of the defense arsenal. They include not only gun rounds, missile propellants, and explosives, but also pyrotechnic materials such as flares and smokes. The energetic materials in munitions are hazardous and toxic, and the manufacturing process requires additional toxic materials such as solvents and heavy metals. An estimated 500 million pounds of energetic materials are produced each year, producing millions of pounds hazardous wastes. SERDP research has led to innovative techniques and materials that have significantly reduced munitions toxic waste.

Pyrotechnics are used in a variety of military applications (Figure II-21). Two such applications are infrared decoy flares and colored signal flares. Many such pyrotechnic flare compositions contain chlorate or perchlorate oxidizers. Residual perchlorates released to the ground from these devices may potentially migrate to groundwater and require remediation. Other additives in pyrotechnic flares may also contain chlorine compounds, such as hexachlorobenzene (HCB) or polyvinyl chloride (PVC), which are used as chlorine donors for color enhancement in colored signal flares. HCB is a known carcinogen, reproductive toxicant, and a Superfund hazardous substance that is subject to Toxic Release Inventory (TRI) reporting requirements. When these chlorine-containing devices are employed, hydrogen chloride (HCl) is evolved as one of the reaction products. HCl can react with water in air to form hydrochloric acid, an EPA-regulated toxic chemical that poses a hazard to personnel who may be exposed during the use of these items.

Figure II-21. Pyrotechnic Flares Used by a C-17 Cargo Aircraft.

In a SERDP project entitled, **Elimination of Chlorine Containing Oxidizers from Pyrotechnic Flare Compositions, (PP-1280),** a research team from the Naval Surface Warfare Center-Crane Division (NSWC-Crane) is investigating the feasibility of reformulating a variety of pyrotechnic compositions to reduce or eliminate chlorine-containing ingredients. From an initial study of infrared decoy flare compositions, a great deal of information was obtained. Baseline chlorine-free compositions, which contain potassium perchlorate as the oxidizer, were successfully produced using potassium nitrate as the oxidizer. Another fuel additive material exhibited burn times that were longer than the baseline, and had higher integrated band energies, an indication that these new compositions were more energetic. During FY 2002, these successful candidate compounds with band energy ratios that are within the range of the baseline compounds were selected for testing at the prototype scale. Full-sized flare units containing these chlorine-free compound units will be tested under static and high wind-speed conditions to determine their performance characteristics. Studies have also begun on red- and green-colored signal flares at the laboratory scale, utilizing some of the same fuel additives.

In addition to the concerns regarding chlorine-containing compounds, the DoD has acknowledged that heavy metal contamination is a critical environmental problem. As a result, DoD has begun reducing the use of heavy metals, including lead (Pb), in the design, manufacture, and operational use of its munitions. SERDP researchers are developing an advanced chemistry program that explores the electrical and thermal properties of metastable intermolecular compounds (MICs) for use in ammunition primer materials. MIC is typically composed of a mixture of nano particle aluminum as a fuel and an oxidizer, such as molybdenum trioxide (MoO_3).

The SERDP project, **Medium Caliber Lead Free Electric Primer, (PP-1331),** began as a SERDP Exploratory Development (SEED) project in January 2001 and is now a fully funded follow-on SERDP project. This project, led by a scientific team from the Naval Air Warfare Center Weapons Division (NAWCWD), is further developing the results of the SEED project to eliminate the use of lead in electrically-initiated, medium-caliber ammunition primers. Two successful and significantly different design approaches were identified during the course of this project in FY 2002. The first design is based on the configuration of the 20mm M52A3B1 electric primer, where the primer mix is electrically conductive and

Figure II-22. MIC Primer Ignition.

is initiated by passing through a strong pulse of electrical current. The alternate approach, which appears to have distinct advantages in terms of primer mix ignition properties, utilized the ‘exploding foil’ (EF) concept for primer initiation (Figure II-22). The principal outcome of the SEED project was to verify that MIC material has the potential for use in the manufacture of medium caliber electrically initiated primers. Research proved that the MIC-loaded primers can be safely handled and loaded into typical electrical primer parts, as well as effectively initiate the propellant charge of medium-caliber munitions. This project is now part of a larger SERDP umbrella program, Green Medium Caliber Ammunition, that is designed to address a wide array of environmental issues with the production and use of medium caliber munitions.

Elimination of Chromium and Cadmium

Preventing the corrosion of metal components of military vehicles, aircraft, and weapon systems is a multi-billion dollar challenge, accounting for 60 percent of annual DoD maintenance costs. Hexavalent chromium, an important component of high-strength steels and coatings, is a known carcinogen. Cadmium, an effective anti-corrosion agent, is toxic to human metabolism, and can lead to bone disease and kidney damage. SERDP research has achieved major breakthroughs in the reduction of heavy metals in military waste streams, the development of more efficient application and removal technologies for protective coatings, and the replacement of heavy metals with environmentally benign materials.

Figure II-23. An Example of Structural Components of Aircraft Landing Gear.

Many of the major weapons system components that are cadmium-plated, such as aircraft landing gear (Figure II-23), are sensitive to hydrogen embrittlement during maintenance of the protective coatings, and to stress corrosion cracking during use. This sensitivity makes stress corrosion cracking the primary failure mechanism for landing gear, a failure that often causes significant collateral damage to aircraft. Therefore, regardless of which coating is used to replace cadmium on landing gear and other major structures, these failures will remain a problem, becoming more frequent as weapons systems age.

The best long-term answer to these problems is not a new coating, but a new steel that not only obviates the need for a corrosion protection coating, but also eliminates these failures. The SERDP project, **Computational Design of Corrosion Resistant Steels for Structural Applications in Aircraft, (PP-1224)**, used an innovative computational materials-by-design method that significantly reduces the number of prototypes, or melts, needed to develop a steel alloy. This project, led by a scientific team from QuesTek Innovations LLC, assembled a strong inter-disciplinary team of experts to develop a new superior stainless structural steel that combines mechanical properties equivalent to current ultra-high strength steels, with anti-corrosive properties that virtually eliminate the need for toxic metal plating. The result of QuesTek’s effort is the successful development of a new stainless steel, Ferium S-53, that matches the mechanical characteristics of the current alloy and adds corrosion resistance equivalent to 15-5PH stainless steel. Their design methodology represents a quantum leap in the development of new steel alloys and reduced development time, from over a decade, to just a few years, at roughly 5 percent of the normal development cost. This steel will be used in new landing gear designs and for the sustainment of legacy weapons systems.

Air Emission Reduction

Figure II-24. Typical CARC Painting of a Tracked Vehicle.

The painting of military vehicles, ships, and aircraft is required for identification, camouflage, stealth, and corrosion protection (Figure II-24). Every year, the military uses tons of paints and strippers in the maintenance and repair of its numerous weapons platforms. These materials often contain toxic chemicals and hazardous air pollutants. In a project entitled **Mechanisms of Military Coatings Degradation, (PP-1133)**, a research team from the Army Research Laboratory (ARL) is investigating the primary components of military coatings that will provide enhanced durability and minimize costly refurbishment of military weapon platforms and support equipment. The major goal of this project has not been to develop a new coating system, but rather to develop a comprehensive knowledge base to promote the production of more durable military coating systems and to allow program managers to make informed decisions regarding coating selection.

One particular success of this program in FY 2002 was an advance in the area of polymeric based flattening materials in chemical agent resistant coatings (CARC). A combination of analytical, characterization, and rigorous environmental exposure testing was conducted to compare the currently used silica-based flattening agents to the new polymeric flattening agents. The results of these analyses indicated that the polymeric flattening agents are far superior, based on key measures such as mar and impact resistance, flexibility, and weather resistance. The US Army Research Laboratory will now be able to introduce these advanced polymeric agents into the military's existing CARC formulations. Marine Corps and Army platforms that require a more durable coating may use a polymeric based topcoat for tactical and related support equipment. This program will have a positive impact on both pollution prevention and cost avoidance for the DoD, through the reduced use of toxic chemicals and a reduction in the quantity of hazardous wastes generated during the production of high-durability coatings for military platforms.

Next Generation Fire Suppression

Fire suppression is essential to the readiness and effectiveness of nearly all weapon systems. The fire suppressant chemical Halon 1301 (CF_3Br) has a high ozone depletion potential and thus has been out of production since January 1994. Inefficient near-term alternative compounds for both backfit and new fire suppression systems make Halon phase-out difficult because of serious weight and volume concerns, as well as negative operational and financial impacts. The **Next Generation Fire Suppression Technology Program (NGP), (PP-1059)** is attempting to demonstrate by the year 2005, alternatives for economically-feasible, environmentally-acceptable, and user-safe fire suppression processes, techniques, and fluids to meet the operational requirements satisfied by Halon 1301 systems used in aircraft. Through SERDP sponsorship, the National Institute of Standards and Technology (NIST), Gaithersburg, MD, has led a team of government, academic, and industrial scientists in identifying new fire suppression chemicals and improving the effectiveness of the delivery of these chemicals to suppress fires.

A large number of objective cost factors and subjective value factors must be considered when selecting a fire suppression system for military applications. The NGP has developed a comprehensive method to compare the total life cycle costs of alternative fire suppression technologies, while superimposing a subjective value system on this comparison. This approach determines the net cost of the fire suppression systems; i.e., the cost (a function of system size and weight) minus the cost savings (a function of extinguishant effectiveness and number of aircraft saved). One comparison of an alternative completed in

FY 2002, for protecting the engine nacelles of cargo aircraft (Figure II-25), quantifies the contributions of the various cost factors and fire suppressant performance data being developed under the NGP. In this example, the value of a Halon 1301 system was compared to that of an HFC-125 system of equal performance, with no ozone depleting potential. The latter system is slightly more expensive, but each system represents only about 0.2 percent of the total life-cycle cost of the aircraft. Therefore, the cost of this alternative is within an acceptable range, indicating promise for the use of this non-ozone-depleting alternative.

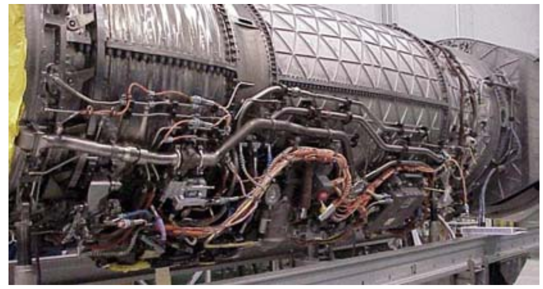

Figure II-25. Fire Suppression Duct Work Around a Military Aircraft Engine Nacelle.

UXO Accomplishments

UXO Detection and Discrimination

Figure II-26. The Result of Handheld Magnetometer Detection, Known as "Mag and Flag", is Literally a Sea of Flags, most of which are Non-UXO Metallic Clutter or Geological Features.

The active use of military ranges and live munitions is an integral part of maintaining DoD's mission readiness. The public and many regulatory agencies are becoming increasingly concerned about environmental and safety issues associated with the use of live munitions. Military training exercises and weapons testing spanning many decades have resulted in unexploded ordnance (UXO) contamination across significant areas of land. The list of areas potentially containing UXO includes active military sites, as well as land transferred for private use, such as Base Realignment and Closure (BRAC) sites and Formerly Used Defense Sites (FUDS). Innovative and cost-effective technologies are required to better characterize sites containing UXO (Figure II-26). The most important metrics for the success of these technologies are high UXO detection rates and low false alarm rates (i.e., the frequency of declaring a UXO object present when none is there). High false alarm rates often result in cleanup delays and excessive costs. Current electromagnetic (EM)-based UXO detection systems were originally designed for other uses, such as locating buried 55- gallon drums, and modified to accommodate the detection of UXO.

SERDP funded research in FY 2002 to improve the detection and classification of UXO using EM induction sensors. A SERDP-funded team from Lawrence Berkeley Laboratory under the project, **Detection and Classification of Buried Metallic Objects, (UX-1225)**, is developing an active EM system. Since its initiation as an FY 2000 SEED effort, this project has sought to design an optimum EM system that provides the most accurate detection of UXO, with the lowest field survey cost. To achieve this goal, the team employed a systematic approach for the design and fabrication of an optimum active EM system, based on methods used in the mineral exploration industry. The intent of the optimized system is to detect, discriminate, and classify buried metal targets.

FY 2002 work for this project focused on the development of a general inversion modeling code to determine the depth and principal polarizabilities of an arbitrary buried target. The inversion modeling code has been used to compare several existing EM systems as well as proposed EM systems. The code computes the uncertainties in the depth and polarizability estimates using noise estimates derived from the performance analysis of existing systems.

The implementation of multi-receiver active EM systems is predicated on the feasibility of using small dipole-like receivers (Figure II-27a) rather than the large air-cored loops currently in use. The criteria for evaluating any receiver is that its internal noise, converted to an equivalent magnetic field strength, must be at least equal to or lower than the ambient magnetic field at the measurement site. During FY 2002, the experimental evaluation of a small (12 cm), ferrite-cored solenoid receiver has shown noise levels at or below the ambient noise at one measurement site (Figure II-27b). The internal noise of the receiver (depicted in red and black), is significantly less than the field site noise (shown in blue) meeting the criteria for success and demonstrating the value of this systematic approach to enhance the capabilities of UXO detection systems.

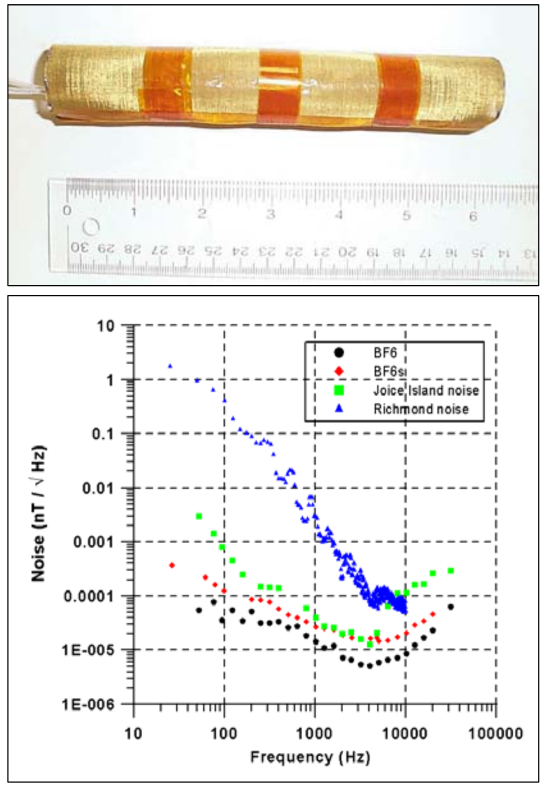

Figure II-27. Innovative Use of Small Receivers (Top) in the Next Generation of EM Sensors Allow Improvements in Sensor Platform Deployment with No Loss in Performance (Bottom).

Data Processing and Statistical Analysis

In FY 2002, SERDP continued to pursue new efforts in the characterization of UXO-contaminated sites. In many cases, UXO contamination is concentrated in a small portion of the potentially contaminated area, such as near a weapons practice target. To better focus detailed geophysical surveys and thus reduce the costs of surveying, SERDP established a goal of developing a sampling technique whereby a fraction of the site is initially investigated to identify clean and contaminated areas. The objective of this initiative was to develop scientifically sound sampling procedures that can exploit modern geophysical surveying techniques to characterize sites, determine confidence levels of the resulting assessments, and lead to cost-effective investigations of UXO-contaminated sites. Existing data processing algorithms also can be utilized to develop the sampling procedures required to meet cleanup objectives and to assess the knowledge gained from statistical sampling in terms of the likelihood that UXO is present.

Two teams from DOE, Pacific Northwest National Laboratory (PNNL) and Sandia National Laboratory (SNL) made significant progress in FY 2002 towards the development of a tool to guide sampling at UXO-contaminated sites. The PNNL team in SERDP project, **Statistical Methods and Tools for UXO Characterization, (UX-1199)**, incorporated additional functionality within Visual Sample Plan (VSP), a software package that helps the user determine the number and location of samples/ swaths required to adequately protect against decision errors. The ability to calculate the probability of traversing and detecting a target area of a critical size, shape, and density given a bivariate distributional pattern of anomalies was completed. The SNL team under **Bayesian Approach to UXO Site Characterization with Incorporation of Geophysical Information, (UX-1200)** focused on two major aspects: where to sample and when to stop sampling. Researchers utilized the kriging variance as a metric to determine the areas of uncertainty in order

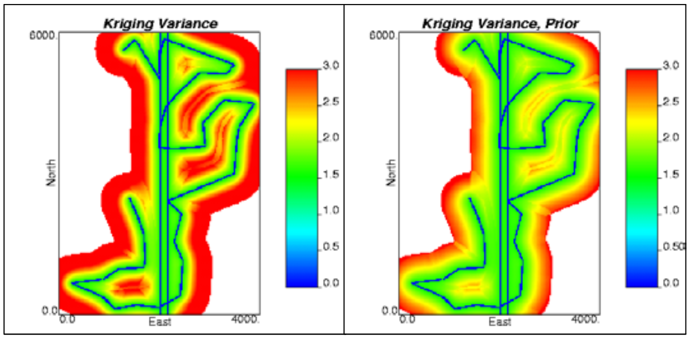

Figure II-28. SERDP Researchers Used Kriging to Provide an Estimate and a Measure of the Uncertainty of the Estimate (The Kriging Variance). (Results of the Analysis on Left Indicate in Red the Increased Uncertainty and Provide a Guide for Further UXO Sampling.)

to guide future sampling (Figure II-28). The primary emphasis was on the placement of subsequent sampling transects after the data from the initial transects has been processed and on answering the question of when enough sample transects have been collected. This question has been addressed through a recently developed variance minimization approach. This newly developed approach works for either straight or meandering transects and can be used to determine the locations of initial transects or to locate an additional transect given any number of existing transects.

The combined results of these two projects illustrate the progress that was made on developing and establishing statistical sampling methods relevant to typical UXO characterization scenarios. The appropriate approach to sampling depends on the Conceptual Site Model (CSM) and the phase of characterization. Sampling and statistical analysis methods are needed for the generalized CSM characteristics. Significant progress was made, with valuable input from members of the Technical Advisory Committee, towards the establishing a functional CSM that incorporates the methodologies developed under this statistical sampling effort. Advances are expected in the future that will foster the improved integration of the statistical sampling tools into a CSM.

UXO Test Sites for Technology Evaluation

SERDP is keenly aware that the transfer and restoration of contaminated DoD land is contingent upon advanced technologies that can detect UXO and discriminate it from harmless ordnance fragments and other nonordnance items. Technologies under development require access to real world data, as well as testing to verify their performance. Therefore, SERDP has funded the establishment of standardized test sites under project **Standardized UXO Technology Demonstration Sites, (UX-1300)**, to provide a diversity of geology, climate, terrain, and weather, as well as a diversity of buried UXO and clutter. These sites will be used to fully evaluate UXO characterization technologies, compare the performance of different systems, and compare performance in different environments, all on consistently constructed sites with common measurement protocols.

This multi-agency project, spearheaded by the U.S. Army Environmental Center, will provide a screening matrix of UXO technology system performance, a series of standardized site protocols, a standardized repository of buried targets and a variety of technology transfer materials. Current plans are for two sites at Aberdeen Proving Ground (APG), MD and Yuma Proving Ground (YPG), AZ. Efforts in FY 2002 culminated in the opening of the APG site in the summer of 2002, while significant progress was made towards the opening of the YPG site in early FY 2003.

Each UXO test site will include a calibration grid, a blind grid, and an open-field scenario. A recently established 17-acre site at APG is depicted in Figure II-29. The calibration grid (#1) allows demonstrators to test their systems with complete access to truth data for a variety of known buried ordnance targets and clutter objects. In the blind grid, the demonstrators are provided the location of each opportunity, but the contents, either ordnance, clutter, or nothing, will be unknown. The blind grid (#2) allows for UXO sensor characterization in the absence of uncertainties due to navigation and site coverage. The open-field scenarios (#3) test the performance of technologies in multi-acre sites with ordnance and clutter buried at unknown locations simultaneously to evaluate sensors, sensor platforms, navigation systems, and data processing techniques. The open fields present special challenges, including wooded areas, mogul/crater areas, adjacent power lines, steep terrain, and extreme desert environments at YPG.

Performance data gathered on various UXO detection and discrimination technologies via the three standardized test sites will help local project managers identify the most appropriate systems for their specific site applications. Standardized procedures and methodologies developed as part of this project will help to ensure that performance metrics such as system efficiency, UXO detection capability, UXO discrimination capability, and false alarm rate, are accurate and comparable. Data gathered in the process of characterizing and testing sensors and systems will support future research and development efforts and will hasten the development of more effective and less costly UXO remediation operations.

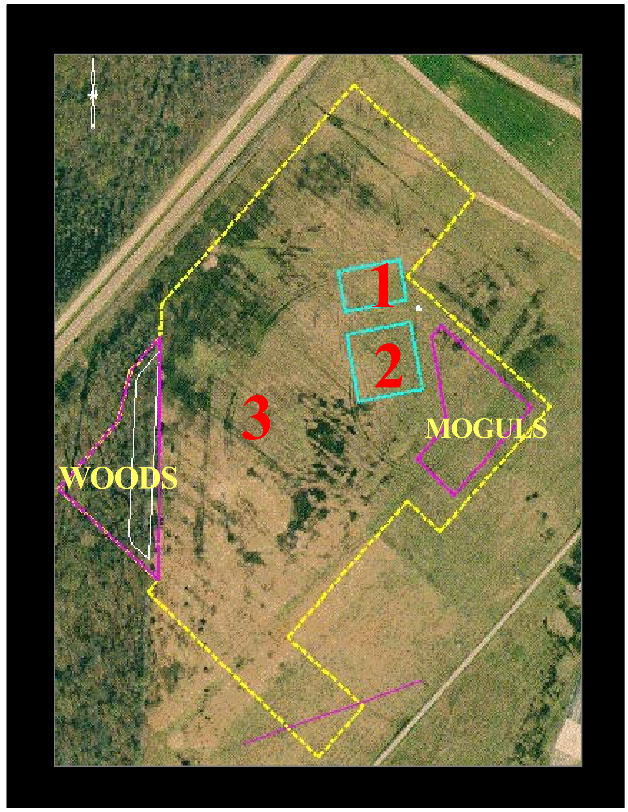

Figure II-29. SERDP Developed Standard UXO Test Sites to Evaluate UXO Technology Performance for a Variety of Targets and Terrain Scenarios.

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III. PROGRAM DESCRIPTION

General

The planning and management of individual projects are fundamental to SERDP's success in technology research and development. This section describes each of the SERDP Thrust Area Programs and how the projects respond to DoD needs and requirements. Topics include the goals of each Thrust Area, the environmental and operational drivers directing the needs for new and improved technologies, the major areas of research and development (R&D) within each Thrust Area, and the planned initiatives. Each FY 2002 and FY 2003 project is listed according to subthrust categorization and completion status.

The SERDP Program contains the following five Thrust Areas: Cleanup, Compliance, Conservation, Pollution Prevention, and Unexploded Ordnance (UXO). Each year the Executive Director, with the assistance of the Executive Working Group (EWG) and the Scientific Advisory Board (SAB), determines the funding balance among the Thrust Areas. Figure III-1 illustrates the distribution of funds to specific Thrust Areas for FY 2002 and FY 2003.

Program Development

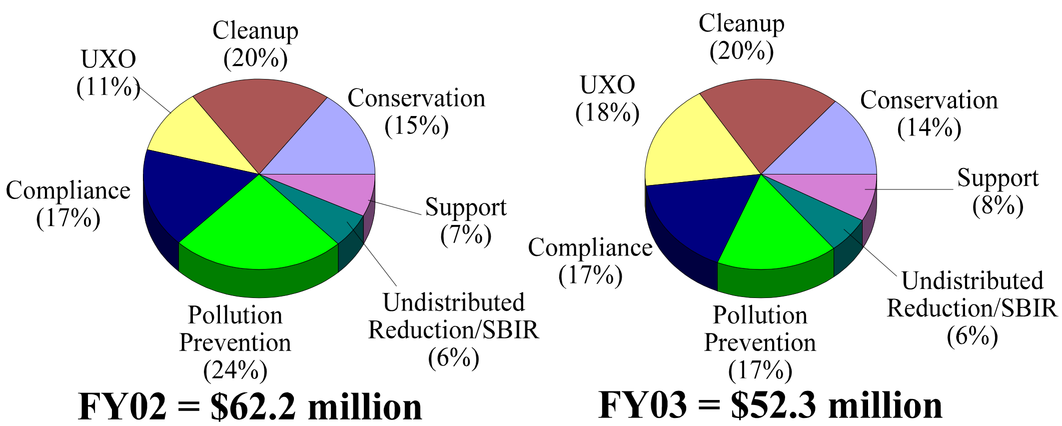

Figure III-1. Distribution of Total Appropriated SERDP Funding, FY 2002 and FY 2003.

SERDP funds environmental research and development through a competitive process in accordance with the established Congressional direction and is further guided by policies provided by the SERDP Council. There are usually two solicitations annually. One is the major, or core, solicitation and provides funding in various amounts for multi-year projects. The other is the SERDP Exploratory Development, or SEED, program designed to provide initial funding for high-risk, high-payoff projects. SEED projects are limited to a one-year time period and a maximum of $100,000 in funding.

SERDP PROJECTS

FY 2002	
165	Total projects
61	Completed projects
FY 2003	
133	Total projects
29	New Start projects

Because both government and private sector parties may compete for SERDP funds, there are two announcements for each solicitation: (1) a Call For Proposals to the Federal sector and (2) a Broad Agency

Announcement (BAA) for the private sector. In the FY 2003 Federal Calls For Proposals, participating organizations and their laboratories were asked to solicit proposals that responded to the Statements of Need (SONs). Each Federal organization conducted its own internal down-select procedure and forwarded its best proposals to SERDP for consideration. The BAAs requested direct submission of proposals in response to the same SONs from non-Federal participants in industry, non-profit entities, and academia. Both the core and SEED BAA solicitations appeared in the Commerce Business Daily.

Each year, a peer review panel is used in the core solicitation to assist in the selection of Federal and non-Federal proposals. Following the peer reviewers' evaluation of technical merit and personnel, those proposals that were recommended by the peer review panels were forwarded to SERDP's multi-agency Technology Thrust Area Working Groups (TTAWG) who were tasked with reviewing both the Federal and non-Federal submissions of both solicitations for all evaluation criteria. All proposals recommended by the TTAWGs and approved by the Executive Director were briefed to the SERDP SAB prior to recommending their approval to the SERDP Council.

In addition to the annual core and SEED solicitations, during the early part of FY 2002, SERDP completed the selection of proposals received in response to a supplemental solicitation that was released in late FY 2001 when SERDP received an increase in the amended FY 2002 President's Budget Request (PBR). This supplemental solicitation requested proposals focusing on UXO and other environmental issues related to the sustainability of training and testing ranges. Because the schedule for selecting these proposals carried over into FY 2002, the projects resulting from this supplemental solicitation were not available for last year's SERDP Annual Report and are included in this report.

Titles of all projects may be found in the project listings within each Thrust Area description subsection, and summaries of each project are located in Appendices A through E of this report. Detailed descriptions of the FY 2004 SONs can be found in Appendix F.

CLEANUP

Introduction

The Department of Defense (DoD) and the Department of Energy (DOE) must protect human health and the environment, reduce remediation costs, and provide timely cleanup. Cleanup goals for the DoD are:

- to attend to imminent threats to public health and safety;
- to remediate all defense sites having a significant public health risk as quickly as feasible within the constraints of available resources; and
- to expedite transfer of base realignment and closure (BRAC) sites and formerly used defense sites (FUDS) to future owners.

The DoD and DOE have a legal obligation to meet Federal, state, and local environmental protection and public health regulations. Both organizations own and operate thousands of installations, ranging from training bases to industrial production facilities. DoD's environmental restoration program must address more than 27,000 sites at more than 8,500 installations. Due to the large number of DoD and DOE sites and installations, many significant challenges exist and must be addressed. These challenges include chlorinated solvents, also known as Dense Non-Aqueous Phase Liquids (DNAPLs), as well as recently emerging issues such as perchlorate, metals, and energetic compounds (TNT, RDX, HMX and DNT) in soils and groundwater. Restoration funding levels over the past nine fiscal years have averaged more than $2 billion per year and are projected to continue just below that level into the future. Commensurate R&D funding is necessary to ensure these challenges are met head on.

Experience with past remediation technology development has demonstrated a significant return on investment. Defense environmental managers require cost-effective and timely remediation capabilities that focus on assessment, characterization, and treatment. Within the Cleanup Technology Thrust Area, the primary environmental concerns are that the DoD:

- implement timely, effective, and affordable methods for site characterization;
- ensure the use of effective, affordable remediation technologies; and
- comply with various federal, state, and local regulations for site remediation.

These concerns are addressed by the Cleanup subthrusts and research areas as depicted in Figure III-2.

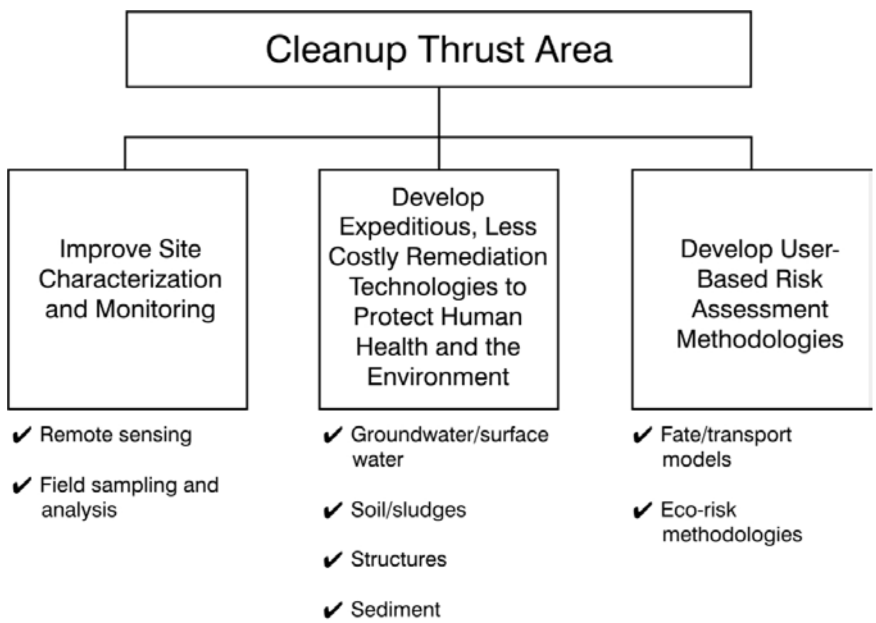

Figure III-2. Cleanup Taxonomy.

While many defense cleanup situations will require that technologies be identified in the near-term, additional research on the scientific fundamentals of contaminant behavior and remediation techniques has the potential to provide the highest return on investment. Congress appropriated funds in FY 2002 specifically to conduct efforts investigating environmental toxicology and remediation or containment of energetic compounds on DoD training ranges.

Principal Driving Requirements

The first subthrust area in Cleanup, **Improve Site Characterization and Monitoring**, seeks to develop better site investigation technologies for locating and characterizing wastes. Identifying and characterizing sites contaminated with chlorinated solvents is a significant issue to the DoD. Chlorinated solvents represent a class of contaminants that are detected at more DoD sites than any other contaminant group. Chlorinated solvents, predominantly perchloroethylene (PCE) and trichloroethylene (TCE), have been used in massive quantities over the last four decades. Release of these liquids to the environment accounts for a significant portion of the contaminated sites requiring cleanup. These contaminants have migrated through the subsurface and entered groundwater at more than 50 percent of the contaminated DoD sites. There is a comparable degree of contamination at DOE and private industry Superfund sites. Estimated annual costs exceed $500,000 for containing and monitoring a single DNAPL plume. Novel technologies to detect and characterize these plumes will significantly reduce these costs.

The second subthrust area in Cleanup, **Develop Expeditious, Less Costly Remediation Technologies to Protect Human Health and the Environment**, focuses on improved remediation of contamination in soils, groundwater, and sediments. Once contaminants reach the groundwater, they often are very mobile and can readily affect off-base receptors. Therefore, this subthrust is directed primarily at developing innovative technologies to address groundwater remediation more effectively. Current groundwater treatment strategies typically employ pump-and-treat technologies which are expensive to operate and are very slow to achieve lasting cleanup. Major limitations to the use of the conventional pump-and-treat technology relate to difficulties in treating DNAPL source areas. These source areas tend to leach contamination into groundwater down gradient, developing large plumes that may migrate into a drinking water source. The pump and treat technology is generally implemented down gradient of the source area and therefore only treats the contamination that has dissolved from the DNAPL source leading to a long term remediation scenario. In the area of energetic contamination, DoD is concerned with nitrated compounds that are widespread contaminants at DoD sites and have been identified at munition training ranges and production facilities. Trinitrotoulene (TNT) is the primary contaminant at these sites, along with dinitrotoluene (DNT), and other nitro substituted explosives (e.g., RDX and HMX). Current approaches used for site remediation typically involve excavation of contaminated soils, followed by incineration or composting, and pump and treat for contaminated groundwater. Because of past DoD and industrial activities, sediments at numerous sites also have some level of impact from anthropogenic (man made) compounds. The DoD must assess and manage contaminated sediments to conduct dredging, base closure, or to cleanup contaminated “hot spots.” Remediation of contaminated sediments has proved to be very costly with current methods and environmentally risky. New and innovative technologies to treat and remediate contaminated sediments are needed to drive costs down and avoid potential impacts to surrounding areas.

The third subthrust area in Cleanup, **Develop User-Based Risk Assessment Methodologies**, involves identifying and evaluating the risk to human health and ecosystems on DoD installations potentially requiring environmental remediation. These include: (1) distinguishing those sites that pose significant environmental risks from those that pose little risk; (2) prioritizing contaminated sites by the degree of risk posed; (3) quantifying the risks at each site; and (4) developing appropriate remedial actions and cleanup goals. Development of improved techniques for risk assessment, which provides a logical framework for making such decisions, is a DoD priority. The effectiveness of existing risk assessment methods will be expanded by research directed at problems particularly evident at DoD installations.

Leveraging with other defense science and technology programs and industry, the Cleanup Technology Thrust Area focuses on the following R&D objectives.

- Develop investigation methods and technologies that are capable of locating and characterizing wastes in a timely and cost effective manner with the highest level of quality control.

- Develop innovative, compliant technologies that reduce remediation costs for sites containing explosives, propellants, petroleum hydrocarbons, solvents, heavy metals, and other organic/inorganic contaminants.

- Facilitate transfer of cleanup technologies to field use. This includes, but is not limited to encouraging the use of the National Environmental Technology Test Sites (NETTS) (see Appendix A for NETTS summaries).

- Develop cost-effective methods and tools to determine fate, transport, and effects of significant defense-related contaminants.

- Develop risk-based modeling and simulation methods for hazard assessment and establishing cleanup priorities and scientifically defensible cleanup levels.

- Develop scientifically defensible environmentally acceptable endpoints (EAEs) for DoD chemicals of concern, including chlorinated organics, explosive compounds, and heavy metals, to facilitate risk-based cleanups at DoD sites.

Cleanup Program

For FY 2002, the Cleanup Technology Thrust Area received approximately 20 percent of the SERDP budget. SERDP conducted two solicitations that requested proposals for funding in FY 2002 in the Cleanup Thrust Area. The annual solicitation issued two SONs in the areas of DNAPL treatment technologies, specifically looking at in situ chemical oxidation and DNAPL source zone delineation. Late in FY 2001, SERDP issued a supplemental solicitation for FY 2002 funding with one Cleanup SON focused on containment of energetic materials on ranges.

CLEANUP	
FY 2002	
44	Total projects
18	Completed projects
FY 2003	
32	Total projects
6	New Start projects

The following list reflects projects completed in FY 2002 and projects continuing into FY 2003. Also included are titles of projects that begin in FY 2003. Complete descriptions of all of the projects for FY 2002 and FY 2003 can be found in Appendix A - Cleanup Project Summaries.

Subthrust: *Improve Site Characterization and Monitoring* — Page

Subthrust: *Develop Expeditious, Less Costly Remediation Technology*

FY 2002 Completed Projects

FY 2003 Continuing Projects

FY 2004 Cleanup Initiatives

The remediation of contaminated groundwater is a major research priority in the Cleanup Thrust Area. To this end, in FY 2004, the SERDP Cleanup area will solicit proposals to research four contaminated groundwater topics.

Statement of Need (SON), **Innovative and Low Cost Methods for Measuring Hydraulic Conductivity**, has been issued. Through this SON, SERDP plans to fund technologies and approaches to develop new or refine existing, low-cost technologies and approaches for the characterization of the hydraulic conductivity of contaminated aquifers. Specific objectives include: (1) Improve upon or develop better tools and procedures for the in-situ measurement of hydraulic conductivity; and (2) Develop protocols and guidance for cost-effectively characterizing the hydraulic properties of contaminated aquifers to aid in selection and design of remediation options. Results from this research will aid in developing strategies for more accurate characterization of the hydraulic properties of contaminated aquifers, and will also aid in the design of a wide variety of groundwater remedial systems. An added benefit will also be to help facilitate the transfer of the technology to the end users.

Another groundwater related proposed area of new research is entitled, **Development of Bioremediation Technologies for Treatment of Nitroaromatic-Contaminated Soil and Groundwater**. The objective of this Statement of Need (SON) is to seek applied studies to develop bioremediation technologies for the treatment of nitroaromatic-contaminated soil and groundwater. Previous SERDP research initiated in FY01 focused on increasing our fundamental understanding of the microbial processes involved in the degradation of nitroaromatic contaminants and seeking methods to improve on these natural capabilities via metabolic engineering. Proposed research under this current SON should build upon this previous research and should lead to development of new treatment approaches, guidance documents, and/or tools for implementing nitroaromatic bioremediation at a given site. Results from this research will aid in developing strategies for more cost-effective and efficient remedial action plans that are protective of human health and the environment. The improved nitroaromatic degradation approaches that will be developed through this SON will improve the reliability of contaminant treatment processes and expedite the cleanup/closure of explosives-contaminated DoD sites.

A third groundwater related proposed area of new research is entitled, **Development of Remedial Technologies for Remediating Groundwater Contaminated with Heavy Metals**. The primary emphasis of this statement of need (SON) is to develop a better understanding of the issues associated with remediation of groundwater contaminated with heavy metals in order to improve remediation and/or management strategies for heavy metal-impacted groundwaters. Results from this research will improve our understanding of the limitations of implementing technologies for remediation of heavy metal-contaminated groundwaters and will ultimately lead to developing strategies for more effective remediation of aquifers contaminated with heavy metals.

A fourth SON, **Investigation of Abiotic Attenuation Processes Impacting Dissolved Chlorinated Solvents,** will clarify the role of abiotic degradation processes in the attenuation of dissolved chlorinated solvents. Specific objectives include: (1) examining the significance of abiotic degradation processes under conditions not normally supportive of reductive dechlorination, (2) defining predominant mechanisms of abiotic degradation processes such as chemical degradation reactions, covalent binding, and/or irreversible sorption; (3) quantifying contaminant removal rates due solely to abiotic degradation processes; and (4) determining geochemical factors that are of primary importance in controlling rates and extent of abiotic degradation processes. Abiotic degradation processes other than dilution, dispersion, volatilization, advection, or reversible sorption are of interest. Results from this work will provide a scientific basis for incorporating an abiotic degradation component into natural attenuation evaluations at sites where there is strong evidence that abiotic degradation is a significant factor in reduction of contaminant levels. This understanding will allow engineers to more accurately predict the time required to attain environmentally acceptable endpoints through natural attenuation.

The last core FY 2004 proposed area of new research will investigate, **Assessing Impacts of In-Place Remedial Strategies for Contaminated Sediment Remediation**. The objective of this Statement of Need (SON) is to understand and develop predictive capabilities for the environmental impact of in-place remedial strategies for contaminated sediments. Specific issues include: (1) Evaluating pathways of contaminant mobility in sediments through which an ecological or human health risk may occur; (2) Evaluating the fate and ultimate bioavailability of contaminants in sediments; (3) Determining what characteristics make a site suitable for in-place remedial strategies. Results from this research will aid site managers in developing strategies for more effective remediation and management of contaminated sediments, thereby resulting in improved protection of human health and the environment.

COMPLIANCE

Introduction

In the United States, the DoD must comply with Federal environmental protection laws, such as the Clean Water Act (CWA), the Clean Air Act and Amendments (CAAA), and the Resource Conservation and Recovery Act (RCRA), as well as state and local regulations. These laws result in specific requirements for the treatment of emissions and disposal of wastes generated during DoD operations, including those generated by vehicles, aircraft, and vessels, as well as from training exercises involving the firing of munitions. At the international level, the International Maritime Organization's Marine Pollution Convention (MARPOL) Annexes (to which the United States subscribes) may restrict or prohibit DoD operations in international waters and MARPOL Special Areas unless vessels meet international environmental statutes. In addition, countries that host DoD facilities are implementing and enforcing compliance with regulations and standards that may restrict or prohibit DoD operations in foreign ports and bases.

Together, these requirements affect numerous defense activities and assets both at home and abroad, including combat testing and training; operational installations; ordnance and weapons manufacturing and disposal; and combat vehicles, ships, and aircraft operations. As a result, DoD is projected to spend approximately $1.7 billion annually for environmental compliance over the next several fiscal years, requiring monitoring and treatment of emissions and wastes generated by military operations and training. New technologies must be developed to reduce this cost and enable the DoD to comply fully with increasingly stringent requirements while fulfilling its mission unencumbered by regulatory fines, restricted access or mobility, or negative public reactions. In addition, full compliance with environmental regulations is a critical step in DoD's initiative to manage its infrastructure and training ranges in a sustainable manner.

Therefore, the mission of the Compliance Technology Thrust Area in SERDP is to research and develop new technologies to:

- address current and future environmental compliance requirements of the DoD and DOE while maintaining military readiness; and
- reduce the costs associated with these requirements.

Compliance technologies are not to be directly related to site restoration but are related to meeting current and future environmental compliance requirements of DoD and DOE. They are applied, for example, to end-of-pipe treatment and/or recycling (i.e., waste that is reused for other than its original purpose), or investigations to assist the development of new regulations which often involve the fate and transport of defense-related air and wastewater discharges. Compliance technologies do not include elimination of waste streams through substitution or process modification which are included in the Pollution Prevention Thrust Area.

The primary concerns in this technology thrust area include deterioration or loss of operational capability and the high costs of regulatory compliance. These primary DoD environmental concerns reflect the need to:

- better characterize wastes though improved measuring/monitoring technologies;
- develop effective treatment/recycling technologies for defense wastes and/or emissions; and
- develop improved fate and transport prediction capabilities for emissions and/or discharges of specific compounds or contaminants such as explosives, residues and metals.

DoD user requirements respond to specific environmental regulations that have been developed under the Clean Air Act Amendments (CAAA), the Clean Water Act (CWA) and amendments, and, for solid and hazardous wastes under the Resource Conservation Recovery Act (RCRA). Given the compliance requirements that result from these three major laws and their amendments, as well as related standards, SERDP addresses Compliance according to the six major subthrust areas related to affected environmental media shown in Figure III-3.

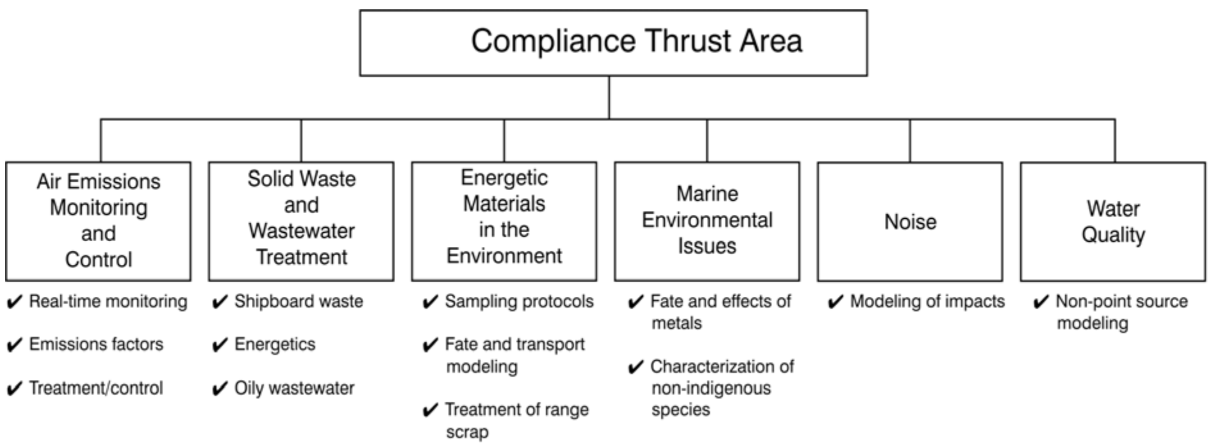

Figure III-3. Compliance Taxonomy.

SERDP's Compliance Technology Thrust Area funding investment is anticipated to remain level over the next five years. Congress appropriated funds in FY 2002 specifically to conduct efforts in support of health and safety training related to environmental remediation work, including the scrapping of Navy ships.

Principal Driving Requirements

For FY 2002, SERDP responded to requirements resulting from specific regulatory developments via investments in the six Compliance subthrusts. The **Air Emissions Monitoring and Control** subthrust addresses DoD's need to develop new and effective measuring/monitoring and treatment/control technologies for air emissions resulting from DoD activities. In the course of implementing the CAAA of 1990, a number of local air quality jurisdictions (many facing non-attainment status for one or more priority air pollutants) have imposed local standards that are more stringent than national emissions standards. The employment of military-unique systems such as liquid-fuel rockets, military jet engines, and off-road equipment will require that DoD treat and control emissions of NOx, ultrafine particulate matter (PM), volatile organic compounds (VOC), and hazardous air pollutants (HAP) at DoD installations. One difficulty associated with monitoring and controlling these emissions is that they frequently are episodic and/or high-volume and low-concentration, such as those from jet engine test cells, and from painting, stripping, and cleaning operations. Existing CAAA regulations continue to test the limits of existing emissions monitoring and control technology, which in some cases does not currently meet portability or detection limit requirements.

Anticipated future requirements, such as the expanded National Emission Standards for Hazardous Air Pollutants (NESHAPs), will increase the number of production and maintenance processes that require continuous monitoring and control, thereby creating further technology needs and applications. Additionally, the generation of dust and resultant fugitive dust emissions via military activities is becoming an issue of growing concern due to encroachment around military ranges. Without new technologies to address these challenges, the curtailment of military missions, closing of facilities, and assessment of fines are real possibilities.

The **Solid Waste and Wastewater Treatment** subthrust addresses DoD's need to meet international environmental regulations limiting the disposal of solid waste and plastics at sea. To address this need, the Navy must develop compact, efficient equipment for the destruction of solid waste and sludges from waste water onboard DoD vessels. The CWA requirements also prohibit the discharge of untreated sewage (blackwater) by ships in navigable waters. Shipboard greywater is the product of hotel and commissary-type activities aboard U.S. Navy ships. Common sources of greywater are showers, sinks, and galley and scullery equipment. No greywater holding capacity has been required for U.S. Navy ships with the exception of operations within the Great Lakes. However, with anticipated tightening of global wastewater discharge regulations, DoD must develop technologies that are appropriate to control and treat combined shipboard greywater and blackwater (i.e., non-oily wastewater).

Within the **Energetic Materials in the Environment** subthrust, research and development is aimed at managing military ranges as a sustainable resource. This subthrust focuses on developing techniques to assess the potential for environmental impacts of residual energetic materials found at military ranges that result from the use of live munitions. The research conducted under this subthrust is intended to contribute to the DoD's capacity to: (1) understand range environmental issues; (2) improve management of these critical resources; (3) assure the long-term viability of these key assets; and (4) facilitate compliance with current and proposed regulations. SERDP research in this subthrust supports the 1996 Defense Science Board (DSB) Report and Environmental Security Plan for test and training range sustainment. The disposal of the large stockpile of munitions and propellants by Open Burning/Open Detonation (OB/OD) is also addressed by this subthrust. Concerns have been raised about the impacts of OB/OD activities on the health of humans and ecosystems, severely restricting and sometimes prohibiting OB/OD. Additionally, the EPA is implementing TRI reporting requirements for munitions which will require new and innovative technologies to monitor and characterize emissions of TRI chemicals from munitions firing. On a related issue, DoD needs to dispose of an increasing amount of metal scrap material produced by testing and training activities that use munitions and other energetic materials. These scrap materials may contain energetics residues that could pose a hazard to efforts to recycle this metal scrap.

The **Marine Environmental Issues** subthrust is focused on the scientific fundamentals of the fate and impact of metals from DoD sources in harbors and estuaries, which will be used to develop a scientific basis for future approaches to copper and zinc regulations. Copper and zinc are two of the most ubiquitous metal contaminants found in many industrial and non-point source effluent, including discharges from DoD facilities, ships, and small craft into the marine environment and sediments which are disrupted during dredging operations. Studies have shown that copper and zinc are highly toxic to some marine organisms. DoD needs to provide risk assessments that can identify the DoD sources of copper and zinc discharging into or present in harbors and/or estuaries and evaluate the risks to marine species from these metals. Examining the fate and impact of these metals has the long-term benefit of providing empirical evidence to support the development of more realistic scientifically-based water quality criteria and standards. SERDP is also conducting research to characterize non-indigenous plant and animal species that may be transported and released from the hulls and ballast water of Navy vessels into estuaries and harbors.

For the **Noise** subthrust, efforts are required to provide refined acoustic models for improved ability to accurately predict the resulting noise footprint and potential impact of DoD operations. They would assist environmental specialists in proposing mitigation techniques to site managers and operators. This would be particularly advantageous in regions where the impacts of such operations are dependent on the interaction of environmental conditions. Another objective is to create a fully validated model for high performance aircraft noise and other high intensity noise sources to provide a legally defensible characterization of DoD noise impacts.

The **Water Quality** subthrust efforts address non-point source pollution from DoD activities and the impact to water quality. Section 319 of the Clean Water Act amendments established the Non-Point Source Management Program, which requires an assessment of the extent of non-point water quality problems and the development and implementation of best management practices (BMPs) to prevent water runoff from being polluted, and where it is polluted, to reduce the amount that reaches streams, rivers, lakes and estuaries. To comply with these regulations, the DoD needs to identify the sources of NPS pollution, the impact to water quality and provide installation commanders with proactive management plans.

Compliance Program

For FY 2002, the Compliance Thrust Area received approximately 17 percent of the total SERDP budget. SERDP conducted two solicitations that requested proposals for funding in FY 2002 in the Compliance Thrust Area. The annual solicitation issued three SONs in the areas of air toxics monitoring, predicting impacts of air emissions from DoD activities, and characterizing aquatic non-indigenous species for DoD vessels. Late in FY 2001, SERDP issued a supplemental solicitation with two SONs focused on advanced acoustic models to assess noise impacts from aircraft and land management impacts on the fate and transport of energetic materials on ranges.

COMPLIANCE	
FY 2002	
30	Total projects
10	Completed projects
FY 2003	
24	Total projects
4	New Start projects

The following list reflects projects completed in FY 2002 and projects continuing into FY 2003. Also included are titles of projects that begin in FY 2003. Complete descriptions of all of the projects for FY 2002 and FY 2003 may be found on the pages referenced in Appendix B - Compliance Project Summaries.

Subthrust: *Air Emissions Monitoring and Control*

FY 2003 New Start Projects

Subthrust: *Solid Waste and Wastewater Treatment*

FY 2002 Completed Projects

FY 2003 Continuing Projects

None

FY 2003 New Start Projects

Subthrust: *Energetic Materials in the Environment*

FY 2002 Completed Projects

FY 2003 Continuing Projects

FY 2003 New Start Projects

None

Subthrust: *Marine Environmental Issues*

Subthrust: *Noise*

Subthrust: *Water Quality*

FY 2004 Compliance Initiatives

FY 2004 Compliance initiatives reflect an emphasis related to (1) developing prediction models for aircraft firing noise, (2) improving methods for monitoring systems for impulse noise, (3) studying noise impacts on structures, (4) characterizing DoD particulate matter (PM) emissions from DoD unique activities, and (5) characterizing NOx and air toxics emissions from military aircraft.

Routine testing and training range operations can generate complaints and damage claims from civilian communities around DoD installations resulting from noise emissions. These claims can lead to testing and training restrictions and expenditure of funds for damage. Due to encroachment, the once rural and remote installations are now in the midst of densely populated areas. Aerial gunnery ranges are located throughout DoD installations, including those of Army National Guard and Air National Guard. Currently, no model accurately predicts the noise due to firing of guns or missiles from DoD aircraft. To proactively respond to this potential restriction of DoD operations, SERDP has issued a SON for FY 2004 entitled **Prediction Model for Weapons Noise Sources from Airborne Platforms**. The objectives of this SON are to (1) characterize the noise generation and propagation from noise sources, and (2) develop a cost effective model or enhance an existing model that will enable installations to generate aggregate overall noise level contours for all types of noise in order to plan and manage military operations.

Impulse noise is characteristically associated with such sources as explosions, impacts, the discharge of large caliber weapons (20mm or greater), and sonic booms. Impulse noise monitoring is an important tool for assessing noise impacts from military training and testing activity. Current noise monitoring systems are impacted by wind that induce pressure fluctuations over a microphone or windscreen. These fluctuations produce signals with both temporal and spectral characteristics very similar to actual impulse noise events which result in thousands of false-positive events that obscure real events. To resolve this issue, SERDP has issued a SON for FY04 entitled **Improved Methods and Monitoring Systems for Impulse Noise**. The objective of this SON is to improve methods for monitoring and analysis of impulse noise by focusing on reducing the recording of false-positives, eliminating labor-intensive data analysis, improving diagnostic software, and providing the capability for date/time data queries. These improvements will provide installations with an accurate; less labor intensive and efficient means to manage testing and training impulse noise to verify or reject impulse noise complaints and damage claims.

Powerful sound waves emitted by military training activities such as firing large guns and detonation of explosives can travel long distances in the atmosphere. These waves can be clearly audible under some propagation conditions, and can even cause buildings to shake and rattle. Without supporting data to correlate noise and vibration to annoyance and damage, the civilian community is reluctant to accept an installation's evaluation. To respond to this concern, SERDP has issued an SON for FY 2004 entitled **Characterization and Prediction of Potential Impact of Military Generated Noise on Structures**. The objectives of this SON are to (1) characterize the pressure waves that are generated by military activities which are propagated through air and/or ground that may affect structures, (2) evaluate the currently-used weighted peak sound level, and (3) develop prediction models for assessment of military generated noise on structures. This work will result in scientifically defensible evidence to support or reject claims that military noise emissions are capable of producing stress waves with sufficient strength to cause structural damage. Additionally, the DoD will have scientifically defensible value of dBP to evaluate a damage threshold.

DoD training and testing activities at installations across the U.S. often involve the movement of vehicles and personnel on unpaved surfaces, prescribed burning to clear brush and unwanted vegetation, as well as the use of smokes and obscurants for battlefield simulations. The proximity of installations engaged in training and testing activities to federal air quality Class I areas raises a concern about the impact of the Regional Haze Rule on military training and readiness. Current dust suppression techniques utilized by the Army are not always effective and are costly. To proactively respond to this potential restriction of DoD operations, SERDP has issued a SON for FY 2004 entitled **Particulate Matter Emission Factors for Dust from Unique Military Activities**. The objective of this SON is to identify, characterize, and monitor the airborne emissions of particulate matter (PM) resulting from DoD testing/training activities related to tracked vehicles, fixed-wing aircraft, rotary-wing aircraft, and artillery. The anticipated results of this work will become part of an overall effort to understand dust generation and its effect on human health and possible effects on the ecosystem.

State and Federal regulators are developing emissions inventories of NOx and air toxic compounds and performing fate and transport analyses to determine the risks associated with ambient concentration of air toxics. More specifically, EPA is planning to determine by 2004 if significant risks are posed by air toxics from mobile sources and if additional emissions controls are needed (U.S. EPA, 2000). Inventories of NOx emissions are needed for the development of State Implementation Plans. The impact on DoD activities of promulgation of EPA regulations in non-attainment areas or for source-specific emission limits could be substantial. Therefore, accurate emission factors estimates for DoD activities are needed to determine if they contribute to risks from ambient concentrations of air toxics. To fulfill this need, SERDP has issued an SON for FY 2004 entitled **Development of Emissions Factors for Particulate Matter (PM), Nitrogen Oxides (NOx), and Ambient Air Toxic Compounds Emitted from Military Aircraft**. The objective of this SON is to characterize emissions specifically generated by military aircraft gas turbine and turbo prop engines.

CONSERVATION

Introduction

DoD is a major user of land, sea, and air, and manages approximately 25 million acres of land on more than 425 major military installations. It is the third largest Federal land management department in the United States. DoD requires continued access to these lands, waterways, and airspace to maintain mission readiness. Land is needed for munitions testing, deployment of weapon systems, and combat training exercises. Marine and estuarine environments are needed to conduct training exercises, test vessels and submarine tracking equipment, evaluate missile weapon systems, and conduct shock trials on new ships. Airspace is needed to train pilots and test fighter planes and air-based weapon systems. The specific landscapes and unique natural features of the land, sea, and air space used by DoD are crucial to maintaining military readiness. Varied training regimens and differing climatic, topographic, hydrologic, and biological settings prepare troops to operate equipment and carry out operational plans under conditions that they may encounter in future conflicts. With a broad geographic distribution (largely domestic but some foreign), DoD lands represent a remarkably diverse collection of ecosystem and habitat types, including forests, grasslands, wetlands, and deserts. DoD's ability to conduct realistic training exercises and to test weapon systems and equipment cannot be ensured without responsible land stewardship and sensible management and conservation practices.

DoD must sustain the ability to train personnel and test weapons while maintaining the natural and cultural resources of the installations upon which it depends. It also must comply with legislation and regulations designed to protect these resources. By better understanding the environments in which they operate, the Department can improve its resource-use decisions to promote conservation and stewardship, while continuing to fulfill their primary missions. The DoD Conservation goal is to support the military mission by: (1) providing for sustained use of its land, sea, and air resources; (2) protecting valuable natural and cultural resources for future generations; (3) meeting all legal requirements; and (4) promoting compatible multiple uses of those resources.

Furthermore, military facilities face increasing demands as a result of base closures and realignments, new weapon systems and equipment requiring larger training ranges, additional regulatory constraints, and changes in tactics and doctrine. Training intensity on remaining installations will continue to rise, often preventing full recovery of vegetation and animal populations between training exercises. The U.S. Army alone has millions of acres of training and testing lands with significant land repair and maintenance costs. On-site and off-site environmental impacts, wildlife conservation issues, cultural resources concerns, and the need for training realism all dictate that natural resources must be maintained and enhanced on these installations. The tasks of balancing military land uses, complying with resource regulations, and assessing impacts on the sustainability of both the resource base and the military mission are complex and challenging. Activities to alleviate one problem can often exacerbate others. All too often, decision-makers on military installations are faced with making critical land management decisions without the benefit of complete environmental information nor complete knowledge of other, competing objectives and/or land use requirements.

Leveraging with other Defense science and technology programs and similar programs in industry and academia, SERDP focuses on the following Conservation research and development objectives to support DoD's Conservation goals.

- Develop standardized, cost effective methods to inventory, characterize, and monitor natural and cultural resources to help ensure compliance with applicable laws and requirements. Where appropriate, use defense-unique data collection and assessment tools to develop these methods.

- Develop and demonstrate more effective methods and techniques to maximize availability of military lands in support of military missions, with minimal impact to natural and cultural resources in a manner consistent with the Services' mission and Federal environmental regulations.

- Develop and demonstrate efficient and effective techniques to conserve and restore natural and cultural resources proactively, particularly threatened and endangered species and the ecosystems on which they depend.

- Develop and demonstrate effective, user-friendly computer-based models to determine the incremental and cumulative impact of military activities on natural and cultural resources, and assess effectiveness of conservation and restoration techniques.

- Develop state-of-the-art techniques to assess and predict the impact of military use on those critical elements of the ecosystem impacting sustainability.

- Develop the needed methods, tools, guidelines, and decision support systems for effectively implementing integrated resource management techniques.

These research and development objectives are addressed and implemented under five related but distinct subthrusts which makes up the Conservation Taxonomy (as depicted in Figure III-4). Current focus areas or critical paths to DoD conservation goals are listed under each subthrust. These focus areas may change from year to year in order for the subthrust to appropriately adapt to new DoD requirements.

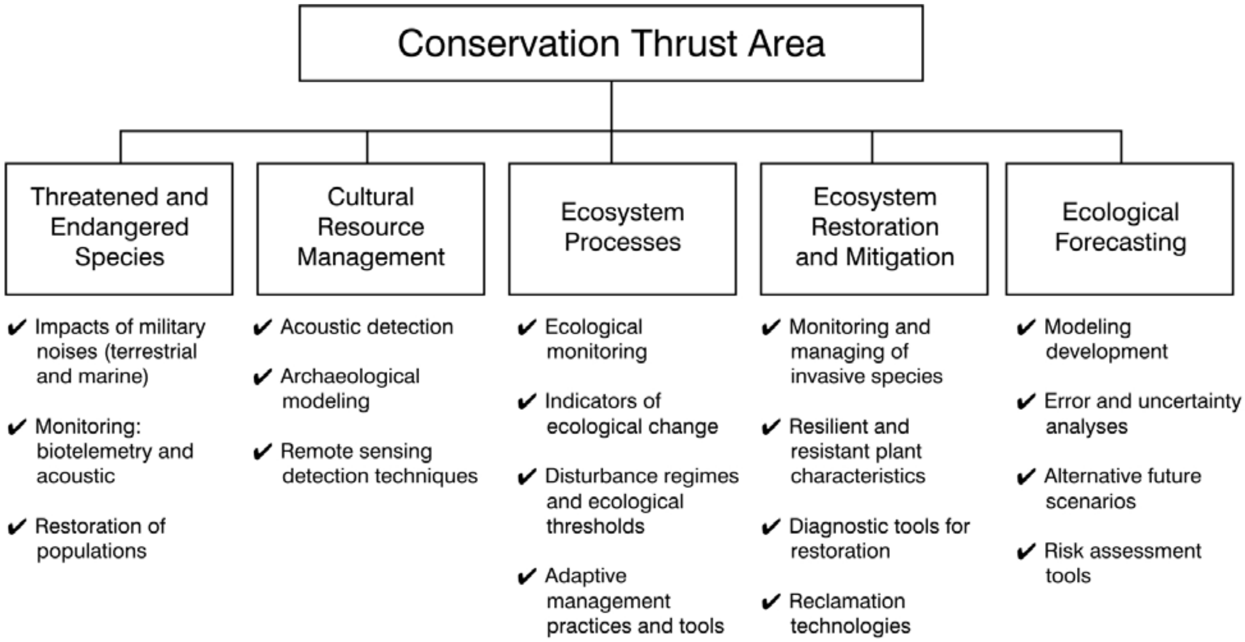

Figure III-4. Conservation Taxonomy.

Principal Driving Requirements

DoD manages species of concern, and specifically Threatened and Endangered Species, to comply with the same laws and statutory provisions as all other Federal Agencies, including the Endangered Species Act (ESA) of 1973, the Marine Mammal Protection Act of 1972, and the Migratory Bird Treaty Act. In addition, the following legal authorities apply specifically to the management of Threatened and Endangered Species on DoD owned or managed lands: "Conservation Programs on Military Installations (Sikes Act)," National Environmental Policy Act, the Fish and Wildlife Coordination Act, and others. The **Threatened, Endangered, and Sensitive Species** subthrust addresses DoD specific requirements that pertain to those species that are identified as either threatened or endangered (both currently and potentially). It is known that more than 200 installations provide habitat for at least 400 plants and animals that are listed on, or candidates for, the Federal endangered species list. This is the highest known density of threatened and endangered species found on any Federal lands. Research and development must be responsive and as proactive as possible in meeting all DoD requirements pertaining to these plants and animals.

The research and development focus for the Threatened, Endangered, and Sensitive Species subthrust has included the effects of aircraft overfights on birds of prey, biotelemetry, marine mammal responses to low frequency noise, whale monitoring, training noise impacts on the Red-Cockaded Woodpecker, salmon in the Pacific Northwest, and acoustic monitoring of Threatened and Endangered Species in inaccessible areas. The challenge for the Threatened, Endangered, and Sensitive Species subthrust will be to integrate the approaches and findings of research and development pertaining to specific species into the context of an ecosystem management approach. DoD recognizes that a species-by-species approach to resource management is potentially inefficient and can lead to contradictory management strategies. DoD has adopted an ecosystem approach to managing its natural resources. This approach considers groups of plant and animal species, instead of focusing on single-species management. It promotes adaptive management, the use of benchmarks and the best available science, and sustainable use for both human and ecological purposes. One way of doing this will be to integrate regional management strategies more effectively by reducing conflicting individual approaches. Working within an eco-regional context can help protect the viability of resident populations and reduce the likelihood of future listing of species under the ESA.

DoD lands contain more than 100,000 archaeological sites, and at least 200 installations have properties that are listed on or eligible for the National Register of Historic Places. Approximately two percent of all the military's buildings and structures are considered historic. Management of cultural resources on the many and varied military installations in the United States is necessitated by respect and by public laws that include, but are not limited to, the National Historic Preservation Act of 1966 as amended; the Archaeological Resources Protection Act of 1979 as amended; and the Native American Graves Protection and Repatriation Act of 1990. The **Cultural Resource Management** subthrust addresses the research and development needs associated with the detection, sampling, and preservation of cultural resources on DoD installations. The R&D focus for this subthrust has included acoustic detection, archaeological modeling, and remote sensing detection techniques. As a result of a co-sponsored SERDP/Legacy Program Cultural Resource Management workshop in June of 2000, a number of new research and development initiatives were identified in the categories of detection, preservation and data management. The reduction of cost and increase in efficiency are key drivers for defining the research and development investments in the Cultural Resource Management subthrust.

As part of its stewardship goal, DoD is charged to maintain and improve the sustainability and native biological diversity of terrestrial and aquatic (including marine) ecosystems while supporting human needs, including the DoD mission. All of the DoD services have expressed the need to better understand ecological processes and trends on military lands, the ecological relationship of military lands to their surrounding lands, and the interactions between mission activities and ecological processes. The goal of the **Ecosystem Processes** subthrust is to provide knowledge, tools, and techniques to permit military land managers to evaluate the ecosystems on their installation and to predict the responses to military operations as well as to effectively manage the lands for long term sustainability and use. This subthrust focuses on addressing science and technology requirements for ecosystem management of DoD military installations. The current R&D focus for this subthrust includes the creation of long term monitoring site(s) on DoD lands to observe ecosystem trends over time, identifying ecosystem change indicators, understanding disturbance within the ecosystem resulting from military mission activities and land management practices, and development of adaptive management practices and tools based on ecosystem monitoring. The challenge for the Ecosystem Processes subthrust will be to incorporate the findings/result of ecological monitoring and new understanding of ecosystem processes into the development of practical adaptive management tools for installation resource managers that are transferable across an ecoregion.

Within the DoD, the military services are required to maintain and restore remaining native ecosystems across their natural range of variation, and to ensure long-term sustainability of military training and testing lands and waters in support of the National Defense mission (DoD Instruction 4715.3). The **Ecosystem Restoration and Mitigation** subthrust addresses the research and development needs associated with the restoration of natural systems and their functions and values, with a goal of sustaining the health, productivity, and biological diversity of ecosystems in concert with the mission of military readiness and environmental compliance requirements. The research and development focus for the Ecosystem Restoration and Mitigation subthrust includes monitoring and managing of invasive species, identification of resilient and resistant plant characteristics, diagnostic tools for restoration, and reclamation technologies. In practice, much of DoD's restoration efforts are engineering driven and site specific without much regard to the significance of the functions in which the site(s) serves within the ecosystem or ecoregion. With the increased emphasis on an integrated ecosystem-based approach to management of Federal, State, and private lands, ecosystem restoration has emerged as an important area of interest. To be fully realized and implemented, ecosystem restoration requires the integration of the understanding of ecological processes into reclamation technologies and engineering practices. The goal of the Ecosystem Restoration and Mitigation subthrust is to identify research and development opportunities that will facilitate this integration.

Ecosystems provide the background for the DoD to maintain its military readiness. To sustain these ecosystems, decision makers must take into account potentially interactive effects of natural variability and human induced change on ecosystem structure, function and productivity. A key role of science is to provide insights into the potential scale, direction, and nature of that change. SERDP funded research and development in the **Ecological Forecasting** subthrust is aimed at forecasting the ecological response to current and/or expected change using models and other decision-making tools. The current R&D focus for the Ecological Forecasting subthrust includes modeling development, error and uncertainty analyses, alternative future scenarios, and risk assessment tools.

A key driver over the next decade for the Ecological Forecasting subthrust will be urban change in areas surrounding DoD installations. Research and development should have a critical contribution to the establishment of a comprehensive understanding of the dynamics of urban change outside DoD installations and how this change will effect the sustainability of military range lands. Decision tools will be instrumental for the development and implementation of installation-community planning policies, procedures and forums, as well as, serving to facilitate daily management decisions on DoD installations.

Conservation Program

For FY 2002, the Conservation Thrust Area received approximately 15 percent of the SERDP budget. SERDP conducted two solicitations that requested proposals in the Conservation Thrust Area. The annual solicitation issued five SONs in the areas of cultural resource management, the impacts of fog oil on TES, the impacts of land-use change on the sustainability of military installations, the impacts of noise on TES, and sensors for monitoring ecosystems. Late in FY 2001, SERDP issued a supplemental solicitation for funding in FY 2002 with one conservation SON focused on the impacts of land management and training activities on TES.

CONSERVATION	
FY 2002	
25	Total projects
9	Completed projects
FY 2003	
20	Total projects
4	New Start projects

The following list reflects projects completed in FY 2002 and projects continuing into FY 2003. Also included are titles of projects that begin in FY 2003. Complete descriptions of all of the projects for FY 2002 and FY 2003 may be found on the pages referenced in Appendix C - Conservation Project Summaries.

Subthrust: *Threatened and Endangered Species* **Page**

FY 2003 New Start Projects

Subthrust: *Cultural Resource Management*

FY 2002 Completed Projects

None

FY 2003 Continuing Projects

FY 2003 New Start Projects

None

Subthrust: *Ecosystem Processes*

FY 2002 Completed Projects

FY 2003 Continuing Projects

FY 2003 New Start Projects

Subthrust: *Ecosystem Restoration and Mitigation*

FY 2002 Completed Projects

FY 2003 Continuing Projects

FY 2003 New Start Projects

None

Subthrust: *Ecological Forecasting*

FY 2002 Completed Projects

FY 2003 Continuing Projects

FY 2003 New Start Projects

None

FY 2004 Conservation Initiatives

The 2004 initiatives reflect an emphasis on (1) control of non-indigenous invasive plant species, (2) determination of the elements of a marine mammal habitat and their association to marine mammal distribution and abundance, (3) inventory and monitoring of threatened and endangered species, (4) measurement of physiological stress in threatened and endangered species, and (5) development of landscape status indicators for the Fort Benning ecosystems.

An FY 2004 SON for the Ecosystem Restoration and Mitigation subthrust area is entitled **Control of Non-Indigenous Invasive Plant Species Affecting Military Testing and Training Activities**. The objective of this initiative is to develop new or improve existing methods for the control, reduction and elimination of non-indigenous, invasive plant species while effectively protecting native species and their habitats on Department of Defense installations. Improved methods for impact evaluation and mitigation developed as a result of this Statement of Need (SON) will not only reduce costs for these activities, but will also decrease impediments to military training caused by the degradation of natural areas and the nature of the plant species itself; e.g., the thorny spines of yellow star thistle. In addition, these efforts may preclude access limitations due to the listing as threatened or endangered of native plants on military reservations.

The FY 2004 SON entitled **Marine Mammal Behavioral Ecology and Predictive Modeling** supports initiatives under the Threatened & Endangered Species subthrust. The main objective is to determine the fundamental relationships of the physical, biological and chemical ocean elements that define marine mammal habitat, and to understand how these elements contribute to marine mammal distribution and abundance. The ultimate goal is to be able to predict the location, distribution and abundance of marine mammals based on the determined precursors. The results of efforts proposed under this SON will provide the basis for more accurate environmental risk assessment to comply with the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA). This information will also contribute to the development and implementation of improved mitigation procedures to protect marine mammal species without degrading realistic Navy training, which is imperative to maintain military readiness.

Two FY 2004 SONs were released under the Threatened and Endangered Species subthrust. One of the SONs, entitled **Development of Innovative Inventory and Monitoring Techniques for High Priority Threatened and Endangered Species**, will provide population level and demographic data, in addition to confirming species presence or absence. It is anticipated that the techniques developed pursuant to this SON will result in reduced costs to conduct inventory and monitoring surveys of high priority listed species and/or improved accuracy of inventory and monitoring data. The development of sound scientific information on the population status and trends of listed species on installation lands can lead to reduced restrictions on military training and testing activities.

The second FY 2004 SON for the Threatened and Endangered Species subthrust is entitled **Quantifying Physiological Stress in Threatened and Endangered Species Due to Military Activities**. The objective of this initiative is to develop methods or technologies to identify and measure appropriate physiological indicators of stress in terrestrial threatened and endangered species (plant or animal) due to potential disturbance from military operations. Research will be directed to investigate: (1) identification of appropriate physiological indicators; (2) response of these indicators to military related activities versus non-military related activities; and (3) the relationship between physiological indicators of stress and more traditional endpoints such as individual or population fitness. Efforts proposed under this SON will provide military land managers improved, cost-effective and faster techniques using physiological indicators to assess potential biological consequences of disturbance of endangered terrestrial plant and animal species due to military activities. Furthermore, it would assist land managers to respond more quickly and proactively to military mission-critical requirements and information requirements of regulators. In addition, these efforts will provide information for future biological assessments, biological opinions and threatened and endangered species management plans.

The FY 2004 SON entitled **Developing Terrestrial Productivity Measures and a Carbon Budget for the Fort Benning Ecosystems** supports initiatives under the Ecosystem Processes subthrust. The objectives of this effort are to: (1) develop watershed/mesoscale landscape status indicators, based upon existing data, that provide both an estimate of net ecosystem production (NEP) and a carbon budget analysis; (2) consider the sensitivity of these indicators to land use types and land management activities both on and off the installation lands; and (3) provide technical documentation regarding the data requirements and analytical steps, including data transformations and alignment data sets with different scales, required to obtain both the carbon budget and the net ecosystem production indicators, so that similar analyses might be conducted at other military sites. The results of this SON will provide a valuable linkage between installations plans, activities and overall ecosystem status. On a broader level, this work will provide a valuable data set for the Fall Line region along which numerous DoD properties are sited. Comparison of the carbon budget and NEP developed from this research with other regional land uses may be especially important in future efforts by DoD to acquire new lands, realign or alter uses of existing lands, or to partner with non-DoD organizations to establish conservation easements on lands currently beyond installation boundaries.

POLLUTION PREVENTION

Introduction

The DoD and DOE have a number of unique functions, such as the development and operation of sophisticated weapons systems, which demand specialized, high-performance materials. Many of these materials are toxic and are targeted for voluntary reduction. The challenge to DoD and DOE is sustainability, which translates to finding new high-performance materials that are not toxic and/or to determine innovative ways to control the use of toxic chemicals in order to reduce releases and off-site transfers.

The SERDP Pollution Prevention Technology Thrust Area focuses on reducing or eliminating the generation of pollution within the DoD. The application of pollution prevention technologies will influence positively the other DoD environmental Thrust Areas by encouraging the use of innovative technologies and practices such as recycle, recovery and reuse, reducing pollutants to be managed at the source, and promoting the sustainable use of natural resources.

As defined under the Pollution Prevention Act of 1990, pollution prevention means “source reduction” and other practices that reduce or eliminate the creation of pollutants through increased efficiency in the use of raw materials. Source reduction is defined as any practice that reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal.

The Pollution Prevention Thrust Area, at the recommendation of the SERDP Scientific Advisory Board, is adopting a proactive approach to provide solutions to the highest priority defense-related environmental problems. The Pollution Prevention Thrust Area, in addition to addressing near-term multi-service DoD problems, also will address more forward looking, high-risk, long- term projects to achieve the goals that will be set forth by future regulations. For example, the development of the next generation of environmentally advantaged DoD systems is key to meeting potential future regulations. This will be done by designing tools to alert planners to potential environmental issues. SERDP will work closely with military planners, Service research organizations, and the Office of Deputy Under Secretary of Defense for Installations and Environment to identify long-term needs for the DoD.

The Pollution Prevention Technical Thrust Area Working Group (TTAWG) continues to emphasize a program shift toward the more global, Tri-Service issues and on developing seed technologies to address emerging regulatory issues. The TTAWG has envisioned SERDP’s role as a facilitator in communication and collaboration to enhance technology transfer and to leverage Service and SERDP resources. This will be achieved through increased interaction with the National Defense Center for Environmental Excellence (NDCEE), the National Center for Manufacturing Sciences (NCMS), and participation in the Joint Group on Pollution Prevention (JG-PP).

The primary DoD environmental concerns in Pollution Prevention are:

- identifying alternatives for hazardous and toxic chemicals and materials;
- reducing the use of hazardous and toxic chemicals and materials;
- reducing the volume and toxicity of wastes and pollutants through source reduction;
- improving the efficiencies of mechanical and chemical systems;
- incorporating environmental ramifications as key evaluation considerations in major system design and acquisition;
- considering the life-cycle effects of materials and systems; and
- evaluating the sustainable use of resources.

These DoD Pollution Prevention needs are addressed by the five major sub-thrust areas of Air Emissions, Halon Replacements, Elimination of Chromium and Cadmium, Green Energetic Materials, and Reduction of Hazardous Materials and Solid Waste, and are further delineated in Figure III-5.

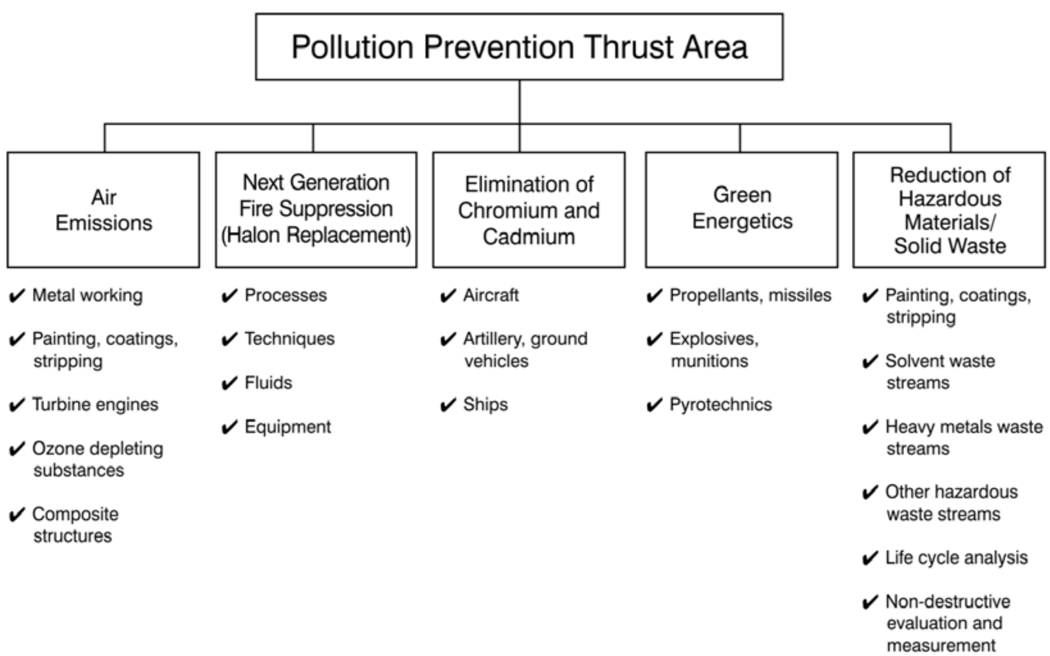

Figure III-5. Pollution Prevention Taxonomy.

Future SERDP Pollution Prevention projects will be selected based on the following general metrics: (1) expected payoff (i.e., potential cost avoidance); (2) magnitude of the environmental problem that the technology will address; (3) clearly identifiable potential environmental benefits and impacts on the defense establishment, regardless of whether the project addresses current, near-, mid-, or long-term needs; and (4) leveraged funding from Services/Agencies applied to the project.

Principal Driving Requirements

Congress has enacted several laws that are primary drivers for DoD and DOE to green up their manufacturing, production, and repair operations. Just a few include the Clean Air Act, Clean Water Act, Pollution Prevention Act, Resource Conservation and Recovery Act, Solid Waste Disposal Act, and Toxic Substances Control Act. The White House has also directed the Federal Government through a series of Executive Orders (EO) to take actions to prevent pollution. In 1999, EO 13123 "Greening the Government Through Efficient Energy Management," and EO 13134 "Bio Based Products and Bioenergy," were signed by the President. In April 2000, EO 13148 "Greening the Government Through Leadership in Environmental Management" directed DoD and other Federal agencies to establish new pollution reduction goals. In response, DoD has implemented three new reduction goals: (1) reducing the Toxic Release Inventory by 40% by 2006; (2) reducing the use of 15 targeted chemicals by 2006 by focusing on replacement of common processes and chemicals; and (3) eliminating the purchase of all Class I OSDs by December 31, 2010.

In the **Air Emissions** subthrust, SERDP is funding a wide array of projects addressing reduction or elimination of Volatile Organic Compounds (VOCs) in adhesives, lubricants, and sealants, pollutants in composites and low observable coating, and emissions from engines. The 1990 Clean Air Act Amendments (CAAA), the Resource Conservation and Recovery Act (RCRA), and state and local regulations restrict the emission and disposal of these hazardous materials. Ozone depleting substances (ODS) are being phased out of production under national policy and international (Montreal) protocol. DoD directives require significant reductions in hazardous wastes and development of alternative materials and processes that meet environmental restrictions and allow DoD to continue operations. Operations and training activities at DoD installations and facilities generate large quantities of hazardous, non-hazardous, and special wastes that are expensive to manage and dispose. The Military Services as well as SERDP are addressing the upcoming 10-year Surface Coating National Emission Standards for Hazardous Air Pollutants (NESHAP), through research and development.

The replacement of Halon, an ODS , in fire fighting technologies is a major focus of research in the **Next Generation Fire Suppression** subthrust. Halon 1301 (CF3Br) has long been the choice for fire extinguishment in most weapon systems and mission-critical facilities. However, due to its high ozone-depletion potential, halon 1301 was banned from production as of January 1, 1994, under the Copenhagen Amendments to the Montreal Protocol on Substances that Deplete the Ozone Layer. The objective of this subthrust is to develop and demonstrate environmentally acceptable and user-safe processes, techniques and fluids that meet the operational requirements currently satisfied by Halon 1301 systems in aircraft, ships, land combat vehicles, and critical mission support facilities. The results will be specifically applicable to fielded weapons systems and will provide dual use fire suppression technologies for preserving both life and operational assets. The benefits of this subthrust will be demonstrated alternatives to halon 1301 usage that will enable DoD weapon system managers to make prudent decisions in removing their dependence on a key zone-depleting substance in a manner that offers the least fiscal and operation barriers to implementation.

The research in the **Elimination of Chromium and Cadmium** subthrust focuses primarily on finding environmentally friendly sealants and coatings as well as better application methods. Sealants are required in aircraft systems and on weapons to provide protection against corrosion, prevent moisture entry, provide a fuel barrier, and provide electrical insulation. Traditionally, sealants use chromium as the primary corrosion inhibiting substance. Chromium has been designated as hazardous and is targeted for elimination in order to comply with either current or pending Occupational Safety and Health Administration (OSHA) requirements. Most sealants also contain VOCs such as methyl ethyl ketone (MEK) and toluene. The DoD and DOE have committed to replace chromate-based metal finishing in present and next generation systems. It is well known that chromates pose a significant toxic hazard to human health and their use has been subject to strict regulation. It is the desire of regulating agencies, manufacturers and the user community to replace chromate corrosion protection technologies. Chromate corrosion protection technologies will only be replaced when environmentally friendly corrosion protection technologies achieve acceptable levels of performance. Significant, strategic investments in chromate elimination research have been made, and these efforts have contributed significantly to our understanding of corrosion protection by chromates.

The **Green Energetics** subthrust assesses the current environmental issues associated with energetic materials and energetic material-containing systems to identify major areas of concern and investigate innovative technologies for the synthesis of environmentally friendly ammunition, energetics, propellants, smokes, and flares. Medium caliber ammunition (20mm to 60mm in size) environmental problems are being addressed in a systematic manner, through an umbrella program, advised by a Technical Advisory Committee (TAC). Based on TAC recommendations, key areas of interest include a green priority matrix identifying specific contaminants and quantities. The matrix assigned a high, medium, or low priority for the various contaminants and calibers involved. Elimination or replacement of lead and toxic heavy metals was deemed highest priority based on the pollution contribution quantity and toxicity. Primary sources of these materials in medium caliber ammunition are the primer and detonator in the fuze. The development of environmentally benign alternatives will reduce or eliminate range contamination; mitigate the long term exposure effects on plant, wildlife, and water systems, and drastically curtail the use of toxic materials at the various 20mm to 60mm ammunition manufacturing facilities. It will also result in reduced safety risks and reductions in prolonged exposure of both user and production personnel to harmful levels of contaminants and combustion products that occur in the material handling and disposal of toxic materials during production, test, and operational use of medium caliber munitions. Economic benefits include reduced ammunition, training and production site cleanup costs. Significant cost avoidance could be realized through elimination of approximately 10 tons of lead required to support production of medium caliber training ammunition over the next six years.

During this decade, an increased emphasis has been placed on pollution prevention to reduce environmental impacts associated with DoD weapon systems acquisition. The DoD Pollution Prevention Strategy of August 11, 1994, established a goal to identify and develop environmental life cycle cost estimating tools that inject pollution prevention and other environmental concerns into acquisition decisions. Development and application of modeling and simulation tools to identify and test technical solutions that reduce reliance on toxic materials and processes are required. Within the **Reduction of Hazardous Materials/Solid Waste** subthrust, SERDP is funding numerous, wide-ranging projects addressing alternatives to hazardous and toxics chemicals and processes such as cleaning agents, anti-freeze, corrosion protectors, and coatings as well as the reduction of solid waste associate with the packaging of military rations. Virtually all DoD maintenance and repair activities for weapon system components involve the use of toxic or hazardous substances. In 1998, EO 13101 directed "Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition." It encouraged the expansion of markets for recovered materials, environmentally preferable products, (including biobased products), and established the organizational structure to ensure full accountability. Under this EO, Federal agencies must establish specific goals for (1) waste prevention and recycling or solid waste diversion, (2) affirmative procurement of products that are made with recovered materials, and (3) procurement of environmentally preferable products and services for which a pilot project has been successfully completed. Agencies will annually evaluate their progress toward attaining these goals.

Additionally, SERDP continues to use topical studies and workshops as tools to identify DoD/DOE user needs, to better understand the existing state-of-the-art technology in these areas, and to identify environmentally driven requirements. In addition to fostering technology transfer, this information is used to help focus the SERDP program on the highest priority issues and to avoid duplication of effort. SERDP's Pollution Prevention program has taken a systems approach to continue to work on the next generation of concepts/materials through the development of SONs derived from DoD user requirements. These workshops provided an opportunity for communication between the Requirements, User Communities and SERDP.

These communication lines will enhance future efforts to provide guidance and devote resources to the pressing environmental issues that continue to face the DoD.

Leveraging with other DoD, DOE, and EPA science and technology programs and industry, the Pollution Prevention subthrust areas focus also on the following research and development objectives.

- Alternative materials and processes to replace defense use of hazardous heavy metals (e.g., lead, nickel) and metallic compounds and hazardous air pollutants.
- Techniques to regenerate, recycle, and re-use defense unique toxic chemicals and materials.
- Cost-effective, environmentally preferable packaging and recycling approaches to reduce generation of solid waste from defense-related operations.
- Predictive models (which include environmental life cycle costing) to aid in the development of environmentally sound weapon systems and platforms during concept development, design, test and evaluation, maintenance (logistics support documentation), and decommissioning.

Pollution Prevention Program

For FY 2002, Pollution Prevention received approximately 24 percent of the SERDP budget. SERDP conducted two solicitations that requested proposals for funding in FY 2002 in the Pollution Prevention Thrust Area. The annual solicitation issued five SONs in the areas of new energetic materials, innovative polymer matrix composites, remote identification of munitions, low temperature powder coatings, and environmentally acceptable pyrotechnic formulations. Late in FY 2001, the supplemental solicitation for FY 2002 funding issued three Pollution Prevention SONs in the areas of environmentally acceptable electro-explosive devices, percussion primers, and incendiary compositions for medium caliber munitions.

POLLUTION PREVENTION

FY 2002	
37	Total projects
19	Completed projects

FY 2003	
27	Total projects
9	New Start projects

The following list reflects projects completed in FY 2002 and projects continuing into FY 2003. Also included are titles of projects that begin in FY 2003. Complete descriptions of all of the projects for FY 2002 and FY 2003 may be found on the pages referenced in Appendix D - Pollution Prevention Project Summaries.

Subthrust: *Air Emissions* **Page**

FY 2003 New Start Projects
None

Subthrust: *Next Generation Fire Suppression*

FY 2002 Completed Projects
None

FY 2003 Continuing Projects

FY 2003 New Start Projects
None

Subthrust: *Elimination of Chromium and Cadmium*

FY 2002 Completed Projects

FY 2003 Continuing Projects

FY 2003 New Start Projects

Subthrust: *Green Energetics*

FY 2002 Completed Projects

FY 2003 Continuing Projects

FY 2003 New Start Projects

Subthrust: *Reduction of Hazardous Materials/Solid Waste*

FY 2002 Completed Projects

FY 2003 Continuing Projects

FY 2003 New Start Projects
None

FY 2004 Pollution Prevention Initiatives

SERDP is proposing five new Pollution Prevention initiatives through the issuance of five core SONs. The focus of the FY 2004 program is development of (1) an alternative to ammonium perchlorate, (2) an environmentally benign cadmium plating alternative, (3) non-ozone depleting solvents for precision cleaning, (4) a non-toxic medium caliber incendiary compositions, and (5) a benign synthesis route to manufacture trinitroluene (TNT).

The objective of the first core SON, **Alternatives for Ammonium Perchlorate in DoD Missile Propulsion Applications**, is to develop environmentally benign solid rocket propulsion technologies which do not rely on the use of ammonium perchlorate as an oxidizer. The results of this research may integrate various efforts in DoD and industry to find ammonium perchloarate alternatives that:

- eliminate/reduce future groundwater contamination by ammonium perchlorate (AP) by eliminating the need for the production and use of AP as an oxidizer in solid rocket motors; and

- meet or exceed current safety and DoD performance requirements and offer significantly reduced environmental impact.

The objective of the second core SON, **Environmentally Benign Alternative for Cadmium Plating on High Strength Steels**, is to develop an environmentally benign cadmium plating alternative for use in high-strength (greater than 180ksi) steel applications on DoD weapon systems. Applications include but are not limited to: high strength fasteners, pneumatic/hydraulic actuator rods and cylinders, and aircraft engine attach points, thrust pins, and torsion links. The results of this research may integrate various efforts in DoD and industry to find cadmium plating alternatives that:

- provide corrosion protection for high-strength steels that is equal to or exceeds that provided by the currently used cadmium coatings;

- address technical performance, production, material and operational support costs and environmental safety occupational health (ESOH) issues from a systems perspective; and

- demonstrate the ability to coat non-line-of-sight components/parts/surfaces.

The objective of the third core SON, **Alternatives for Class II Ozone Depleting Substance Solvents for DoD Precision Cleaning Applications**, is to develop non-ozone depleting, zero HAP, low VOC, non-hazardous materials or processes for precision cleaning DoD systems. Specifically, the research project will aim to develop qualified replacements for HCFC-141b and other Class II ODS cleaners used for precision cleaning of DoD parts. As part of the proposed effort, the work must:

- address materials and processes from a systems level and exhibit lower life cycle environmental impact than current processes;

- consider depot support issues (maintenance and repair) and systems' applications;

- establish and track baselines in materials types, quantities, costs, and environmental impact during the development effort; and

- support the environmental merit of the selection.

The objective of the fourth core SON, **Environmentally Acceptable Incendiary Compositions for Medium Caliber Ammunition**, is to develop alternative chemistries to eliminate the use of toxic, heavy metals and volatile organic chemicals (VOC) that are currently used in the manufacture of incendiary compositions for medium caliber (20mm - 60mm) ammunition applications. The work will eliminate or minimize the use of VOCs in the manufacturing process of incendiary materials, while providing equivalent or increased levels of performance compared to current formulations.

The objective of the fifth core SON, **Elimination of Redwater from TNT Manufacture**, is to develop a relatively environmentally benign synthesis route to manufacture military grade trinitrotoluene (TNT). Specifically, the proposed process must not generate redwater and should minimize the generation of other hazardous or toxic byproducts.

UXO

Introduction

SERDP established the Unexploded Ordnance (UXO) Thrust Area because UXO has been identified by the Services as the highest priority environmental need. UXO presents a major challenge to DoD in its effort to remediate closed, transferred, and transferring (CTT) ranges, such as sites designated for base realignment and closure (BRAC) and formerly used defense sites (FUDS). It also is a challenge for active military installations seeking to manage their test and training ranges as sustainable assets. In the United States alone, current estimates indicate that more than 50 million acres of land with varying terrain, vegetation, and topography are potentially contaminated with UXO. Using current technologies, cost estimates for identifying and disposing of UXO in the U.S. range from $10’s of billions to over $100 billion. New technologies capable of detecting UXO with high detection rates and low false alarm rates are required to reduce drastically the cost of site characterization and cleanup.

Until recently, “mag and flag” was the standard procedure for site characterization for UXO. In a “mag and flag” operation, a magnetometer or electromagnetic induction sensor is used and anomalies are identified by real-time human interpretation of sensor response, which is usually presented as an audible signal set at some operator-determined threshold. “Mag and flag” has generally produced detection rates that are unacceptably low and the number of nonhazardous items detected that must be investigated far outnumber real ordnance. Technical capability has developed beyond “mag & flag” for open terrain; digital sensors paired with modern GPS navigation collect data systematically, providing a map of sensor responses. Such systems have led to improvements in detection and reduction in false alarms at simple sites. However, advances are still needed to improve detection and discrimination under a variety of operational conditions, to develop sampling techniques for wide-area surveys, to improve vehicle and man-portable production surveys, and to interrogate individual items for explosive hazard.

The DoD is focused on protecting human health and the environment, reducing remediation costs, and providing timely cleanup of UXO-contaminated sites. Technology objectives for the DoD are:

1. develop tools to perform initial assessment of sites that require large area survey;

2. develop tools to provide detailed site characterization;

3. develop tools for cost-effective, cued object discrimination;

4. develop advanced sensors and innovative data processing and data fusion techniques for increased discrimination between UXO and non-UXO items;

5. develop tools for assessment and quantification of risk;

6. develop standards and protocols for navigation, geolocation, and data acquisition and processing; and

7. develop tools to aid in the cost-effective removal and disposal of UXO.

These technology objectives are addressed by the major subthrust areas depicted and further defined in Figure III-6.

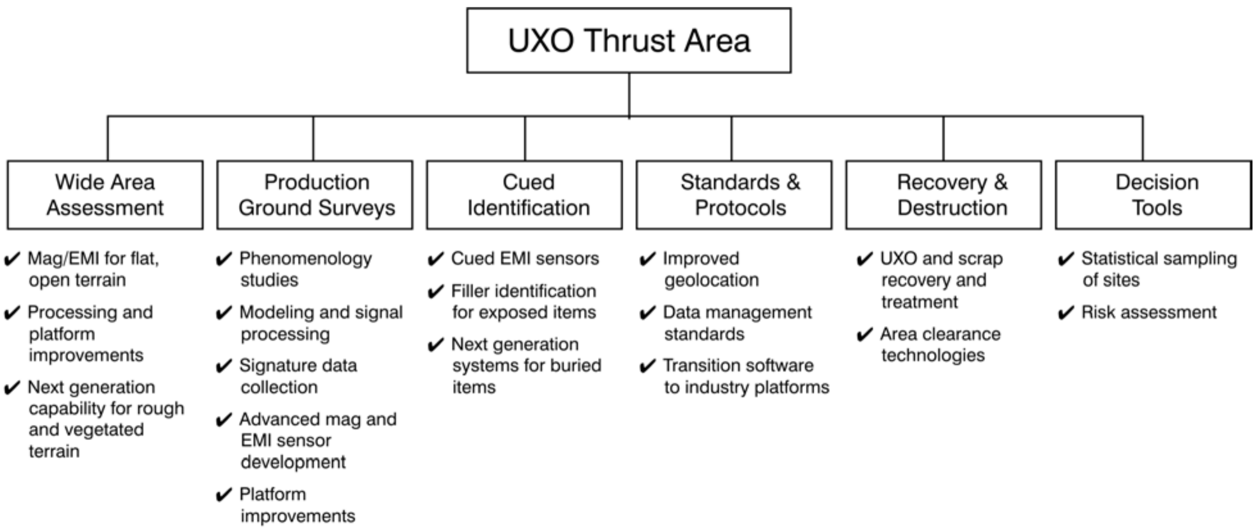

Figure III-6. UXO Taxonomy.

While ongoing defense UXO characterization and remediation projects will rely on technologies that can be identified in the near-term, UXO cleanup, at the current rate of progress, will require decades to complete. Thus, additional research in this area has the potential to provide the highest return on investment decreasing both overall cost and cleanup time. The Department requested and Congress appropriated an additional substantial increment of funds for FY 2002 specifically to conduct UXO-related research. Following a competitive selection process, projects in response to this appropriation were initiated late in FY 2002 and will continue into FY 2003 and beyond. This increase in UXO-related research funding has established a firm foundation for SERDP to continue to be the leader in DoD for UXO-related R&D.

Principal Driving Requirements

SERDP's UXO thrust area supports the Department's efforts to advance the state of the technologies used in conducting UXO investigations. SERDP investments in UXO have two principal objectives. First, these efforts seek to improve the overall effectiveness of response activities in the areas of worker safety, overall protection of human health and the environment, and long-term effectiveness. Second, these efforts are seeking solutions that may assist in reducing the overall program cost associated with the DoD munitions response program. With the wide variations in site size and complexity, terrain, vegetation, geology, the type of ordnance used at the site, the reasonably anticipated future land use, and other factors, in support of these objectives DoD is pursuing UXO technology advancement on a broad front, seeking improvements that will be useful across a broad spectrum of sites.

To provide focus to the program, the Department has established six objectives specific to UXO technology development. These objectives do not represent single endpoints of the technology development process, rather they describe classes of technologies required to meet specific operational needs. Consequently, SERDP has organized its UXO research program (see Figure III-6. UXO Taxonomy) into subthrust areas that mimic the same technology objectives.

The first subthrust area in UXO, **Wide Area Assessment**, involves technology that can enable the rapid identification of areas that require detailed characterization. Unit costs (e.g., dollars per acre covered) for wide area surveys are much lower than costs for detailed characterization, as these systems are primarily airborne platforms that allow rapid coverage of large areas. It is important to note that because of their relatively high speed and the height of the sensor above the ground, these systems are currently capable only of detecting large objects or dense clusters of small objects. With the exception of operations in flat, open areas, these systems are not able to provide the high degree of detection efficiency and geo-location accuracy found with man-ported or vehicle mounted systems. Future developmental activities are focused on extending the use of these systems to a wide variety of terrain and improving their ability to detect smaller ordnance.

The second subthrust area, **Production Ground Surveys**, is the most heavily invested area at present. Production ground surveys currently use single or multi-sensor arrays to collect the data used to detect and locate UXO. Following collection, this data is analyzed using computer modeling and simulation software. Significant progress has been made in improving detection capabilities, however, discrimination between UXO and innocuous materials with similar sensor signatures has not seen the same level of improvement. New sensor concepts are in development, which when coupled with similar efforts to improve the post-collection processing systems, should lead to even greater improvement in detection and discrimination capabilities. Advanced towed, man-portable and hand-held systems that improve the current detection and discrimination capabilities and that are deployable across all sites are being developed.

The next subthrust area, **Cued Identification**, supports the definitive identification of UXO located during production ground surveys. Cued identification is a key element in discriminating between UXO and innocuous materials with similar sensor signatures, and is a critical feature of efforts to reduce the inefficiencies caused by poor discrimination.

The fourth subthrust area, **Standards and Protocols**, involves technologies focused on developing standardized methods for the collection, management, and evaluation of geophysical data. It includes, the establishment of standardized test facilities and protocols, which enable the evaluation of detection systems under reproducible conditions. These facilities also aid in generating valuable data to support further development and optimization of these systems. While not presently funding research in this area, SERDP maintains an awareness of ongoing related activities and considers it an area for future exploitation given the availability of funding.

The fifth subthrust area, **Recovery and Destruction**, is focused on developing systems that will improve the safety and efficiency of UXO recovery and destruction activities. Developing tools for mass clearance of highly contaminated areas, removal and destruction of UXO in all environments, and treatment of residues are of primary interest. While not presently funding research in this area, SERDP maintains an awareness of ongoing related activities and considers it an area for future exploitation given the availability of funding.

The final subthrust area, **Decision Tools**, is focused on developing methods to guide and evaluate actions throughout the UXO response process. Developing statistical assessment tools, quality control tools and hazard assessment are of primary interests. At most sites, UXO is concentrated in specific areas and effective footprint reduction is a goal so that resources can be focused in the area of highest contamination. Supporting footprint reduction decisions, decision process protocols developed with SERDP funding will fulfill the need for a statistically defensible procedure to assess sites through sub-sampling.

Leveraging with other defense science and technology programs and industry, the UXO Technology Thrust Area focuses on a subset of the R&D objectives that are listed under the Cleanup Thrust Area. Namely, those objectives that apply to the UXO problem are as follows.

- Develop investigation methods and technologies that are capable of locating and characterizing UXO in a timely, cost effective, and quality manner.
- Develop innovative, compliant technologies that reduce remediation costs for sites containing UXO.
- Facilitate transfer of those UXO-related technologies to field use. This includes, but is not limited to encouraging the use of the Standardized UXO Test Sites developed under SERDP and ESTCP funding.
- Develop risk-based modeling and simulation methods for hazard assessment and establishing remediation priorities and scientifically defensible "no further action" decision points for UXO-contaminated land.

UXO Program

For FY 2002, the UXO Technology Thrust Area received approximately 11 percent of the SERDP budget. In FY 2001, SERDP conducted three solicitations that requested project proposals in the UXO Thrust Area. Late in FY 2001, the supplemental solicitation (mentioned previously) with FY 2002 funding issued UXO SONs. Due to the late timeframe and the large number of projects selected for funding, SERDP conducted only a SEED solicitation that requested small innovative project proposals in the UXO Thrust Area for FY 2003.

UXO	
FY 2002	
29	Total projects
5	Completed projects
FY 2003	
30	Total projects
6	New Start projects

The following list reflects projects completed in FY 2002, and projects continuing into FY 2003. Also included are titles of projects that begin in FY 2003. Complete descriptions of all of the projects for FY 2002 and FY 2003 may be found in Appendix E - UXO Project Summaries.

Subthrust: *Wide Area Assessment* — Page

FY 2002 Completed Projects

None

FY 2003 Continuing Projects

FY 2003 New Start Projects

None

Subthrust: *Production Ground Surveys*

FY 2002 Completed Projects

FY 2003 Continuing Projects

FY 2003 New Start Projects

Subthrust: *Cued Identification*

FY 2002 Completed Projects
None

FY 2003 Continuing Projects

FY 2003 New Start Projects
None

Subthrust: *Standards and Protocols*

FY 2002 Completed Projects
None

FY 2003 Continuing Projects
None

FY 2003 New Start Projects
None

Subthrust: *Recovery and Destruction*

FY 2002 Completed Projects
None

FY 2003 Continuing Projects
None

FY 2003 New Start Projects
None

Subthrust: *Decision Tools*

FY 2002 Completed Projects

FY 2003 Continuing Projects

FY 2003 New Start Projects
None

FY 2004 UXO Initiatives

SERDP is diligently seeking to develop technologies that will provide new solutions to the diverse detection and discrimination problems of UXO-contaminated land sites. To this end, in FY 2004, the SERDP UXO Thrust area will solicit proposals for research under the following Statement of Need (SON): **Advanced Approaches to Unexploded Ordnance (UXO) Detection and Discrimination**. The intention is to fund efforts to address the development of new sensors, platforms (including hand-held, man-portable, vehicular and airborne), discrimination techniques, or signal processing approaches. Proposals may also address improved technologies to support detection and discrimination efforts through navigation, geo-location or hazard assessments associated with erosion, migration of ordnance, frost heave, and the like. Advances are needed in all aspects of the procedures for the detection and discrimination of UXO.

Another UXO-related proposed area of new research is entitled, **Innovative Technology for Identification of Filler Material in Recovered UXO**. The objective of this SON is to develop technologies that will provide new solutions to determine explosive hazards posed by UXO. These technologies may be aimed at developing new sensors or signal processing techniques. The task of this system is to correctly identify suspected items as live explosives or inert in as non-intrusive, timely, cost-effective way. The majority of items found on the surface, excavated, partially exposed, or identified for excavation by a production survey often pose no risk. Due to age and condition, unknown items often must be treated as though they contained high explosives or other hazardous material. Often items are not determined to be inert until they have been detonated where they were found, a practice referred to as “blow in place.” This leads to unnecessary potential impacts to the environment and communities, as well as costs that could be potentially avoided. Positive identification of subsurface anomalies is currently accomplished by excavation and inspection. Systems that could improve identification of suspected anomalies or partially exposed items during excavation have the potential to significantly lower both the risks to personnel and costs. To be useful, systems must be competitive with manual inspection and blow-in-place in terms of manpower, time requirements, and risk, as well as provide very high reliability.

The final UXO-related proposed area of new research is entitled, **Site Characterization and Remediation Technologies for UXO-contaminated Underwater Sites**. The objective of this SON is to develop technologies to support characterization and/or remediation actions for unexploded ordnance found on underwater sites. Research and development proposals should focus on one or more of the following activities: (1) Novel engineering-based techniques or platforms that overcome the access limitations for locating UXO present in underwater locations (e.g., coastal areas, marine sediments, harbors, estuaries, lakes, ponds and wetlands); (2) Improved sensors or signal processing to aid in detection and discrimination in underwater UXO-contaminated areas; (3) Characterization and phenomenology of underwater UXO, including migration and depth of burial in various underwater environments; and, (4) Removal and disposal techniques for underwater UXO.

Detailed descriptions of the FY 2004 UXO Statements of Need may be found in Appendix F.

APPENDIX A
Cleanup Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program–McClellan AFB, CA; CU-861

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Don Gronstal; McClellan Air Force Base – Sacramento, CA

FY 2002 COMPLETED PROJECT

DESCRIPTION: The National Environmental Technology Test Site (NETTS) program goal is to enable efficient demonstration of innovative detection, monitoring or remediation technologies, either on an individual basis or in parallel with similar projects, under representative hydrological and climate regimes as found at many contaminated sites in the Department of Defense (DoD). Current environmental cleanup technologies are costly, slow, and largely ineffective. The NETTS program provides test beds for research to fully understand the mechanisms in proposed treatment processes. The NETTS National Test Location at McClellan Air Force Base (AFB) provided test sites to investigate technologies primarily for treatment of unsaturated soils and extracted soil-gas contaminated with chlorinated solvents, as well as ex-situ treatment of contaminated groundwater.

As a NETTS test location, McClellan AFB provided a well-characterized demonstration site for applied research, demonstration, and evaluation of promising remediation and monitoring technologies. McClellan AFB has twenty operational soil vapor extraction (SVE) systems, all with dedicated utilities adjacent to them allowing for convenient slip-stream demonstrations. McClellan AFB's groundwater treatment plant currently services 53 extraction wells. There is an additional groundwater pretreatment system with 7 extraction wells. The SVE systems and groundwater treatment facility provided opportunities for demonstrating in-situ and ex-situ techniques for remediating soils and groundwater contaminated with solvents. There are more than 400 groundwater monitoring wells located on and around McClellan AFB.

BENEFIT: Test locations are fully characterized. The NETTS test locations help save time and money for technology demonstrators by providing on-site management, pre-characterization, and timely permitting. An established, dedicated test site enables technology demonstrations to be performed at a cost lower than that of a one-time demonstration elsewhere.

ACCOMPLISHMENTS: The McClellan AFB NETTS location supported demonstrations of in-situ and ex-situ techniques for characterizing and remediating soils and groundwater contaminated with chlorinated solvents. The NETTS infrastructure included the SVE systems and groundwater/soils treatment facilities. McClellan AFB was host to both DoD and non-DoD funded technology demonstrations. Information on demonstrations can be found at http://www.afbca.hq.af.mil/mcclellanem.

TRANSITION: This project supported the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full-scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program – Naval Base Ventura County, Port Hueneme, CA; CU-863

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Ernest Lory; Naval Facilities Engineering Service Center – Port Hueneme, CA

FY 2003 FUNDS: $600K

DESCRIPTION: The objective of the Naval Base Ventura County (NBVC) National Environmental Technology Test Sites (NETTS) National Test Location (NTL) at Port Hueneme, CA, is to support demonstration of technologies for characterizing and remediating soil, sediments, and groundwater contaminated with fuel hydrocarbons, waste oil, and fuel additives such as methyl tert butyl ether (MTBE). It provides test sites to investigate both ex-situ technologies for treatment of soils and in-situ technologies for groundwater. The Test Location Manager (TLM) at NBVC, Port Hueneme provides programmatic, infrastructure and technical support to researchers for characterization and remediation demonstrations. Programmatic support includes integration of the following: (1) Quality Assurance/Quality Control (QA/QC) procedures, (2) test protocol guidance, (3) demonstration reporting format, and (4) environmental setting, cost-and-performance data retrieval guidance. Infrastructure and its management (operation and maintenance) include: (1) monitoring wells, (2) in-line sensor network, (3) ex-situ treatment facility with hazardous material handling capability, (4) utilities, and (5) contaminated soil, sediments and groundwater resources. Technical support will include: (1) characterizing and monitoring contaminants, (2) processing permits, (3) supporting stakeholder involvement, and (4) transferring technologies.

BENEFIT: The NTL for fuel hydrocarbon and waste oil provides well characterized test locations, controlled field conditions for comparative evaluations of technologies, uniform evaluation criteria for demonstrations, reporting of results and technology transfer, and cost savings through amortization of infrastructure and management.

ACCOMPLISHMENTS: The Port Hueneme NETTS was established in 1993 to support fuel hydrocarbon contaminated soil and groundwater innovative characterization and remediation technology evaluations. The NETTS infrastructure includes a large gasoline/MTBE plume, an ex-situ treatment facility with contaminated soil, and an aboveground fuel farm. The 80-acre Hueneme Harbor with 2 miles of canals/wetlands is also available for conducting remediation and characterization test and evaluations. Over 45 projects have completed evaluations, some were conducted with EPA ETV, RCI, ITRC, and Cal EPA oversight. In support of the transition of demonstrated technologies, the Port Hueneme NETTS conducts tours and hosts workshops, meetings, and courses. Information on demonstrations can be found at http://enviro.nfesc.navy.mil/erb/support/netts/main.htm.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full-scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program – Dover AFB, DE; CU-866

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Tim McHale; Air Force Research Laboratory – Dover AFB, DE

FY 2003 FUNDS: $567K

DESCRIPTION: This National Environmental Technology Test Sites (NETTS) National Test Location at Dover AFB, which is managed by the Air Force Research Laboratory, provides test sites for the application of characterization and remediation technologies for soil and water contaminated by chlorinated solvents. Its centerpiece is the Groundwater Remediation Field Laboratory (GRFL). The GRFL consists of isolated, well-monitored, in-situ controlled release test cells, in which mass-balance studies of the fate, transport and remediation of dense non-aqueous phase liquids (DNAPL) may be performed. Operations consist of long-term compliance monitoring of the site and infrastructure maintenance, as well as project support to include among other things injection and monitoring of the test constituents (primarily trichloroethylene and perchloroethylene), demonstration of innovative technologies, some analytical support to demonstrators, and management and disposal of a minimal amount of waste from the tests. The process for obtaining permits for contained releases is established. In addition to supporting the contained release test cells and accompanying infrastructure, several demonstrations located in existing plumes on Dover AFB are given significant field and laboratory support, as well as coordination of activities and permitting as required by State, Federal, and local regulations. More recently, the Dover National Test Site (DNTS) has undertaken research initiatives to address concerns over a methyl tert-butyl ether (MTBE) plume that has migrated onto the Base boundary. The State of Delaware regulatory branch requested a corrective action from Dover AFB. As a result, several cooperative efforts between Dover AFB, the DNTS, and the U.S. Geological Survey have culminated to produce an MTBE Technology Demonstration Program.

BENEFIT: The GRFL is a unique resource, the primary purpose of which is to provide contained release cells for DNAPL research and development that avoid making the gross assumptions that would be necessary if experiments were conducted in previously contaminated aquifers. DNAPLs are immiscible with and denser than water, and when spilled on the ground, migrate below the water table. Once below the water table, they are difficult to locate and remove.

ACCOMPLISHMENTS: Since its inception, the DNTS has supported innovative technology demonstrations ranging from plume characterization and monitoring techniques to remediation of chlorinated solvents and fuel components. The DNTS infrastructure includes the contained release test cells constructed within a natural geologic environment and the MTBE plume. Seven major projects have been completed within the test cells, five of which were led by the Environmental Protection Agency. These demonstrations provided significant data on in-situ surfactant and cosolvent flushing technologies as well as partitioning inter-well tracer test technology used to delineate residual solvent contamination. Led by the DNTS, the MTBE Technology Demonstration Program consists of characterization efforts and three technology demonstrations focusing on remediation of the plume. A DNTS web site (http://www.dnts.org/) and interactive CD have been developed.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: An Innovative Passive Barrier System Using Membrane-Delivered Hydrogen Gas for the Bioremediation of Chlorinated Aliphatic Compounds; CU-1124

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Michael Semmens; University of Minnesota – Minneapolis, MN

FY 2002 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to examine the gas transfer behavior and performance of hollow fiber membrane curtains that are installed as passive barriers. Research assessed the suitability and effectiveness of the membrane for delivering hydrogen (H_2) to accelerate the in-situ remediation of chlorinated organic compounds like trichloroethene (TCE) and perchloroethene (PCE). Membranes were investigated in a systematic way to determine what factors control the overall remediation process. Tasks included: (1) gas dissolution behavior of membranes, (2) impact of gas composition changes and condensation, (3) impact of biofilm growth on gas transfer, (4) evaluation of solvent transformation, (5) mathematical model development, and (6) pilot reactor studies.

BENEFIT: The overall goal of this research was to develop an innovative passive barrier remediation technology that would reduce the costs and risks associated with contaminated site cleanup. H_2 appears to be an effective electron donor for the biodegradation of halogenated aliphatics when it is sufficiently bioavailable. However, it is difficult to provide sufficient H_2 to organisms due to its low solubility. Gas permeable membranes, used as a passive treatment barrier, can be used to provide H_2 as an electron donor for in-situ bioremediation. The technical feasibility of using membranes for H_2 delivery to contaminated groundwaters was assessed, and the engineering data required to complete a cost analysis and transition the membrane-module remediation system into field scale application was generated.

ACCOMPLISHMENTS: Clean water gas transfer studies are complete. A dimensionless correlation was developed to describe gas transfer out of the hollow-fiber membrane under creeping-flow conditions. A finite difference model for predicting changes in gas composition as a function of design and operating parameters has been developed and verified experimentally. Condensation studies were conducted for both sealed-end and flow-through membranes. Biological fouling decreased gas transfer at high-flow velocities. Under creeping-flow conditions, the liquid film resistance was still greater than the fouled membrane resistance. Similar results were observed for abiotic fouling. Transmembrane H_2 flux as a function of biofilm thickness was determined, and the effect of biofilm on gas transfer to the water was assessed using SF_6 tracer gas. A one-year column study was performed to determine if membrane-fed H_2 could stimulate PCE dechlorination under simulated aquifer conditions. Results demonstrated that, despite significant methane production, PCE dechlorination to vinyl chloride and ethene was greater in the H_2-fed column than in the control column. In this experiment, membrane fouling occurred, which stopped gas transfer. Composition analyses of the foulant indicated large amounts of calcium, phosphorus, carbon, and oxygen in the coatings. The membranes used in the experiment were quite fragile and ill-suited to field installation. A second column study was then performed with a more robust silicone-coated membrane and aquifer material from a TCE-contaminated site, with cis-DCE observed as the major product in the effluent. A one-dimensional finite-differences model was developed to simulate PCE dechlorination in a completely anaerobic aquifer supplied with H_2 via an in situ gas-permeable membrane curtain. A pilot reactor study was then performed to investigate passive and pumped systems.

TRANSITION: The project intends to transition to the user community, including Porous Media, Minntech Corp. and Membran Corp. The project also intends to select a site within DoD for further field demonstration/validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Effective Aerobic Cometabolic Systems for the In-Situ Transformation of Problematic Chlorinated Solvent Mixtures; CU-1127

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Lewis Semprini; Oregon State University – Corvallis, OR

FY 2002 COMPLETED PROJECT

DESCRIPTION: The goal of this research was to demonstrate the potential of using propane and butane-utilizing microorganisms to transform problematic chlorinated aliphatic hydrocarbon (CAH) mixtures. The demonstration was aimed towards creating in-situ bioreactive passive barriers in contaminated aquifers as microcosm studies conducted with subsurface solids and groundwater from contaminated Department of Defense (DoD) sites have shown that propane and butane-utilizers are often absent in the subsurface or have long lag periods before effective stimulation is achieved. The technical approach consisted of four components: (1) Laboratory studies to select the bioaugmentation approach and to develop kinetic information for single substrate and mixed substrate addition for the transformation of CAH mixtures; (2) Exploration of molecular probe methods for tracking the added organisms in laboratory and field studies; (3) Field demonstrations to evaluate the bioaugmentation approach and to determine the effectiveness in treating problematic mixtures of 1,1,1-TCA, 1,1-DCE, and TCE using propane or butane as a single cometabolic substrate, and mixed cometabolic substrates, propane or butane with phenol or toluene; and (4) Modeling evaluations of the laboratory and field studies, including simulations to aid in the design of the field demonstration tests.

BENEFIT: The primary benefit from this project is a field documented, in-situ cometabolic process that transforms problematic mixtures of CAHs. This technology represents a new in-situ application of aerobic cometabolism for complex CAH mixtures. In addition, a bioaugmentation methodology for in-situ cometabolism was developed for possible use as a remediation alternative at sites where natural attenuation or biostimulation will not work. This technology may be used as a passive process that can be applied in deep aquifers or in a stratigraphy with multiple clay lenses. Other products from this research include development of an approach for establishing effective microbial communities for in-situ cometabolic treatment, modification to the Cometabolism Transport Model, assessment of community structure changes with bioaugmentation and cometabolic transformation, and specific probe method development for propane and butane bioaugmentation cultures.

ACCOMPLISHMENTS: Molecular techniques were used to characterize the butane-utilizing mixed culture to be used for bioaugmentation and to track the culture in microcosm studies that mimic conditions of the field demonstration. A clone library analysis permitted the 16S rDNA sequencing of dominant microorganisms within the mixed culture, without the need to isolate the microorganisms as pure cultures. These sequences were used to develop rRNA probes for Fluorescent In-situ Hybridization (FISH) to track specific microorganisms in the mixed culture. The terminal restriction fragment length polymorphism (T-RFLP), a polymerase chain reaction method, was developed to evaluate microbial population dynamics in the microcosm studies and to study the transport and fate of the bioaugmented culture in the field study. Microcosm tests were conducted prior to the initiation of the field study to evaluate butane, 1,1-dichloroethylene (1,1-DCE), and 1,1,1-trichloroethane (TCA) degradation kinetics and the fate of the bioaugmented culture. Numerical model parameters, including expressions for microbial growth and decay, substrate and oxygen utilization, and cometabolism of dual contaminants, were determined independently in kinetic studies of the butane-utilizing culture and in microcosm studies. The field demonstration was conducted at Moffett Field, CA and included two parallel test legs, one for bioaugmentation and the other for stimulation of the indigenous microorganisms. A chlorinated solvent mixture of 1,1-DCE, 1,1-DCA and 1,1,1-TCA was continuously injected into both experimental legs prior to the bioaugmentation and biostimulation experiments. Butane and oxygen amended groundwater was injected into both experimental legs in short alternating pulses. Butane consumption and CAH transformation was apparent in the bioaugmented leg six days after bioaugmentation. CAH transformation was correlated with butane consumption. The best transformation conditions achieved during the first two weeks after bioaugmentation were: 98 percent removal of 1,1-DCE, 84 percent removal of 1,1-DCA, and 60 percent removal of 1,1,1-TCA. Two weeks after adding butane and oxygen, no butane uptake or CAH transformation was observed in the indigenous experimental leg. Transformation of the CAHs was also shown to be strongly inhibited by the presence of butane. Model simulations with laboratory-derived kinetic parameters yielded transformation of 1,1-DCE, 1,1-DCA, and 1,1,1-TCA similar to that observed in the field test. Experimental conditions were then switched to long-pulse cycles, and minimal transformation of the CAHs was observed. The demonstration reverted back to short-pulse cycles and showed good utilization of butane and effective transformation of 1,1-DCE in both the bioaugmented and indigenous legs; however, effective treatment of 1,1-DCA and 1,1,1-TCA was not achieved. 1,1,1-TCA transformation as a single contaminant in the field was then evaluated. 1,1,1-TCA was not effectively transformed in either the indigenous or the bioaugmented leg, with about 10 to 20 percent of the TCA added transformed during these tests. Groundwater samples were obtained prior to bioaugmentation, just after bioaugmentation, and during different stages of the biostimulation and biotransformation studies for microbial analysis. Analysis of the samples using T-RFLP indicated that the pure culture that was bioaugmented either did not travel far or did not establish itself well and that indigenous microorganisms were biostimulated in both the indigenous and bioaugmented leg. A final field test involved bioaugmentation with two pure cultures, a well-studied *Rhodococcus* culture and the same culture used in previous demonstrations, of butane utilizers that are capable of 1,1,1-TCA, 1,1-DCE, and 1,1-DCA transformation.

TRANSITION: The project intends to transition to the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Biological Assessment for Characterizing Contaminant Risk at the Genetic-, Individual-, and Population-Level; CU-1129

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Todd Stephen Bridges; U.S. Army Corps of Engineers Engineer Research and Development Center, Environmental Laboratory – Vicksburg, MS

FY 2002 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to develop a suite of technically defensible assays that could be effectively used in regulatory programs to quantify the ecological risk of contaminated sediments at the molecular-, individual-, and population-level. Researchers quantified the biological/ecological meaning of genetic responses, collected using genosensors, by way of comparison to whole-organism assessments of toxicity and modeled population-level impacts. Dose-response information was simultaneously generated using genosensors and whole-organism bioassays for military-relevant compounds. Four sediment-dwelling organisms that have been used by the Environmental Protection Agency (EPA) and the Corps to develop chronic, sublethal sediment bioassays for national regulatory programs were used. Comparisons made among the endpoints at each level of organization were tested using field collected sediments ranging in degree of contamination.

BENEFIT: Currently, there is a lack of defensible methods to measure and assess ecosystem responses to insults by Department of Defense (DoD) relevant contaminants. This project provided tangible benefits to DoD cleanup efforts by reducing the driving uncertainties in the estimation of risk in MUC contaminated sediments, namely, (1) contaminant bioavailability, (2) the toxicity of MUCs, (3) the toxicity of complex MUC mixtures, and (4) extrapolating to higher order effects (e.g., population-level impacts). The methods and data generated during this project have improved DoD's capability to defensibly define risk to aquatic organisms exposed to MUCs and to set reasonable cleanup levels that are based on the potential for toxicity at multiple levels of biological organization. Given the number of contaminated DoD/DOE sites (17,000), the potential for remedial cost avoidance is considerable.

ACCOMPLISHMENTS: The relative toxicity of the major degradation products of TNT was evaluated, and the additivity assumption commonly applied in risk assessment was tested for mixtures of these compounds. The lethal toxicity of TNT and three of its metabolites (TNB, 2-ADNT, 2,4-DANT) was determined. The magnitude of the lethal effects of TNT and 2-ADNT was similar and substantially greater than effects from 2,4-DANT. TNB was found to be considerably less potent than TNT in sediments; however, the two compounds were similarly toxic in water. The nature of the chemical interaction among these four nitroaromatic compounds was examined in a mixture experiment where TNT, TNB, ADNT, DANT were represented in equitoxic concentrations. The compounds were found to interact in a manner that was less than dose additive. Similar antagonism was found to exist between lead, phenanthrene, and TNB. Polymerase chain reaction (PCR) primer sets designed for isolation of stress gene fragments from experimental animals were used to directly examine changes in gene expression. Amplified, expressed genes from acute exposures of invertebrates were cloned and sequenced. Genetic assays were developed for assessing exposure effects of contaminants on benthic invertebrates to begin understanding the effects of TNT at the cellular level. These assays were found to correlate with tissue residue concentrations and whole organism survival effects. Since significant effects were observed at sublethal levels of TNT exposure, genetic assays will be useful as tools in screening field-contaminated sediments. This is being tested with sediments from Picatinny Lake in New Jersey.

TRANSITION: The project intends to transition to the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ Bioreduction and Removal of Ammonium Perchlorate; CU-1162

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Coates; Southern Illinois University – Carbondale, IL

FY 2002 COMPLETED PROJECT

DESCRIPTION: This project provided a better understanding of the microbiology involved in perchlorate reduction and removal. The factors controlling the applicability of microorganisms to the in-situ treatment of ammonium perchlorate contamination of natural water supplies were determined. This work also assisted in the development of protocols and molecular tools required for the modeling and application of in-situ bioremediation strategies to treat perchlorate contamination in the environment. The objectives were addressed under the following hypotheses: (1) Perchlorate-reducing bacteria are ubiquitous and indigenous in perchlorate contaminated environments; (2) All perchlorate-reducing bacteria contain a conserved chlorite dismutase (CD) enzyme; (3) Indigenous microbial perchlorate reduction can be easily stimulated in contaminated environments; (4) Stimulated perchlorate reducing populations can remove perchlorate concentrations to levels significantly lower than 18 µg/L; (5) Rates of microbial perchlorate reduction will be affected by the environmental conditions; and (6) Stimulated perchlorate-reducing populations will also enhance biodegradation of co-contaminating organics.

BENEFIT: Results from these studies provide a better understanding of the microbiology involved in perchlorate reduction and the factors controlling the activity of these organisms. These studies also allow the development of a molecular probe that is specific for all perchlorate-reducing bacteria. Such a probe can be used for predictive determinations of the success of a biological in-situ treatment process and also as a monitoring tool for intrinsic or enhanced bioremediative efforts. Finally, this study identified the potential of a stimulated perchlorate-reducing population.

ACCOMPLISHMENTS: Enumeration studies of perchlorate-reducing bacteria that were performed on samples collected from a broad diversity of environments have demonstrated that microbial perchlorate reduction is ubiquitous. More than thirty chlorate-reducing bacteria have been isolated and characterized, and the dominant groups found in most environments have been identified. A perchlorate-reducing organism capable of anaerobic degradation of benzene was isolated and fully characterized, demonstrating for the first time that organic contaminant degradation could be coupled to perchlorate reduction. A culture collection for dissimilatory perchlorate-reducing bacteria (DPRB) was established. Kinetic studies in pure culture indicated that the CD enzyme is essential for the reduction of (per)chlorate, as it catalyzes the dismutation of toxic chlorite into chloride and oxygen. CD expression is not constitutive, and the active enzyme is only present under certain environmental conditions. The presence of oxygen inhibits the expression of an active CD enzyme. Perchlorate is required for the induction of an active CD enzyme. The presence of nitrate inhibits the expression of an active CD enzyme and perchlorate reduction only in organisms that grow by nitrate reduction. Perchlorate reduction is also dependent on molybdenum. Batch culture experiments with several pure cultures indicated that all perchlorate-reducers tested can remove perchlorate levels to below detection under ideal conditions. The CD gene was isolated and sequenced and now can be used as a gene probe. An immunoprobe specific to the CD enzyme has also been developed. A chemotactic response of DPRB was identified, and the ability of DPRB to fractionate stable isotopes of chlorine was demonstrated.

TRANSITION: All results have been published in peer reviewed journals. A website has been developed to document the results, tools, and techniques produced. Research has resulted in 4 patent applications, which have attracted the interest of several biotechnological/ bioremediation companies.

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ Bioremediation of Perchlorate-Impacted Groundwater; CU-1164

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Evan Cox; GeoSyntec Consultants Inc. – Guelph, Ontario, Canada

FY 2002 COMPLETED PROJECT

DESCRIPTION: Groundwater contamination related to the production, handling and use of rocket propellants such as ammonium perchlorate has been identified as a widespread problem at Department of Defense (DoD), Department of Energy (DOE) and defense contractor facilities. Few cost-effective technologies exist for the treatment of perchlorate-contaminated groundwater. Of the technologies being evaluated, in-situ bioremediation is among the most promising because it has the potential to destroy perchlorate in place rather than transferring perchlorate to another waste stream requiring costly treatment or disposal. This research program included laboratory studies and a small field demonstration to: (1) evaluate the ubiquity of perchlorate-degrading bacteria in groundwater at a variety of impacted DoD and related facilities; (2) assess the applicability of in-situ bioremediation in varying geochemical environments; and (3) generate preliminary field data for technology scale-up and demonstration/validation through a follow-on program.

BENEFIT: The presence of perchlorate in drinking water supplies is a national concern that requires the timely development of robust, reliable and cost-effective treatment technologies for large volumes of groundwater. The costs for remediation of perchlorate-impacted groundwater are expected to be in the billions of dollars, which may jeopardize major DoD and propulsion contractor production programs. Given the number of perchlorate-impacted DoD and related contractor sites that may require groundwater remediation in upcoming years, in situ bioremediation may represent a cost savings in the $100Ms to DoD. The ability to jointly treat perchlorate and common co-contaminants such as nitrate and chlorinated solvents via in situ bioremediation will also increase cost savings to DoD. A significant number of other federal and defense contractor facilities may benefit from the development of cost-effective in-situ remediation technologies for perchlorate-impacted groundwater.

ACCOMPLISHMENTS: Results of this study demonstrated that perchlorate-reducing bacteria are ubiquitous and that perchlorate concentrations could be reduced from as high as 660 mg/L to less than the provisional action level of 0.018 mg/L within weeks to months at the varying sites. The results of the field pilot test clearly demonstrated that the approach was capable of jointly biodegrading perchlorate, nitrate and TCE to environmentally-acceptable end products. Perchlorate concentrations declined quickly from the steady state influent of 8 mg/L to less than the practical quantitation limit (PQL) of 0.004 mg/L within several weeks of electron donor (ethanol) addition. Similarly, nitrate concentrations were reduced from an average influent of 24 mg/L to less than the PQL of 0.5 mg/L within weeks of electron donor addition. Concurrent with perchlorate reduction, trichloroethylene (2 mg/L) was completely dechlorinated to ethene within 35 feet from the electron donor delivery well. The data confirm that in situ bioremediation is a highly effective technology for the joint treatment of perchlorate, nitrate and chlorinated solvents, which are common co-contaminants.

TRANSITION: This project has transitioned to the Environmental Security Technology Certification Program (ESTCP) for full-scale demonstration/validation of the technology to provide design and cost data in support of implementation within DoD, DOE and industry.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Extraction Tests for Determining the Bioavailability of Metals in Soil; CU-1165

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Michael Ruby; Exponent Environmental Group – Boulder, CO

FY 2003 FUNDS: $290K

DESCRIPTION: The primary objective is to develop a suite of simple and easy-to-use extraction tests to predict human and ecological exposures to metals in soil. Such tests will provide inexpensive and rapid tools for establishing the bioavailability of metals in soils at hazardous waste sites. Soils used in the project will be characterized for metal species and soil parameters to provide a mechanistic basis for any differences in metals bioavailability among the samples. Therefore, results from the project will also provide an understanding of how various species of a metal may differ in bioavailability, and also how various soil properties may affect metals bioavailability and the stability of the measured bioavailability estimates. The project will be framed around specific metals that are cost drivers for remediation of soils at Department of Defense (DoD) sites and will focus on the most important receptors and exposure pathways for these metals. An extraction technique developed by Exponent has already been demonstrated to predict human oral exposure to lead, arsenic, and other metals in soils. A research consortium founded by Exponent is currently completing validation of this method for lead, and working on validation of the method for arsenic. This project will extend application of this technique to other metals of concern (cadmium, copper, nickel, and zinc). The results of this extraction technique should also be applicable to assessing exposures of terrestrial mammals in ecological risk assessments. The project will include an evaluation of method parameters that might be modified to better predict relative bioavailability of metals in soil in different kinds of mammals (e.g., rodents vs. ruminants). A second aspect of the project will focus on assessing dermal absorption of arsenic and cadmium from soil.

BENEFIT: The most promising simple tests for quantifying the bioavailability of metals from soil are extraction tests to measure the fraction of a metal that is soluble and available for absorption. Evaluation of metal speciation in soils by electron microprobe analysis, as well as complete characterization of soil parameters, will be used to provide mechanistic explanations for the results of the extraction tests. Once developed, these simple tests will be useful for assessing metals bioavailability during site assessment, evaluating any changes to bioavailability after remediation or restoration, and studying the long- term stability of metal species in amended soils.

ACCOMPLISHMENTS: Research is moving forward on all aspects of the study, including that for wildlife receptors, as well as the relative oral and dermal bioavailability to human receptors. Appropriate animal models for the in vivo research have been identified, and formal study protocols have been developed. In addition, pilot studies have been undertaken using both the avian and mammalian wildlife receptors. This pilot research was necessary to understand the appropriate target doses of metals, dosing regimens, and specifics of care and handling required for these non-standard research species. The results of the in vivo research (full dosing trials) will be used over the course of the next year to understand the soil characteristics that affect the relative bioavailability of metals in soils to all studies receptors (human surrogates, and wildlife receptors). This research will also form the basis for determining the need for site-specific in vitro assays for relative bioavailability of metals, and a database for the development and validation of such in vitro methodologies.

TRANSITION: A suite of simple extraction tests will be available to DoD personnel for site-specific evaluation of metals bioavailability from soil at field sites and will result in more accurate exposure and risk estimates that are still protective of human health and the environment.

PROJECT SUMMARY

PROJECT TITLE & ID: Quantifying the Bioavailability of Toxic Metals in Soils; CU-1166

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Phil Jardine; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2002 COMPLETED PROJECT

DESCRIPTION: Thousands of sites at Department of Defense (DoD) installations contain metal-contaminated soils, including lead (Pb), arsenic (As), chromium (Cr), and cadmium (Cd). When evaluating a contaminated site, risk assessors estimate the risk from a number of different potential exposure pathways. For future residential or recreational land use scenarios, the ingestion of soil by children is almost always the critical human health exposure pathway. When metal-contaminated soil is ingested, the default risk assessment guidelines for most metals implicitly assume that the metal is completely absorbed by the body (i.e., 100 percent bioavailable). Soils, however, often tightly bind metals, potentially reducing their bioavailability. As a result, implicitly assuming metals in soil are 100 percent bioavailable may overstate the risk posed by the soils. Specific objectives of this project were to: (1) measure changes in relative bioavailability over time, via an in vitro protocol, in a wide range of soil types which may be encountered at DoD sites; (2) develop a predictive capability to quantify toxic metal bioavailability on the basis of soil properties; and (3) investigate the fundamental relationship between molecular-level speciation and bioavailability to enhance the understanding and predictive capability of the fate of toxic metals in soil. Analysis of soluble metals provides insight into the ability of soils themselves to limit metal bioavailability, without regard to any unique site-specific speciation.

BENEFIT: Improved fundamental understanding and predictive capabilities of the processes that control the long-term sequestration and bioavailability of metals in a wide array of DoD soils will allow site managers and risk assessors to make better initial estimates of site risk than using the default value of 100 percent. Although site-specific data always will need to be considered in final cleanup decisions, results can be used to prioritize sites and to justify site-specific bioavailability studies such as detailed soil speciation investigations and in vivo studies. These results contribute to DoD's goal of mission readiness by avoiding unnecessary diversion of DoD funds for unwarranted site cleanup.

ACCOMPLISHMENTS: Results have indicated that soil-metal interactions significantly reduce the bioavailability of Cr and As from soils relative to the default value. Naturally-occurring organic matter in soil, for example, can reduce chromium(VI) to chromium(III), significantly reducing its bioavailability. To provide a better fundamental understanding of the relationship between bioavailability and speciation, macroscopic laboratory measurements were correlated with microscopic metal speciation measured with synchrotron-generated x-ray absorption spectroscopy. From this information, multivariable linear regression models were developed that will allow risk assessors to estimate soil-metal bioavailability based on common soil properties. A model developed through this research successfully predicted the bioavailability of As in soils (as measured in swine feeding studies) to within an average of 10 percent based on the soil's pH and iron oxide content.

TRANSITION: Results of this research will be transitioned to DoD cleanup activities through both broad-based information transfer and site-specific technology transfer. A user-friendly spreadsheet-based tool to estimate bioavailability based on soil properties is in the process of being developed. In future SERDP-funded research, the project team will expand on its finding that certain soil chemical and physical processes can sequester metals and limit bioavailability. The researchers will investigate the strategic use of non-toxic, low-cost, commercially available soil amendments to decrease the bioavailability of toxic metals at sites where the natural conditions do not promote sequestration.

PROJECT SUMMARY

PROJECT TITLE & ID: Aerobic and Anaerobic Transformation of cis-DCE and VC: Steps for Reliable Remediation; CU-1167

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Tiedje; Michigan State University – East Lansing, MI

FY 2002 COMPLETED PROJECT

DESCRIPTION: Considerable research has focused on the anaerobic transformation of perchloroethylene (PCE) and trichloroethylene (TCE), which are among the most common chlorinated solvents found in groundwater. However, relatively little is known about the types of microorganisms and specific environmental conditions associated with the dechlorination of cis-1,2-dichloroethene (cis-DCE) and vinyl chloride (VC). Recent research identified four different microbial processes that are involved in the fate of these compounds in groundwater. These processes include anaerobic chlororespiration, anaerobic energy-yielding oxidation, aerobic co-oxidation, and aerobic energy-yielding oxidation. In this project, the microbiology of each process was characterized, and the team of researchers evaluated each process for its potential applicability for groundwater remediation. Specifically researchers (1) compared the different dechlorination/degradation processes for their requirements and their rates, (2) subsequently focused on the most viable process(es) or combinations thereof, (3) developed the basic physiological understanding and molecular methods for detection of the most active organisms, and (4) combined the microbial information with site geochemical and activity information to produce criteria for site-specific recommendations.

BENEFIT: This research will identify which geochemical and microbial factors should be evaluated in determining the fate of chlorinated ethenes at a site. Natural attenuation and engineered bioremediation are often the most cost-effective corrective actions for addressing groundwater contaminated with cis-DCE and VC. By conducting additional field geochemical measurements and laboratory studies to characterize biodegradation at a site, these cost-effective remedial options can be reliably identified. The additional cost of conducting these studies, typically $30,000-40,000, is recovered by avoiding installation or long-term operation of a pump-and-treat system. In addition, information from these studies can be used in designing in-situ biostimulation processes for cis-DCE and VC degradation.

ACCOMPLISHMENTS: The community structure of four VC-to-ethene-dechlorinating cultures was determined based on 16S rRNA gene analyses including terminal restriction fragment length polymorphism (T-RFLP), restriction length polymorphism (ARDRA), cloning, and sequencing. A total of 288 clones were analyzed. All cis-DCE- and VC-dechlorinating cultures contained at least one *Dehalococcoides* population. Physiological studies demonstrated that hydrogen is the required direct electron donor for cis-DCE- and VC-dechlorinating populations. Organic electron donors support the reductive dechlorination process only in the presence of fermenting (e.g., hydrogen-producing) populations. Microcosms from numerous pristine and contaminated environments, including several U.S. military sites, were established under different redox treatments including Fe(III)-reducing, Mn(IV)-reducing, denitrifying, and aerobic conditions. Sediment-free cultures were obtained from microcosms showing degradation of the target compounds. Dilution-to-extinction series were established with the VC-to-ethene-dechlorinating culture derived from the Bachman Road site. VC dechlorination activity was recovered three time from 10-7 dilutions, and soft agar shake cultures have been established. Dilution-to-extinction series were also successfully used to derive a highly enriched culture that oxidizes cis-DCE/VC under aerobic conditions. Efforts to isolate pure strains continue. Aliquots of the highly diluted culture were transferred to mineral salts medium-agar plates, which were incubated in desiccators containing cis-DCE/ethene vapors. Three distinct colonies appeared after 1 week of incubation. Each colony was transferred to a liquid medium containing cis-DCE and ethene for incubation and analysis. Site geochemical and contaminant data has been compiled. The data are being entered in Excel spreadsheets to facilitate comparisons between sites and to link these datasets with the microbial activity data obtained in the microcosm studies. A reliable Real-Time (RTm) Polymerase Chain Reaction (PCR) approach for the quantification of *Dehalococcoides* and *Desulfuromonas* populations has been established. This protocol has been refined, tested and validated for the 16S rRNA gene of *Dehalococcoides sp.* strain FL2. RTm PCR was also tested on the VC-dechlorinating Bachman culture, and it confirmed VC-dependent growth of the VC-dechlorinating *Dehalococcoides* population.

TRANSITION: This project will develop a site characterization protocol for use in feasibility studies at sites contaminated by chlorinated solvents. This protocol would complement existing documents, such as the Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water (EPA/600/R-98/128). A flow chart will be developed to aid the practitioner in identifying which chlorinated solvent transformation process may be relevant at a site. Rate constants of cis-DCE and VC transformation in microcosm studies will also be included to aid in modeling studies.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of the Aerobic Oxidation of cis-DCE and VC in Support of Bioremediation of Chloroethene-Contaminated Sites; CU-1168

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Gossett; Cornell University – Ithaca, NY

FY 2002 COMPLETED PROJECT

DESCRIPTION: The lesser chlorinated ethenes , cis-1,2-dichloroethene (cDCE) and vinyl chloride (VC), tend to accumulate at chloroethene-contaminated sites under anaerobic conditions, limiting the application of natural attenuation and enhanced reductive anaerobic in-situ treatment technologies. Aerobic degradation of lesser-chlorinated ethenes has been demonstrated; however, present understanding of the transformation potentials of cDCE and VC is limited, limiting the reliability of, and confidence in, natural and enhanced biological alternatives for site remediation. This project determined the distribution and metabolic capabilities of microorganisms able to mineralize cDCE and/or VC in aerobic subsurface environments. Two complementary approaches were used to locate organisms capable of growth-coupled, aerobic oxidation of cDCE and/or VC at contaminated sites: microcosm enrichments and direct isolations from site material. Once located, the organisms were isolated and characterized. The relationship that exists between chloroethene degraders and ethene degraders was evaluated to determine whether the chloroethene degraders were derived from the indigenous ethene degraders. Once the relationship became clear, spatial distribution of aerobic chloroethene degradation and the distribution of chloroethene-oxidizing bacteria in the field was assessed.

BENEFIT: Results delineated the roles of cometabolism vs. growth-coupled degradation in the natural attenuation of lesser-chlorinated ethenes. Results will lead to improved site assessment (sites can be screened for existing and potential aerobic oxidative degradation activities); improved remedial-action decision-making (the effects of oxidative mechanisms can be better taken into account in modeling either natural attenuation or the effects of enhancement alternatives); and more reliable bioremediation technologies (enhancement strategies can be developed to take advantage of the aerobic transformation mechanisms). A better understanding of these growth-coupled, aerobic oxidative pathways will expand the number of sites judged suitable for bioremediation alternatives (natural and enhanced), with potential savings to DoD in the millions of dollars.

ACCOMPLISHMENTS: Thirty-eight samples from a variety of sites were screened with the goal of locating and characterizing organisms capable of growth-coupled, aerobic oxidation of VC and cDCE. In more than half of the samples, such VC-oxidizers were found. In two samples, cDCE oxidizers were detected. From these site evaluation studies, it was concluded that (1) Aerobic VC-assimilating bacteria are often present at chlorinated ethene-contaminated sites; (2) Distribution of VC degraders within a contaminated site is heterogeneous; (3) VC degraders are not often found at sites with no history of VC contamination; and (4) cDCE can be biodegraded by aerobic microbes in the absence of cometabolic substrates. The researchers then proceeded to characterize the isolates derived from enrichments, focusing on phylogeny, pathways, ability to use alternative substrates, kinetics, and cross-induction. From the isolation of VC degraders, researchers have concluded that (1) There is diversity among VC degrading bacteria even at the sub-species level; (2) All *Mycobacterium* isolates share similar growth parameters; (3) *Nocardioides* JS614 is distinguished by higher growth yields and growth rates but lower tolerance of VC starvation; and (4) All isolates grow faster and to higher yields on ethene than VC, hence VC degraders probably derived from indigenous ethene degraders. After eleven 5 percent transfers of the Dortmund cDCE-degrading culture, serial dilutions in liquid medium yielded a pure culture (JS666) that can utilize cDCE as the sole carbon and energy source for growth. Correlation of spatial distributions of cDCE/VC oxidizers and ethene oxidizers is being conducted at Moody AFB.

TRANSITION: Transition will occur by the following: (1) incorporation of the aerobic, oxidative pathways into comprehensive fate- and-transport models, providing site managers with enhanced tools for decision-making; and (2) as appropriate, incorporation of the findings into Air Force and EPA natural-attenuation protocols for chlorinated ethenes and into the ESTCP protocol for assessment of suitability for Reductive Anaerobic Biological In-Situ Treatment Technology (RABITT).

PROJECT SUMMARY

PROJECT TITLE & ID: Factors Affecting cis-DCE and VC Biological Transformation under Anaerobic Conditions; CU-1169

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Alfred Spormann; Stanford University – Stanford, CA

FY 2002 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to establish a better understanding of the aerobic and anaerobic transformation of cis-dichloroethene (cis-DCE) and vinyl chloride (VC). Most remediation approaches involve the extraction of contaminated groundwater and its cleanup at the surface through expensive physical and/or chemical methods. However, anaerobic biological processes have resulted in the natural destruction (intrinsic bioremediation) of chlorinated solvents in some cases. Cis-DCE and VC are intermediates in the biological reductive dehalogenation of PCE and TCE. Molecular hydrogen appears to be a key electron donor for these reductive processes. However, the transformation of cis-DCE to VC and of VC to ethene is very slow. A major question raised in such biodegradation is why the process does not go to completion to ethene. How can hydrogen most effectively be funneled towards reductive dehalogenation of cis-DCE and VC? How can one determine at a given site the reason for lack of complete biodegradation? Laboratory studies were performed to better understand these questions and to develop procedures that could be used in the field for their evaluation.

BENEFIT: The benefits of this research are the following: (1) New basic information on the mechanism of biological reductive dehalogenation of cis-DCE and VC; (2) Molecular probes for reductive VC dehalogenation; (3) Test of mathematical model for growth limitation at low substrate concentrations; (4) Data on inhibition of cis-DCE and VC reductive dehalogenation by other co-contaminants; (5) Field procedure to determine availability of hydrogen for reductive dehalogenation; (6) New basic information on microbiology of anaerobic cis-DCE and VC oxidation; and (7) Simple field procedure to measure electron donor release for simple use at field sites.

ACCOMPLISHMENTS: The genes encoding the reductive VC dehalogenase have been isolated via an inverse-polymerase chain reaction (PCR) approach, and their gene sequences were obtained. In order to quantify growth of microorganisms, probes that are specific for each of the microbes present were developed and a competitive PCR (cPCR) protocol was established. Growth yields, maximum utilization rate coefficients, and decay coefficients were determined. Results suggest that cPCR is not a good measure of active cells under conditions where the growth rate is low and decay has been an important factor. However, when the growth rate is high, the signal from dead/inactive cells can be considered insignificant. An important finding is the ability of a microorganism (bacterium VS) to grow on VC, in contrast to the cometabolic VC dehalogenation exhibited by *D. ethenogenes*. In order to visualize the dehalogenating microorganism in the mixed culture, a Fluorescent In-situ Hybridization (FISH) procedure was established that allows the relative abundance of the microbes during growth to be monitored. Growth enhancing factor(s) in mixed culture were characterized.

TRANSITION: Research that has been conducted over the past several years on reductive dehalogenation, in conjunction with the Remediation Technology Development Forum (RTDF) and EPA, DOE, and DoD, has been used by DuPont in the application of reductive dehalogenation for enhanced bioremediation of PCE and TCE at their sites. The project team has helped to advise the development of enrichment cultures for bioaugmentation and to determine the requirements for carrying out this process. Through these cooperative studies, the results of this research will be quickly disseminated to the RTDF consortium members and others.

PROJECT SUMMARY

PROJECT TITLE & ID: Foam Delivery of Hydrogen for Enhanced Aquifer Contacting and Anaerobic Bioremediation of Chlorinated Solvents; CU-1203

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. George Hirasaki; Rice University – Houston, TX

FY 2003 FUNDS: $241K

DESCRIPTION: Hydrogen sparging of aquifers contaminated with chlorinated solvents has been shown to enhance microbial dechlorination in-situ. The major concern in the application of this remedial approach is the ability to distribute hydrogen effectively throughout the contaminated interval such that complete dechlorination can occur. A promising method to improve hydrogen contact throughout a contaminated interval and to greatly extend the horizontal migration of hydrogen in the subsurface is to deliver the hydrogen as an "in-situ generated foam" - a dispersion of gas in water that is stabilized from coalescence by the presence of a small amount of surfactant. The objective of this effort is to investigate the ability of hydrogen-foams to more effectively contact aquifer sands, thereby supporting rapid dechlorination activity compared to conventional hydrogen sparging. The foam is generated by injection of a slug of dilute surfactant solution into the well, followed by gas injection. The gas bubbles that form are inhibited from coalescence by the surfactant adsorbed at the interfaces, and the lamellae or "soap films" between the bubbles increase the resistance of the gas to flow through porous media.

BENEFIT: The expected benefit of hydrogen delivery as foam is increased well spacing and decreased frequency of sparging. If foam can increase the distance that hydrogen contacts the base of the aquifer from 3 feet to 15 feet, the area of the base of the aquifer contacted by hydrogen may increase by a factor of 25. Alternatively, an aquifer can be remediated with 1/25 as many wells if foam improves the aquifer contact by the amount of this illustration. If the residual hydrogen gas saturation after sparging is increased, a longer amount of time will pass before the hydrogen is depleted and sparging needs to be repeated. Thus, foam delivery of hydrogen may reduce the frequency of sparging per well. If the trapped gas saturation in the contacted region is increased from 10 to 50 percent, the frequency of sparging per well can then be reduced by a factor of 5. Combined with a reduced number of wells required to conduct the remediation, the frequency of sparging a well in the entire project can be reduced by a factor of 125.

ACCOMPLISHMENTS: 2-D sandpack experiments and vertical column experiments have shown increased lateral transport and increased hydrogen persistence, respectively, in the presence of foam. Several surfactants were evaluated as candidates for enhanced aquifer contacting with hydrogen bioremediation. Mixtures of C12-3EO sulfate and C13-4PO sulfate were more effective than either surfactant alone. A 1:1 mixture resulted in effective foam at a concentration of 0.1 percent active material. The anionic surfactants were found to be resistant to excessive biodegradation, but they inhibited the biodegradation of cis-DCE. Other cultures are being evaluated. UTCHEM was used to simulate foam injection in an Experiment Controlled Release System (ECRS), and air/water and air/surfactant solution injections are being evaluated. A 3-D sandpack is being constructed.

TRANSITION: The studies are designed to yield the information required for field applications. To facilitate the transition to the field, a conceptual design component has been included in the objectives. Additionally, results will be provided to DoD stakeholder and industrial affiliates for incorporation into ongoing cleanup projects. Site-specific design and site characterization for the use of hydrogen-based foams is beyond the scope of this project. Therefore, this project intends to transition through the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Permeable Reactive Barriers Using Edible Oils; CU-1205

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Borden; North Carolina State University – Raleigh, NC

FY 2003 FUNDS: $66K

DESCRIPTION: Permeable reactive barriers (PRBs) are being considered at many sites because they are expected to have much lower operation and maintenance (O&M) costs than active pumping systems. As solvents or other contaminants migrate through the barrier, the contaminants are removed or degraded, leaving uncontaminated water to emerge from the downstream side. This project will develop and evaluate an alternative barrier system for controlling the migration of chlorinated solvents. An oil-in-water emulsion will be prepared using food-grade edible oils, then injected into the contaminated aquifer in a barrier configuration using either conventional wells or Geoprobe points. As the emulsion passes through the aquifer, a portion of the oil becomes entrapped within the pores leaving a residual oil phase to support long-term reductive dehalogenation of chlorinated solvents that enter the barrier.

BENEFIT: Edible oil barriers have tremendous cost and operational advantages over competing technologies including zero valent iron barriers and anaerobic bioremediation using soluble substrates. Construction costs for zero valent iron barriers are typically in the range of $100 per square foot of barrier. In comparison, installation of a 40 ft deep by 200 ft wide edible oil barrier is estimated to cost less than $100,000 or approximately $15 per square foot of barrier. If the edible oil barrier technology can be adequately developed, this approach has the potential to significantly reduce the cost and improve the effectiveness of aquifer remediation for chlorinated solvents and a variety of other contaminants including nitrate, chromate, and oxidized radionuclides.

ACCOMPLISHMENTS: Techniques have been developed for distributing edible oils throughout the subsurface to enhance the anaerobic biotransformation/immobilization of chlorinated solvents, perchlorate and heavy metals. This has included development and laboratory validation of two mathematical models. The emulsion transport model was developed to describe the radial flow of emulsified oil in stratified aquifer material and permeability changes associated with the entrapped oil. The biotransformation model was developed to simulate the performance of oil barriers in enhancing the anaerobic biodegradation of chlorinated solvents including: (1) production of dissolved organic carbon from oil dissolution; (2) consumption of the dissolved organic carbon through sulfate reduction, methanogenesis, and dehalorespiration; and (3) transport, sorption and biodegradation of the contaminants. Continuous flow column and radial flow sand tank experiments are being conducted to evaluate the efficacy of the edible oil process for controlling chlorinated solvent migration and to identify critical failure modes that may limit performance in the field.

TRANSITION: Results will be presented at research symposia and in peer-reviewed journals and will be shared with practitioners currently using the edible oil process at field sites. Three companies are conducting demonstrations of the edible oil process at Air Force Bases around the U.S. These companies are actively marketing the edible oil process to public and private clients. Laboratory results obtained in this project will be implemented rapidly in the field demonstrations being conducted for the Environmental Security Technology Certification Program (ESTCP) and the Air Force Center for Environmental Excellence (AFCEE). As a consequence, results will be rapidly communicated to the user community.

PROJECT SUMMARY

PROJECT TITLE & ID: Low-Volume Pulsed Biosparging of Hydrogen for Bioremediation of Chlorinated Solvent Plumes; CU-1206

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Charles Newell; Groundwater Services, Inc. – Houston, TX

FY 2002 COMPLETED PROJECT

DESCRIPTION: Chlorinated solvents are among the most prevalent of groundwater contaminants found at Department of Defense (DoD) sites. Laboratory studies have shown that the addition of hydrogen as an electron donor is effective in stimulating the biological reductive dechlorination of chlorinated solvents. The challenge in scaling up this technology for field applications is the effective distribution and mixture of the hydrogen with the contaminants in-situ. One promising method that has the potential to effectively mix hydrogen in contaminated groundwater is low volume pulsed hydrogen biosparging (LVPB-H_2). The objective of this project was to further develop this innovative mixing approach by answering these key questions: (1) How much hydrogen gas can be pulsed into the subsurface safely? (2) What is the effective zone of influence of an LVPB-H_2 pulse? (3) How long do residual hydrogen bubbles persist before complete dissolution? (4) What are the reductive dechlorination rates that can be achieved using LVPB-H_2? and (5) Is LVPB-H2 an effective DNAPL removal technology? Experiments were conducted using the 5400 gallon pilot-scale Experiment Controlled Release System (ECRS) developed by the DoD's Advanced Applied Technology Demonstration Facility (AATDF) for testing emerging remediation technologies. Use of this research apparatus allowed the project team to perform tightly controlled studies. Besides air and water sampling during the experiments, Time Domain Reflectometry (TDR) equipment allowed the project team to visualize the migration and subsequent dissolution of hydrogen gas channels through the porous media.

BENEFIT: The benefit of this work is a more fundamental understanding of hydrogen dissolution and transport in the unsaturated zone and its effectiveness in promoting reductive dechlorination of chlorinated solvent-impacted plumes. The results will allow biosparging systems to be better designed.

ACCOMPLISHMENTS: Following preparation of the ECRS tank, it was determined that hydrogen could safely be sparged at 0.5 scfm for 1 minute (50% of breakthrough time). In abiotic experiments, it was also determined using TDR that the hydrogen sparge would last at least 6 days with a delivery radius of 4 feet. A baseline sampling event was conducted prior to bioaugmentation in which perchloroethene (PCE) concentrations ranged from 0.6 to 1.2 mg/L. No daughter products were identified, confirming the inactivity of native bacteria. Thirty gallons of 36 mg/L VSS dechlorinating bacteria were added to the ECRS tank. cis-DCE was found in the effluent approximately 1.5 weeks after bioaugmentation. Vinyl chloride (VC) and ethene were observed after 3 weeks of operation. Over the course of the experiment, the average PCE removal was 87 percent and the average removal of chlorinated constituents was 70 percent. Approximately 2 percent of the added PCE volatilized. Microcosms found that anaerobic oxidation of VC and cis-DCE was also occurring, helping to explain why the sum of chlorinated PCE daughter products and ethene in the effluent were less than the amount of PCE removed. The DNAPL study indicated that reductive dechlorination to ethene is possible under high PCE concentrations.

TRANSITION: Hydrogen biosparging is a simple technology that will be easy to implement at a variety of military installations. Its configuration can be tailored to site-specific requirements. For example, sparge points can be installed to act as a passive barrier to plume migration or a larger array of sparging wells can be installed for active plume or source zone remediation. This technology involves a minimum of equipment and personnel, significantly reducing capital, labor, training, and maintenance costs.

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ Stabilization of Persistent Organic Contaminants in Marine Sediments; CU-1207

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Richard Luthy; Stanford University – Stanford, CA

FY 2003 FUNDS: $500K

DESCRIPTION: The research team will investigate the feasibility for in-situ stabilization/containment of persistent hydrophobic organic compounds (HOCs) in sediments through the use of low-dose, coal-derived material, such as coke, as sorbent media to sequester persistent organic contaminants. It is proposed that coal-derived material placed on or within sediment is a cost-effective, in-situ, non-removal, management strategy. Previous research has shown that coal-derived materials are strong sorbents that may capture organic contaminants and make them unavailable in the aqueous phase and unavailable for biological uptake. Coal-derived and coaly, particulate sorbent media are two-to-three orders of magnitude more efficient in sequestering HOCs compared to natural sediment organic matter. Thus, the addition of fresh coal-derived sorbents to contaminated sediments would reduce ecosystem exposure by reducing contaminant flux between sediments, pore water, and the water column. Owing to the extreme temperatures employed during manufacture, coal-derived sorbent media like coke is free of volatile materials such as polycyclic aromatic hydrocarbons (PAHs) and is therefore not a regulatory concern. Novel whole-sample, particle-scale, and subparticle-scale techniques will be used to assess the efficacy of the stabilization technology. These techniques allow one to identify the distribution and relative availability of organic contaminants among sediment component materials. In this way, the research team can monitor how effective the coal-derived material is at capturing and binding the readily available fraction of the PAH and PCB contaminants. The team will test various low-cost materials including coke and char and compare the results with those of activated carbon. The research team will monitor the success of the stabilization process by spectroscopic and spectrometric measurements and by survival and growth of organisms currently used to develop chronic, sublethal, marine sediment bioassays for national regulatory programs. The feasibility of the technology for in-situ stabilization of PAH and polychlorinated biphenyl (PCB) contaminants found in marine sediments will be investigated.

BENEFIT: HOCs such as PAHs and PCBs are important contaminants of concern to the DoD. These contaminants associate with fine grained, organic-rich material in sediment and are long-lived. Sediment serves as a contaminant reservoir from which fish and bottom-dwelling organisms can accumulate toxic compounds like PCBs that are then passed up the food chain. Cost-effective and efficient technologies for contaminated sediment management can significantly reduce the expenditure on environmental restoration and achieve the DoD environmental security goals and objectives. The potential benefit of this work is the attainment of in-situ contaminant management by means of a cost-effective and non-removal technology resulting in stabilization to significantly reduce contaminant bioavailability.

ACCOMPLISHMENTS: The intertidal zone of South Basin, Hunters Point Naval Shipyard, San Francisco Bay, was chosen as the study site based on previous sampling at the site, which showed high PCB and PAH concentrations. This site currently is under investigation for remedial action. Sediment characterization was carried out for the bulk material and also for size and density separated fractions. The heavier density (>1.8 s.g.) mineral fraction of the sediment comprising sand/silt/clays contributed to 94 percent of the sediment mass but only 32 percent of the total PCBs and 11 percent of the total PAHs. In comparison, the lighter density organic fraction comprising coal/charcoal/coke/wood comprised only 6 percent of the sediment mass but contained 68 percent of the PCBs and 89 percent of the PAHs. This study is the first documented case showing that PCBs are concentrated on the light fraction of sediment solids. Because there is no reason to suspect co-disposal of PCBs and materials that comprise the light density sediment fractions, it appears that over an extended period of time in the field, PCBs slowly transfer onto strongly sorbing carbonaceous particles present in the sediment through a natural sequestration process. Results from six different biological and physical/chemical tests show that PCB availability is reduced significantly when contaminated sediments are treated with activated carbon and mixed for one month. Aqueous equilibrium PCB concentrations were reduced by 86 percent for granular activated carbon (GAC)-treated sediment relative to untreated. Total PCBs released to semi-permeable membrane devices decreased by 72 percent for GAC-treated sediment. Release of PCBs from sediment in quiescent flux experiments decreased by 53-60 percent with activated carbon mixed or as a cap. Treating sediment with activated carbon reduced PCB bioaccumulation by 69 percent in *Macoma balthica* (clam), 83 percent in *Neanthes arenaceodentata* (worm), and 72 percent in *Leptocheirus plumulosus* (amphipod). Results to date suggest that addition of activated carbon to PCB contaminated sediment may be an effective in-situ stabilization method to reduce contaminant availability to biota and surrounding water.

TRANSITION: Results will provide a proof of concept of the proposed in-situ containment technology and a scientific basis for the support of field implementation of the technology. Successful completion of the research should lead to a future pilot scale demonstration project at a DoD marine site. Partners within this program will publish in peer-reviewed journals and will present information at national and international symposia and informal briefings at DoD, Navy, Army, USACE, and U.S. EPA offices. Results will also be presented in a series of Engineer Research and Development Center (ERDC) reports, utilizing a functional format to encourage demonstration and implementation beyond the proof-of concept-stage. The reports will include information such as process mechanisms, application protocol, process economics, technical points of contact, and process limitations.

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ Enhancement of Anaerobic Microbial Dechlorination of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans in Marine and Estuarine Sediments; CU-1208

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Max Haggblom; Rutgers University – New Brunswick, NJ

FY 2003 FUNDS: $136K

DESCRIPTION: The management of marine and estuarine sediments contaminated with toxic organic compounds, including polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), is a major problem with far-reaching economic and ecological consequences. Application of bioremediation to PCDD/F-contaminated marine and estuarine sediments is currently severely limited by the lack of fundamental knowledge about the microorganisms responsible for their degradation, including anaerobic reductive dechlorination. The research team will characterize the PCDD/F dechlorinating capability of native dehalogenating bacteria from different estuarine and marine sites. Enrichments developed from these sites and an existing dioxin-dechlorinating culture will be used to assess how PCDD/F dechlorination can be stimulated and accelerated under different terminal electron accepting conditions (methanogenic, sulfate-reducing, and iron-reducing) relevant to marine sediments. A variety of intensive amendment strategies will be tested to enhance reductive dechlorination including addition of alternative halogenated primers such as bromophenols; co-amendment with hydrogen, hydrogen donors, and other electron donors; and manipulation of the terminal electron-accepting processes.

BENEFIT: An improved fundamental understanding of dehalogenating bacterial communities that dechlorinate PCDD/Fs in marine and estuarine sediments and how these communities are affected by redox conditions and addition of primers and amendments will be gained. Data collected from enrichments and the accompanying microbial community characterization will be used for the development of conceptual and biological process models to describe and predict the effect of different enhancement methods on the terminal electron accepting process and microbial populations. These findings will result in development of methodologies to assess the potential for PCDD/F dechlorination at specific sites that could ultimately result in significant savings for costly sediment restoration projects.

ACCOMPLISHMENTS: An extensive microcosm protocol with Paleta Creek sediment was completed. It suggests that the successful stimulation of dioxin dechlorination with bromophenol amendment might be more related to the electron donor effect of the degradation of the phenol dechlorination product than the stimulation of halophenol dehalogenating bacteria. A modeling approach was used to characterize the potential mode of action of 2-bromophenol in stimulating dioxin dehalogenation in Paleta Creek sediments. A model developed to simulate dechlorination in the presence of competing terminal electron-accepting processes was modified to include biokinetic expressions for dioxin dechlorination and bromophenol debromination. The prevailing aqueous hydrogen levels in sulfidogenic (1.6 nM) and methanogenic (5.5 nM) enrichments from Paleta Creek was measured and found to be similar to those reported for redox zones dominated by methanogenesis or sulfate reduction as the dominant terminal electron-accepting process. These model simulations suggest that hydrogen concentration imparts extensive control over observed rates of dioxin dehalogenation.

TRANSITION: This project will develop methodologies for monitoring in-situ bioremediation of contaminated sediments, including identification of specific amendments and environmental conditions that prime and/or accelerate the dechlorination of PCDD/Fs. Peer-reviewed articles and conference presentations will transfer findings to the scientific community for future application.

PROJECT SUMMARY

PROJECT TITLE & ID: Pathway Interdiction: A System for Evaluating and Ranking Sediment Contaminant Transport Pathways in Support of In-Place Management; CU-1209

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Sabine Apitz; Space & Naval Warfare Systems – San Diego, CA

FY 2003 FUNDS: $491K

DESCRIPTION: Many of the contaminated marine sediment sites currently under investigation are in shallow, coastal areas and are much more likely than more traditionally studied offshore sediments to be impacted by advective processes such as groundwater flow, tidal pumping, wave pumping, and by resuspension via ship and storm activity. While these processes are recognized in the oceanographic community as having significance to chemical fluxes, they are largely unstudied in contaminated systems, and the relative magnitudes of these processes as compared to the traditionally assessed processes such as diffusion and bioturbation have not been determined. If contaminants are to be left in place, it is critical to evaluate potential pathways by which contaminants might pose an ecological or human health risk and to monitor, minimize, or eliminate these pathways. This effort seeks to apply an integrated suite of methods for the direct characterization of these dynamic transfer pathways for contaminants in sediments. Methods for the quantification of mechanisms, magnitudes, and directions of porewater-mediated contaminant transport will be integrated with sediment/contaminant geochemical characteristics, hydrodynamically-driven particle transport, and biological processes. While each of these processes has been examined individually, they have never been examined together such that they can be ranked and compared to support in-place sediment management.

BENEFIT: Diagnostic tools for characterizing and quantifying potential in-place contaminant pathways will aid in the selection, permitting and monitoring of in-situ management strategies. The payoff for a demonstrated, systematic process for measuring and evaluating contaminant transport pathways within sediment systems in support of in-place management will be twofold (1) by providing solid, measurement-based information on contaminant fate which results in the permitting of in-place management, the savings can be millions of dollars per site, and (2) since pathways of contaminant transport in place can be directly measured, the ecological risk of leaving sediments in place will be reduced.

ACCOMPLISHMENTS: This project involves integrated field deployments at two nearshore contaminated sediment sites. Fieldwork at the first site, Paleta Creek, San Diego Bay, was completed. Extensive field measurements of contaminant transport by various potential pathways were carried out, and hundreds of sediment, seawater and porewater samples were collected. After analysis of all samples, preliminary reports on contaminant fate and transport as a function of each individual transport process (diffusion/bioirrigation, advection, sedimentation, resuspension, bioturbation, biodegradation) were completed. These results are currently being integrated with each other and with complementary and historical site information on storm cycles, ship movement, contaminant inputs, etc. Preliminary screening analyses and field design have been carried out for site II, which will be in Pearl Harbor, HI.

TRANSITION: Site-specific and pathway-specific information will be disseminated via peer-reviewed journals, professional scientific and technical meetings, technical reports, and a guidance document. All work will be carried out at sites undergoing remedial investigation or management, in collaboration with RPMs, regulators and stakeholders. Transition via the Remediation Technology Development Forum, Sediment Working group and the Sediment Management Work Group will also be sought. This project intends to transition through the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Determining the Bioavailability, Toxicity, and Bioaccumulation of Organic Chemicals and Metals for the Development of Eco-SSLs; CU-1210

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Roman Lanno; Ohio State University – Columbus, OH

FY 2003 FUNDS: $385K

DESCRIPTION: The goal of this research is to identify and characterize the predominant soil physical/chemical parameters that modify the bioavailability, bioaccumulation, and/or toxicity of trinitrotoluene (TNT), trimethylenenitramine (RDX), polynuclear aromatic hydrocarbons (PAH), and selected metals in soil invertebrates and plants. Exposure concentrations will be measured as total chemical levels and as the labile portion that is presumed to be bioavailable. Both of these chemical measures will be correlated with toxicity endpoints (e.g., growth, reproduction) and bioaccumulation with the ultimate goal of developing models relating soil chemistry parameters to bioavailability, bioaccumulation, and toxicity.

BENEFIT: Development of an empirical model relating soil physical/chemical characteristics to the bioavailability, bioaccumulation, and toxicity of TNT, RDX, PAHs, and selected metals to soil invertebrates and plants will allow the incorporation of bioavailability into the development of Ecological Soil Screening Levels (EcoSSLs) by facilitating estimation of bioavailable levels of chemicals from literature data where only total chemical and soil physical/chemical characteristics are presented. Current chemical methods for estimating bioavailability have been correlated with biological responses of macroinvertebrates and plants in very few studies. This research will develop these correlations, thereby validating chemical estimates of bioavailability in soils. Validation of chemical measures of bioavailability would provide another tool that can be used in early-tier screening of contaminated soils during ecological risk assessment. A large data set consistent with respect to QA/QC procedures and data criteria will be generated that can be used to develop EcoSSLs for the rapid initial screening of contaminated Department of Defense (DoD), Department of Energy (DOE), and Environmental Protection Agency (EPA) sites. This will allow the removal of low-risk sites from further ecological risk assessment and allow efforts and resources to be focused on sites that present an unacceptable risk.

ACCOMPLISHMENTS: Following preparation of the desired soils, range-finder and definitive toxicity tests, as well as bioaccumulation tests, proceeded with three species of soil invertebrates (Collembola, enchytraeids, earthworms) and three species of plants (millet, alfalfa, ryegrass) and the organic chemicals. Metal bioaccumulation tests only will be conducted with invertebrates and plants. Initial range-finder tests have been completed for all chemicals (pyrene, phenanthrene, TNT, RDX, HMX, Cd, As, Zn, Pb) in all five soils, except for plants and PAHs. Definitive toxicity bioassays have been completed for Collembola, earthworms, and enchytraeids with pyrene in all five soil types. Draft pyrene EcoSSLs have been prepared using preliminary invertebrate toxicity data.

TRANSITION: Both principal investigators are involved with the U.S. EPA Steering Committee for the development of EcoSSLs and could therefore provide a direct conduit for the application of data generated during this research in the development of EcoSSLs. In turn, EcoSSLs generated with data provided from the proposed work could be used in the screening of soil contamination at DoD sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Bacterial Degradation of DNT and TNT Mixtures; CU-1212

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Rebecca Parales; University of Iowa – Iowa City, IA

FY 2003 FUNDS: $288K

DESCRIPTION: The major objective of this effort is to characterize bacterial strains with the ability to efficiently degrade mixtures of dinitrotoluene (DNT) isomers and to expand the degradative capability to include 2,4,6-trinitrotoluene (TNT). Because most contaminated sites contain mixtures of nitroarene compounds, such strains would have the potential for use in the bioremediation of field sites. This research team has isolated bacteria that can degrade both 2,4- and 2,6-DNT and will carry out physiological and genetic studies with those strains to determine whether the DNT isomers are degraded simultaneously or sequentially and how the genes encoding the pathways are regulated. The pathways, enzymes, and inducing molecules will be characterized. Team members will characterize the novel enzymes and the product(s) of TNT oxidation and screen for ring cleavage enzymes that can destroy the oxidized TNT molecule. The TNT dioxygenase and appropriate ring cleavage dioxygenases genes will be introduced into strains that degrade both isomers of DNT. The resulting strains will be tested for the ability to eliminate the toxicity of synthetic mixtures of DNT and TNT. The strains will be inoculated into microcosms containing contaminated soil from Volunteer Army Ammunition Plant and the degradation of DNT and TNT will be monitored.

BENEFIT: Bioremediation is expected to reduce the cost of remediation by $60M over previous estimates for Badger Army Ammunition Plant. Although preliminary results are encouraging, there is an urgent need to understand the regulation and degradation of mixtures. Previous experiments have revealed that 2,4-DNT could be degraded readily in soil and water from Volunteer although TNT and 2,6-DNT were problematic. The new insight about degradation of mixtures including TNT will be directly applicable to the future cleanup at Volunteer and at other TNT manufacturing sites. The research team proposes to generate recombinant organisms for the degradation of nitroarene compounds although field application of the basic discoveries to be made under this project is several years away. Cleanup of in-situ and excavated soil both in the U.S. and abroad should benefit considerably from novel microbial strategies for TNT and DNT degradation

ACCOMPLISHMENTS: To date, the project has (1) demonstrated that multicomponent bacterial nitroarene dioxygenases catalyze the oxidation of aminodinitrotoluenes to form aminonitrocatechols; (2) used these enzymes to enzymatically produce aminonitrocatechols for use as substrates to screen for ring-cleavage enzymes; (3) cloned and sequenced the genes encoding nitrobenzene dioxygenase and determined the substrate specificity of the enzyme; (4) characterized the lower pathway of 2,4-DNT degradation in detail; (5) isolated and begun characterizing new bacterial strains that grow on 2,4-DNT, 2,6-DNT or both isomers of DNT; and (6) characterized the regulation of nitrobenzene and 2-nitrotoluene degradation in two bacterial strains, showing that nitroarene compounds control expression of the nitroarene degradation genes.

TRANSITION: Gains achieved by the research team will be rapidly incorporated into ongoing cleanup strategies and implemented in new cleanup efforts - particularly at Badger and Volunteer. In addition, two private companies have contacted the research team to explore the feasibility for cleanup of DNT contaminated industrial sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Microbial Degradation of RDX and HMX; CU-1213

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jalal Hawari; Biotechnology Research Institute – Montreal, Quebec CANADA

FY 2003 FUNDS: $393K

DESCRIPTION: Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) are powerful highly energetic chemicals whose widespread use has resulted in severe soil and groundwater contamination. Efforts over the past two decades to decontaminate soil and groundwater by biological means have failed because the microbial processes and enzymes involved in degradation are poorly understood. Recently, this research team has discovered that both RDX and HMX can be mineralized under both aerobic (*P. chrysosporium* and the soil isolate *Rhodococcus sp.*) and anaerobic conditions (municipal anaerobic sludge) to nitrous oxide and carbon dioxide despite some previous reports that RDX is not mineralized under these conditions. For example, it has been demonstrated that once RDX undergoes an initial biological attack the molecule autodecomposes. The mechanism leading to mineralization is unknown; however, several testable hypotheses exist regarding how mineralization proceeds. These hypotheses will be tested by conducting fundamental laboratory experiments to identify the enzymes that cause the molecules to disintegrate and to investigate the subsequent biochemical decomposition reactions. In addition, the team will identify intermediate degradation products and study the kinetics and stoichiometry of their formation.

BENEFIT: Although this research is intended to generate the fundamental knowledge needed to understand the enzymatic processes involved in the microbial degradation of RDX and HMX, the results can be used to enhance bioremediation and facilitate future field application. When the specific degrader(s) and enzyme(s) (reductase, hydrolase or oxygenase) responsible for the initial reaction on the cyclic nitramine explosive in liquid media are discovered, it will be possible to design effective field treatment strategies. Therefore, the inclusion and the design of bench scale experiments using soil from contaminated sites will generate the necessary knowledge required for future field demonstration and application. For example, knowledge of degradation mechanisms will allow prediction and enhancement of biodegradation in the site. Insight regarding microbial and enzymatic processes together with their degradation products can be used by site managers and engineers as monitoring tools to understand the fate of explosives after removal.

ACCOMPLISHMENTS: RDX and HMX have been successfully degraded under both anaerobic and aerobic conditions, and key metabolites (methylenedinitramine [MEDINA] and 4-nitro-2,4-diazabutanal [4-NDAB]) were discovered that provide new insights into their degradation pathways. Degradation of cyclic nitramines can be initiated via several routes including reduction of the -NO2 group(s) to the corresponding nitroso derivative(s) (MNX, DNX and TNX), denitration (cleavage of the N-NO2 bond) or cleavage of one of the inner C-N bonds. Experiments were conducted to understand the role and degradation potential of bacterial isolates from sludge and soils and the initial enzymatic steps involved in the degradation process. Alternative methods including photolysis and hydrolysis were applied to degrade RDX and HMX in an attempt to generate sufficient amounts of other suspected enzymatic intermediates that might have escaped detection during biodegradation, particularly early products. Intermediates of particular interest are those expected to be formed following initial denitration.

TRANSITION: Successful lab-scale microcosms for the degradation of RDX and HMX can provide the basis for pilot scale up work to identify engineering parameters for field demonstration and application. Results of this project will be disseminated in such a manner as to facilitate future investigations.

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Pathways of Nitroaromatic Metabolism: Hydroxylamine Formation, Reactivity, and Potential for Ring Fission for Destruction of TNT; CU-1214

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Joseph Hughes; Rice University – Houston, TX

FY 2003 FUNDS: $263K

DESCRIPTION: Independent studies conducted by members of this research team have converged at the discovery of a similar and novel metabolic pathway that yields products from TNT that no longer display aromatic characteristics. It should be possible to exploit this pathway in the development of improved TNT treatment methods, where the destruction of TNT is achieved and the process is carried out in-situ. The goals of this effort are to determine the biochemical mechanism of TNT ring fission and to use this fundamental information to develop strategies that harness the activity in remediation systems. Specific objectives include: (1) Identify the products of the novel TNT transformation pathway that no longer display aromatic characteristics, (2) Determine the mechanism of ring fission and identify the enzymes responsible, (3) Characterize the properties of the enzymes and their regulation, (4) Develop strategies to direct TNT metabolism to ring fission products, and (5) Validate the destruction of TNT in lab-scale microcosm testing where mass balances and toxicity reduction can be determined.

BENEFIT: Studies will yield an improved understanding of the microbial processes involved in the degradation of nitroaromatic compounds. Based on the initial work, it should be possible to develop in-situ treatment methods where the destruction of TNT is achieved. Strategies involving reduction only to the hydroxylamine level with subsequent rearrangement and ring fission would require far less carbon addition and less dramatic shifts in redox potential than conventional strategies for TNT cometabolism. The potential to drive TNT to non-aromatic end points has been demonstrated in two widely different microbial systems, and it occurs at high rates. If demonstrated that this novel metabolism can be induced and sustained in-situ, the development of low-cost remediation systems will be possible. Currently, no such technology exists for the DoD to use in the management of diffuse TNT contamination in soils.

ACCOMPLISHMENTS: Key findings on the anaerobic transformation process focus on identification of the enzyme involved in the initial reduction steps of transformation (a Fe-S hydrogenase), the potential for intermediates to bind to natural organic matter (NOM), and the characterization of transformation products. The reactivity of intermediates with NOM appears to center on the interaction between nitroso-groups and thiols. The characterization of the product of transformation has demonstrated that aromaticity is lost and that the product is considerably different than the last known aromatic intermediate. Intermediates that are suspected to lead to biotic ring fission were also investigated. The yellow metabolite (YM) is formed from 2,4-dihydroxylaminotoluene (DHANT), an intermediate in aerobic TNT transformation by enzymes in the nitrobenzene degradation pathway. YM is thought to be the gateway to ring fission products, and methods were developed for stabilizing YM so that sufficient quantities can be accumulated, isolated, and identified. A purified enzyme that is present in the genome of JS45 but is not expressed in the nitrobenzene degradation pathway converts DHANT to the YM. The role of this enzyme will be examined to determine ways to regulate its expression and activity.

TRANSITION: Microcosms will be conducted with soils from the Volunteer Army Ammunition Plant and the Alabama Army Ammunition Plant. Results will be provided to collaborators for incorporation into ongoing cleanup projects. This project intends to transition through the Environmental Security Technology Certification Program (ESTCP) for further optimization of process parameters.

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Technology for Wide-Area Screening of ERC-Contaminated Soils; CU-1228

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Colin Cumming; Nomadics, Inc. – Stillwater, OK

FY 2003 FUNDS: $300K

DESCRIPTION: There is a need for technologies that can rapidly screen the millions of acres of Department of Defense (DoD) lands suspected of having soil contaminated with energetic compounds. Nomadics developed an advanced landmine detection capability based on use of an amplifying fluorescent polymer (AFP) sensing technology developed at MIT. Research has shown that the energetic material originating from a landmine tends to be spatially heterogeneous. In order to ensure detection of a mine by soil sampling, Nomadics demonstrated that sufficient soil must be sampled in a spatially distributed fashion around the mine. The sensor detects ultra-low concentrations of explosives in the headspace above mines and in the soils close to mines. The AFP-based detection technology is primarily focused on nitroaromatic compounds. Some of these are contaminants derived from the explosive-related compounds (ERCs), while others are formed through biodegradation and photochemical degradation of the ERCs. The amplifying polymer responds primarily to electron-deficient aromatic compounds. This technology is sensitive to analyte concentrations 5 to 6 orders of magnitude lower than the currently fielded soil analysis technologies. This project will evaluate the relevance of the soil sampling and detections methods developed for landmine detection to wide area screening, then develop and evaluate a novel standoff approach based on the use of the AFP sensing technology.

BENEFIT: By combining such a high sensitivity detector with an advanced high-speed sampling system, rapid and reliable wide-area screening is possible. Nomadics has developed an electrostatic precipitator-based soil sampling system that can uniformly capture small soil particles rapidly, such that large areas can be sampled efficiently and confidently. The transduction amplification capability of the polymer makes other deployment scenarios possible as well, including true standoff detection. If the method is successful, costs for screening ranges will be greatly reduced based on the need for fewer samples to cover a large area. The cost of analysis per sample is much less than for currently accepted laboratory methods, further decreasing costs. Since samples will be analyzed in the field, the turn around time for results will enable rapid decisions relating to the level of contamination, and therefore suitability of a range for continued use (or possible need for remediation efforts), to be made on-site.

ACCOMPLISHMENTS: Nomadics has made the Fido sensor more robust, improved its ergonomics, and is making progress towards a high-volume preconcentration subsystem. The performance of the electrostatic particle collector has been improved, and the collector is now more rugged, safe, and easy to use. The soil particle trapping efficiency and holding capacity of the high volume vapor sampling cartridges have been improved, and a lightweight, highly efficient battery-powered collection system was developed. A number of improvements have been made to the standoff detection of explosive materials using glass beads coated with a unique chemosensory material. Laboratory and limited field testing have been performed, demonstrating that the approaches being pursued are technically sound.

TRANSITION: Nomadics will work with collaborators and users to fully explore potentially new and powerful wide-area search paradigms based on ultrasensitivity and speed. Nomadics has taken several technologies and products from the laboratory into commercial sales. As the technology matures and is ready to move forward into production, Nomadics will work with other Defense contractors to ensure that the technology transitions into production.

PROJECT SUMMARY

PROJECT TITLE & ID: Immobilization of Energetics on Live Fire Ranges; CU-1229

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Steffan; Envirogen, Inc. – Lawrenceville, NJ

FY 2002 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to develop a cost-effective technology to immobilize energetic compounds (RDX, HMX, and TNT) at the soil surface to prevent their migration to groundwater. The technology is targeted at Department of Defense (DoD) impact ranges that are used for munitions training and testing activities. The goal was to develop an inexpensive soil treatment that could be readily applied over wide and remote areas using trucks equipped with spraying equipment. The treatment is composed of an organic substrate to promote biological reduction of the energetic compounds and a solid adsorption agent to bind the parent compounds and reduced energetic products. A variety of inexpensive, readily available substrates and sorbents were evaluated in microcosm experiments in the laboratory and the most effective combinations were tested in column studies. Batch adsorption isotherms for each of the explosives were determined. The sorption isotherms and kinetics with these materials were evaluated, and the combined role of biotransformation and adsorption in mitigating the transport of energetics to aquifers underlying ranges was assessed. The fate of energetics in the presence of these additives was carefully analyzed.

BENEFIT: In the past, there has been no economically feasible treatment technology to prevent contamination of ground and surface waters at live fire range sites. The large size of these areas and the presence of UXO and vegetation prohibit the use of traditional engineered solutions for preventing migration of energetic compounds from the ranges. Ultimately, the technology developed during this project will result in considerable short-term and long-term cost savings for the DoD by providing: (1) low cost treatment alternatives for existing contamination problems; (2) long-term protection to sensitive ecosystems and groundwater resources at operating facilities; (3) reduced post activity remediation costs; and (4) minimum disturbance of ongoing training operation.

ACCOMPLISHMENTS: Significant progress has been made toward developing a land-applied technology to reduce the potential for explosives from live fire range activities to contaminate groundwater. Twelve potential sorbents and ten potential carbon substrates were screened for their ability to sorb TNT, RDX, and HMX. Peat moss and sawdust proved to be effective sorbents for all three explosives, especially when compared to native Massachusetts Military Reservation soil. Crude soybean oil and molasses stimulated significant transformation and/or mineralization of the explosives. The placement of a layer of peat moss or peat moss plus soybean oil reduced the downward leaching of explosives and explosive metabolites through the soil cores by up to 50 percent, compared to the unamended control. Mineralization of RDX was also four times greater in the peat moss plus soybean oil treatment compared to the peat moss only and unamended control. Soil additives were also evaluated by applying this technology in larger, vegetated intact soil cores to more closely mimic field conditions.

TRANSITION: Results of the study will be used to evaluate the effectiveness, feasibility, and cost of applying additives over large areas at active range sites to prevent environmental contamination during training operations. The results will also be useful for developing and implementing resource management strategies at training facilities throughout the United States and abroad. Because the study will be performed with the goal of treating active ranges, the technology will ultimately allow protection of environmental resources with minimal interference to existing training activities. The project intends to transition to the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Fe(0)-Based Bioremediation of RDX-Contaminated Groundwater; CU-1231

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Pedro Alvarez; University of Iowa – Iowa City, IA

FY 2003 FUNDS: $271K

DESCRIPTION: RDX is one of the most recalcitrant and toxic contaminants in the subsurface. This project seeks to develop a new and efficient method to remediate RDX-contaminated aquifers, based on combining a novel chemical process (reductive treatment with zero valent iron [Fe^0]) with a promising bioremediation approach (*in-situ* reactive zones). This integrated Fe^0-microbial system is more than a mere juxtaposition of two technologies because Fe^0 and some microorganisms interact synergistically to degrade RDX. The objective of this project is to delineate the applicability and limitations of biologically-active Fe(0) barriers to manage RDX plumes. Through batch and column experiments, the research team will: (1) verify that Fe(0) and anaerobic municipal sludge interact synergistically to mineralize RDX; (2) identify any soluble RDX-degradation products; (3) evaluate RDX removal in flow-through systems mimicking Fe(0) barriers and determine the effect of bioaugmentation on barrier permeability and efficiency; (4) determine how iron (III)-reducing bacteria modify the surface chemistry of oxides that passivate the Fe(0) surface; (5) characterize the structure of the microbial community colonizing iron samples; (6) determine how the Fe(0) surface area concentration affects RDX mineralization; and (7) determine how potential co-contaminants affect RDX removal efficiency.

BENEFIT: While the development of a cost-effective and sustainable remediation approach has great intrinsic merit, this project also has significant extrinsic merit related to enhancing the understanding of biogeochemical interactions in contaminated aquifers and the role of mineral surfaces in natural attenuation. This project will provide a strong basis for designing reactive barriers to intercept exposure pathways associated with groundwater contamination by a wide variety of redox-sensitive contaminants.

ACCOMPLISHMENTS: The rate and extent of radiolabeled RDX mineralization was compared in aquifer microcosms amended with Fe(0), anaerobic sludge, or both. While no mineralization occurred in sterile systems with iron alone, combining bacteria with Fe(0) increased anaerobic activity with an associated increase in the rate and extent of RDX mineralization. No interferences by HMX, TNT, or DNT were observed. Results suggest that the mineralization observed in the bioaugmented Fe(0) system is due to either (1) production of cathodic hydrogen during Fe(0) corrosion providing a source of electrons to stimulate anaerobic bioremediation processes; or (2) Fe(0) degradation of RDX below inhibitory levels and transformation of RDX to byproducts that facilitate microbial participation in the cleanup process, as RDX is toxic to some bacteria at the ppm level. Preliminary data have revealed other biogeochemical niches besides cathodic depolarization that could be exploited for enhanced RDX removal. For example, iron-reducing bacteria enhance the chemical reactivity and long-term performance of iron barriers by reductive dissolution of iron oxides that passivate the iron surface and by modifying the surface chemistry of these oxides to form more reactive species such as magnetite and green rust. Results to date indicate that the efficacy and sustainability of Fe(0) barriers might be enhanced by biogeochemical interactions resulting from bioaugmentation; therefore, physiological constraints of desirable microorganisms should be considered in barrier design.

TRANSITION: The project team will seek to collaborate with other scientists and contractors at Department of Defense (DoD) sites to conduct controlled field demonstrations. The ultimate beneficiary will be the general public through improved risk management and enhanced environmental quality.

PROJECT SUMMARY

PROJECT TITLE & ID: Remediation of Explosives Contaminated Groundwater with Zero-Valent Iron; CU-1232

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Paul Tratnyek; Oregon Graduate Institute of Science & Technology – Beaverton, OR

FY 2002 COMPLETED PROJECT

DESCRIPTION: Explosives that occur as groundwater pollutants at Department of Defense (DoD) sites include nitroaromatic compounds (TNT, trinitrobenzene, and various di- and mono-nitrotoluenes) or nitramines (RDX, HMX, and Tetryl). Under favorable conditions, most of these compounds are reduced rapidly by zero-valent iron (Fe^0), which suggests that permeable reactive barriers containing zero-valent iron (FePRBs) might be useful for remediation of groundwater contaminated with these explosives. However, all of the early work on explosives reduction by Fe^0 was done as batch experiments, usually with mono-nitro aromatic model compounds, and this system produces dissolved aromatic amines as the major products. During the course of an earlier SERDP-SEED project, the project team found that columns of Fe^0 removed large quantities of TNT and associated reduction products. The unexpected absence of TNT or its degradation products in the column effluent was likely due to greater sequestration on Fe^0 under conditions representative of those encountered in field applications. Analogous processes were expected for RDX and other nitramine explosives. This project investigated the products and kinetics of removal of TNT and RDX using columns in the laboratory and at the Umatilla Chemical Depot. The team used a variety of methods to extract and characterize all residues of TNT and RDX, determine the effects of changing several key operating conditions, and integrate all of these results in a reactive-transport model that should be sufficient to begin the design of a full-scale demonstration.

BENEFIT: This project expands the scope of application of FePRBs (a proven technology for in-situ and passive remediation of several contaminants, including chlorinated solvents and chromate) to groundwater contaminated with a variety of explosives, including TNT and possibly RDX. Two approaches for implementing the Fe^0 system for explosives/energetics in groundwater include an above-ground canister or an in-situ permeable reactive barrier.

ACCOMPLISHMENTS: A sequential extraction method for TNT and RDX residues was developed and applied using 14C-labeled TNT and RDX to obtain an unambiguous mass balance. The results showed that only about 1 percent of the carbon from TNT or RDX was retained on the iron with the rest in the aqueous or acetonitrile extracts. Using the analytical method developed for the major breakthrough product (TAT), a self-consistent set of batch experiments were run, in order to get a set of rate constants for the reduction intermediates from TNT to the DANTs. A comprehensive kinetic model is being developed. Several columns in various configurations were run. Final column results showed complete conversion of TNT to TAT. Various columns that had been exposed to TNT were eluted, and variable amounts of TAT were found in the eluant. The fate of TAT is being investigated under controlled laboratory conditions and in columns. Columns with automated monitoring were built for use at Umatilla and have developed a large set of performance data as a function of operating parameters.

TRANSITION: It is anticipated that the FePRB approach would be applicable at a number of other sites. Based on past experience with installation and performance of FePRBs for chlorinated solvents, the team anticipates that implementation of an FePRB for explosives could be accomplished in conjunction with commercial vendors (e.g., EnviroMetal). This project has transitioned to the Environmental Security Technology Certification Program (ESTCP) for full-scale demonstration/validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Development and Application of a Flash Pyrolysis-GC/MS Assay for Documenting Natural and Engineered Attenuation of Nitroaromatic Compounds; CU-1233

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Eugene Madsen; Cornell University – Ithaca, NY

FY 2002 COMPLETED PROJECT

DESCRIPTION: Large groundwater plumes of RDX, HMX, TNT, and DNT are associated with sources on Department of Defense (DoD) live fire ranges as well as explosives manufacturing and other facilities. Development of chemical "fingerprints" for nitroaromatic compounds would allow their fate in field sites to be quantitatively and qualitatively measured, thereby providing a sound scientific and technological basis for managing site cleanup. The objective of this project was to implement a novel assay that would provide new information about relationships between attenuation and geochemical conditions that may prevail or be established at contaminated DoD sites. The mechanisms of contaminant attenuation expected to operate naturally and in engineered settings for TNT, RDX, and HMX included microbial cometabolism and chemical processes that reduce, polymerize, and bind the contaminant. If the contaminant is DNT, microbial use as a carbon and energy source (hence mineralization) would be possible although cometabolic reduction and binding to soil is likely. The reasons for field persistence, hence plume migration for all three co-metabolized explosives is likely one or a combination of the following: toxicity; insufficient organic carbon to drive co-metabolism; insufficient carbon in sediment matrix to bind reduced products; improper redox potential to cause irreversible binding to soil; and nutrient limitations. After developing the means to characterize type and degree of polymerization, this project will be able to devise ways to engineer site conditions to enhance polymerization reactions and explain why and how nitroaromatics have attenuated naturally in some sites and persisted in others. Key assays for discerning the extent of nitroaromatic humification include High-Performance Liquid Chromatography (HPLC) analysis of the reduced monomers (or oligomers), assessing their leachability from site soils, and assessing their degree of incorporation into soil organic matter by Flash Pyrolysis Gas Chromatograph/Mass Spectrometer (FP-GC/MS).

BENEFIT: Despite decades of laboratory, enrichment-based biodegradation studies, clear criteria do not yet exist to seek field evidence for attenuation of nitroaromatics or enhancement of the process. This project sought to develop attenuation criteria (chemical "fingerprints") via a novel suite of chemical and microbiological measures applied to laboratory experiments and field samples.

ACCOMPLISHMENTS: Data on the prevailing geochemical conditions and groundwater/sediment samples were obtained from several DoD sites. Definitive FP-GC/MS data on the occurrence of TNT metabolites as polymeric, humus-bound residues in Louisiana Army Ammunition Plant soil has been obtained. Thus, the fundamental tenet of the project (a new analytical assay for detecting covalently bound forms of explosives in DoD field samples) is valid. Two main obstacles need to be overcome before the promise of this project can be realized: (1) expanding the library of FP-GC/MS- produced analytes that document the status of TNT in real-world soils; and (2) increasing the sensitivity of MS detection of these analytes. The project paradigm used for TNT ought to be applicable to RDX.

TRANSITION: Results may serve as the foundation for a comprehensive plan to assess, classify, implement, and enhance the attenuation of nitroaromatics in contaminated DoD sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Sequential Electrolytic Degradation of Energetic Compounds in Groundwater; CU-1234

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Tom Sale; Colorado State University – Fort Collins, CO

FY 2003 FUNDS: $51K

DESCRIPTION: Energetic compounds (e.g. TNT, DNT, RDX, HMX) are widely present in groundwater at DoD facilities. Of primary concern is the incomplete degradation of the energetics resulting in compounds that may pose a greater risk than the original. There is a need for new technologies that can cost-effectively address potential risks posed by energetic compounds in groundwater. This project involves experiments that will assess the efficacy of flow through electrolytic reactors (e-barriers) to abiotically mineralize dissolved phase energetic compounds in groundwater. The potential of the e-barrier to provide the multiple sequences of reduction and oxidation necessary to completely degrade energetic compounds is perhaps the most distinguishing attribute of this approach. The objective of this project is to develop scientific insights regarding electrolytic oxidation and reduction of energetic compounds, support analysis of the economic feasibility treating energetic compounds via electrolytic processes, and provide a basis for a field demonstration. Ongoing research has demonstrated the potential utility of electrolytic degradation of organic compounds in a permeable reactive barrier format. Flow through e-barriers involve passing contaminated water through charged porous electrodes, resulting in sequential oxidization and reduction of aqueous phase contaminants. Research to date has demonstrated that e-barriers can effectively degrade chlorinated solvents in a laboratory setting. However, research is needed to evaluate the application of an electrolytic approach to degrade cyclic organic compounds such as RDX or TNT. Primary elements of this research include batch voltammetry experiments, flow through column studies, and documentation of results. Voltammetry experiments will involve RDX, TNT, HMX, and DNT. These tests will allow the project to quickly explore issues of optimal electrode materials and operating voltages. More rigorous analysis of treatment efficacy will be achieved using column flow through electrolytic reactors. Column studies will track degradation of RDX and TNT and the production of intermediate compounds of concern.

BENEFIT: If successful, this research will provide three key benefits: (1) fundamental scientific insights regarding electrolytic oxidation and reduction of aqueous phase energetic compounds; (2) a basis for evaluating the economic feasibility of treating aqueous phase energetics via electrolytic processes; and (3) a basis for a field demonstration. The project team aims to determine new scientific knowledge and a new technology that cost effectively addresses risks posed by energetics in groundwater.

ACCOMPLISHMENTS: The proof-of-concept experiment suggested that e-barriers may provide a cost-effective solution for in-situ treatment of dissolved energetic compounds in groundwater. Over 97 percent of TNT and 92 percent of RDX was degraded in flow-through column reactors using electrically induced sequential oxidation and reduction. Minimal intermediate compounds of concern were identified. Calculated power requirements for the experiment indicated that high fractional removal of the target compound could be achieved at less than 5 watts per meter squared of active electrode.

TRANSITION: The research conducted through this project will synergistically complement ongoing e-barrier projects funded by the National Science Foundation, United Technologies Corporation, the Solvents in Ground Water Research Consortium, and the Environmental Security Testing and Certification Program.

PROJECT SUMMARY

PROJECT TITLE & ID: Ecological Risk Assessment of Perchlorate in Avian Species, Rodents, Amphibians, and Fish: An Integrated Laboratory and Field Investigation; CU-1235

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Ronald Kendall; Texas Tech University, The Institute of Environmental and Human Health – Lubbock, TX

FY 2002 COMPLETED PROJECT

DESCRIPTION: The focus of this project was to continue to expand the knowledge base for environmental perchlorate contamination issues with field and laboratory studies designed to assess the associated ecological risks. The principal objective of this research was to examine the impact of environmental exposures of perchlorate on birds, rodents, fish, and amphibians at Longhorn Army Ammunition Plant (LHAAP) near Karnack, TX. Bioavailability of perchlorate across trophic levels was evaluated, and toxicological impacts of perchlorate on exposed biota were assessed. Ecological receptors deemed to be at risk from exposure to perchlorate were identified through a number of inter-related sub-projects including analytical, terrestrial, and aquatic toxicology as well as ecological modeling.

BENEFIT: This program has resulted in the identification of ecological risks and in the development of models of exposure and toxicity that will be useful for the assessment of perchlorate-contaminated sites and the evaluation of remediation techniques. Results will likely be used to establish regulatory standards and cleanup criteria for perchlorate. The products will provide a framework of risk assessment methods and criteria necessary to define acceptable concentrations within ecological systems. These data will be useful not only in the characterization of LHAAP but also in the assessment of other sites operated by DoD and sites potentially affecting valuable water supplies.

ACCOMPLISHMENTS: Research activities have identified exposure pathways, sensitive indicators of exposure, and an understanding of ecological impacts associated with perchlorate contamination. These studies have aided the development of analytical techniques and models of exposure and response that can be used to evaluate sites throughout the U.S. This research has resulted in numerous advances in the analytical chemistry of abiotic and biotic components of ecosystems, as well as a greater understanding of the subtle physiological alterations induced by perchlorate exposure. Analytical techniques have been developed that reduced the minimum quantitation limit of a water sample to 1.0 ppb. Additionally, analytical research resulted in the development of a method for quantitation of perchlorate concentrations in biological matrices. Dosing studies with larval and juvenile amphibians demonstrated the sensitivity of these receptors. Low concentrations (low ppb) of perchlorate caused changes in amphibian growth and development, and at higher concentrations (concentrations found at LHAAP) resulted in blockage of metamorphosis from larval to adult stages. Field studies and subsequent analytical evaluation of ground and surface water, soil, sediment, and biological samples have indicated that perchlorate contamination is prevalent and bioavailable to both aquatic and terrestrial organisms at various sites across the U.S. Biota (including invertebrates, fish, frogs, birds, and mammals) inhabiting perchlorate-contaminated areas can assimilate perchlorate from environmental media. However, exposure to perchlorate at concentrations normally observed in the environment appears to have little effect on earthworm survival or reproduction, fish survival or reproduction, or wild mammals. Finally, data from these studies have been used to develop aquatic and terrestrial food chain models of exposure that permit assessment of effects at the molecular/cellular/organ (endocrine system), individual and population levels of organization.

TRANSITION: Information gained will be transitioned to agencies within the DoD, the U.S. EPA, and other federal and state agencies through reports and peer-reviewed publications.

PROJECT SUMMARY

PROJECT TITLE & ID: Improved Understanding of Fenton-Like Reactions for In-Situ Remediation of Contaminated Groundwater Including Treatment of Sorbed Contaminants and Destruction of DNAPLs; CU-1288

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Richard J. Watts; Washington State University – Pullman, WA

FY 2003 FUNDS: $79K

DESCRIPTION: In-situ chemical oxidation (ISCO) using modified Fenton's reagent (hydrogen peroxide and catalysts) holds the potential to rapidly treat many of the Department of Defense (DoD) sites that are contaminated with halogenated organic chemicals. Research suggests that modified Fenton's reagent used for ISCO is capable of rapid destruction of biorefractory contaminants, enhanced desorption of sorbed contaminants, and enhanced destruction of dense non-aqueous phase liquids (DNAPLs). This project aims to obtain a better fundamental understanding of modified Fenton's reagent as an ISCO process. Two principles serve as themes for the project. The first is that hydroxyl radicals, while necessary for the oxidation of soluble contaminants, are only partially responsible for the success of Fenton-like ISCO. The second is that naturally-occurring trace minerals may play an important role in Fenton-like ISCO relative to soluble iron catalyst addition. The research will focus on detecting the generation of three transient oxygen species in modified Fenton's reactions: hydroxyl radical, superoxide anion, and the hydroperoxide anion, through trace mineral and soluble iron-catalyzed Fenton's reactions. The importance of each oxygen species will be evaluated for DNAPL destruction and the treatment of sorbed contaminants. Finally, practical delivery and stoichiometry considerations will be evaluated. The research will provide definitive elucidation of mechanisms and integrate the results to provide more effective process design for the full-scale application of Fenton-like ISCO.

BENEFIT: Results of this research will provide a solid foundation for implementing more technically effective and cost-effective Fenton's ISCO process conditions to cleanup contaminated sites.

ACCOMPLISHMENTS: Minerals and a natural subsurface sample that can potentially catalyze Fenton-like reactions have been acquired. The naturally-occurring minerals (anatase, bauxite, cuprite, ilmenite, siderite) have been ground and characterized for surface area. The naturally-occurring subsurface solids were obtained from a field site in Georgia and are currently being characterized for porosity, soil organic carbon content, particle size distribution, pH and alkalinity, and cation exchange capacity. The required number of natural soils required to elucidate the effect of subsurface characteristics on hydrogen peroxide stability and potential radical generation has been determined. Analytical parameters for use with the gas chomatography and atomic absorption spectrophotometry for the analysis of probe compounds and metal catalysts, respectively, have been developed and refined.

TRANSITION: Results will be transitioned via controlled large-scale pilot studies and controlled field studies where the delivery of hydrogen peroxide, the formation of transient oxygen species, NAPL destruction, and contaminant oxidation and reduction can be throughly monitored with mass balances on all of the contaminant carbon in the system. Such larger-scale transition research could be sponsored through the Environmental Security Testing and Certification Program (ESTCP) or similar programs to investigate the Fenton's process at meso- and/or full scale. If in-situ Fenton's systems can be fully optimized, hydrogen peroxide requirements (the most expensive chemical in the Fenton's process) could be dramatically reduced, providing significantly lower costs for implementation.

PROJECT SUMMARY

PROJECT TITLE & ID: Improved Understanding of In-Situ Chemical Oxidation (ISCO); CU-1289

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Eric Hood; GeoSyntec Consultants – Guelph, Ontario, Canada

FY 2003 FUNDS: $88K

DESCRIPTION: The use of ISCO treatment of chlorinated solvent source areas is rapidly increasing as the Department of Defense (DoD) and other stakeholders search for remedial approaches that reduce long-term operations and maintenance requirements. While ISCO is a promising technology for some chemicals, there remains significant data needs related to reaction kinetics for common DoD chemicals, the effects of natural oxidant demand on oxidant mobility and delivery under varying site conditions, and the effects of ISCO on long-term groundwater quality. This project will focus on developing a comprehensive approach to quantifying degradation kinetics during ISCO by permanganate and Fenton's reagent, applying this approach to a broad spectrum of common groundwater kinetics. Another aim of this project is developing a rigorous bench-scale experimental methodology to measure the rate and extent of the aquifer matrix natural oxidant demand (NOD) with permanganate and Fenton's reagent and developing a comprehensive conceptual model describing the role of NOD on oxidant mobility in the subsurface. The long-term impacts of ISCO will be researched by identifying significant secondary impacts of oxidant application on groundwater geochemistry and microbial activity at the field scale. Finally, the project team will develop an ISCO guidance document for chlorinated solvent remediation, in association with the other ISCO project teams selected under this Statement of Need (SON). The document will include specific guidance on technology applicability, protocols for effectively employing site-specific laboratory and pilot-scale treatability testing, design guidance for oxidant delivery systems, and approaches for effective technology performance monitoring and validation.

BENEFIT: This research is designed to significantly improve the current understanding of reaction mechanisms and kinetics for chemicals commonly found at DoD facilities and the behavior of permanganate and Fenton's reagent in the various geological and geochemical environments encountered at DoD sites. This fundamental knowledge, which will be distilled into a guidance document, will enable DoD site managers to make better decisions when dealing with chlorinated solvents.

ACCOMPLISHMENTS: Preliminary results using the stopped-flow protocol provide an estimate of the degradation rate of trichloroethene with permanganate that agrees closely with literature values, suggesting that the method provides comparable results to conventional protocols for evaluating oxidation kinetics. Soil collection to support batch and column studies is underway. The dichromate titration method has been setup and applied. Soils will be air-dried and homogenized prior to use in the batch and columns studies; however, additional batch studies using both permanganate and Fenton's reagent (in the absence of oxygen) will be performed to evaluate the impact of soil exposure to atmospheric oxygen during drying/homogenization on the measured oxidant demand and kinetics. The basic soil characterization protocol will focus on total manganese, iron, and sulphur. The sampling and analysis plan for the field monitoring program is in preparation.

TRANSITION: GeoSyntec and its co-development partners will transition the performance and applicability data for the ISCO technology to the federal and non-federal sectors through the publication of research articles, the distribution of videos and pamphlets, the presentation of test results at conferences, and the development of a project web page. GeoSyntec will also market the technology to non-federal defense contractor facilities to communicate its potential to reduce environmental liabilities.

PROJECT SUMMARY

PROJECT TITLE & ID: Reaction and Transport Processes Controlling In-Situ Chemical Oxidation of DNAPLs; CU-1290

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Siegrist; Colorado School of Mines – Golden, CO

FY 2003 FUNDS: $170K

DESCRIPTION: Chemical oxidation has emerged as a promising treatment method for remediation of sites contaminated by chlorinated solvents and petrochemicals. Fundamental and applied laboratory research has elucidated many aspects of the reaction stoichiometry, degradation pathways, and kinetics for common organic chemicals in aqueous systems as well as the effects of temperature, pH, and matrix composition. Currently, there are serious gaps in the knowledge base regarding in-situ chemical oxidation (ISCO) for dense nonaqueous phase liquids (DNAPLs). As a result, ISCO applications at DNAPL sites have been limited and those that have occurred have been plagued with uncertain or poor performance. In this project, proven methodologies involving apparatus of varying scales and complexities will be used to explore two common oxidants (peroxide and permanganate) and contrasting oxidant application methods (low to high dose concentrations and low to high delivery densities) to treat different DNAPL masses and distributions under conditions representative of a range of subsurface settings. The research will also address the potential adverse secondary effects of applications of ISCO as well as the appropriate coupling of ISCO with pre- and post-ISCO treatment operations.

BENEFIT: Completion of this project will yield a knowledge base for the future development of guidance on the principles and practices of ISCO so that it can be selected as a preferred remedy when appropriate and be implemented to reliably achieve a given performance objective.

ACCOMPLISHMENTS: Efforts to date have focused on the design and initiation of bench-scale studies in support of experiments focusing on aqueous phase and DNAPL phase contaminant degradation. Bench-scale studies were conducted to define the dissolved phase reaction kinetics for trichloroethylene (TCE) DNAPL as affected by bulk aqueous phase composition, while comparative studies were conducted with a TCE DNAPL phase present. Key variables examined were (1) TCE as the study DNAPL, (2) Fenton's reagent (peroxide plus iron catalyst) and potassium permanganate oxidants, (3) oxidant load (low/high) and, (4) simulated groundwater flow conditions with respect to DNAPL phase experiments. Oxidation of TCE in the aqueous phase occurred in the systems as expected based upon known kinetic rate expressions. Increased TCE destruction rates and extents, as well as oxidant consumption levels, were observed with increasing reactant concentrations (oxidant and TCE). TCE DNAPL destruction efficiency and effectiveness were a function of oxidant load and mixing conditions (i.e., simulated groundwater flow). Increased oxidant load for both permanganate and Fenton's reagent systems results in more rapid TCE degradation, but TCE destruction kinetics appear to be more highly dependent on DNAPL dissolution to the aqueous phase than upon oxidant loading alone. Results have revealed that oxidation reactions result in enhanced DNAPL dissolution relative to systems without oxidant and that DNAPL dissolution and oxidation rates are enhanced in mixed systems relative to static conditions. Results additionally indicate that the extent of DNAPL phase degradation with both oxidants is similar to comparable aqueous phase systems. Kinetic models are being applied to data sets along with regression analyses to determine main and interaction effects on the rate and extent of reactions.

TRANSITION: Results of this work will produce decision aids that will be designed for future guidance regarding when and how to apply ISCO to cost-effectively remediate DNAPL at a given site, using ISCO either as a stand-alone method or by coupling it with a pre- or post-ISCO operation.

PROJECT SUMMARY

PROJECT TITLE & ID: Optimization of In-Situ Oxidation via the Elucidation of Key Mechanistic Processes Impacting Technology Maturation and Development of Effective Application Protocol; CU-1291

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Beth Fleming; U.S. Army Corps of Engineers Engineer Research and Development Center – Vicksburg, MS

FY 2003 FUNDS: $252K

DESCRIPTION: This project focuses on the idea that soil constituents known to react with chemical oxidizers can dramatically change the biogeochemistry of soils. There are potential benefits of process integration that are dramatic in terms of both cost and performance. The application of chemical oxidizers within non-aqueous phase liquids (NAPLs) is a poorly developed area and there is little data available for use in developing near-field remediation models (primarily with reaction and sorptive mechanisms). The design options are poorly documented and their relative performance has not been evaluated. There are also key safety issues that have not been properly addressed with regard to using chemical oxidizers within in situ chemical oxidation (ISCO) systems. The primary objective of this project is to provide basic scientific information on the impact of applying chemical oxidizers and their fate within soil matrices. Secondary objectives include: (1) better understand and define what soil constituents impact transport of primary oxidizers and then determine how chemical oxidizers impact soil systems; (2) provide a better understanding of oxidizer-pure NAPL interactions; (3) develop and/or refine appropriate reactive, sorptive kinetic models (non-transport); (4) evaluate results using actual soils containing TCE, TNT, and Phenols (two of each); and (5) provide a well-documented evaluation of current and developing design protocols, inclusive of key safety issues.

BENEFIT: Resulting information will be used to refine current design protocols. Definition of the performing mechanisms should lead to significant process optimization. Delineation of those soil constituents that have the greatest impact on oxidizer stability within soil matrices will be achieved. Evaluation of the potential impacts of oxidation processes on receiving soil systems will provide insight into post-treatment options. A database that can be used for later development of biotic/abiotic treatment techniques will be generated. The project will also develop key kinetic information (reaction and adsorption) and generate process design guidance.

ACCOMPLISHMENTS: The reactivity of the four oxidizers (permanganate, Fenton's, ozone, and peroxone) will be evaluated in four natural soils of distinctive characteristics, plus an inert sand. The average soil was collected, dried, sieved, and homogenized. The specific types and locations for the remaining soils have been determined: high iron content, Tellico Loam (TN); high calcium content and high pH, Crot sandy loam (AZ); and high organic content, Gessie loam (IN). Cleaned (ozone-treated), quartz sand has been prepared as the control medium. Batch tests to investigate the impact of soil properties on oxidant stability have been initiated using the average soil type and the control filter sand with hydrogen peroxide. Assembly of the experimental setup for the column work has begun.

TRANSITION: Peer-reviewed papers and technical presentations will be prepared on the following topics: oxidizer fate, soil condition post-ISCO application, NAPL remediation, modeling, and design issues. The project intends to transition through the Environmental Security Technology Certification Program (ESTCP). There is a plan to organize an Engineering Foundation Conference on Application of Chemical Oxidation for Soils Remediation, working with other organizations. The research team also provides the Corps of Engineers with in-house expertise on ISCO, enabling further transfer of results.

PROJECT SUMMARY

PROJECT TITLE & ID: Decision Support System to Evaluate Effectiveness and Cost of Source Zone Treatment; CU-1292

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Charles Newell; Groundwater Services, Inc. – Houston, TX

FY 2003 FUNDS: $56K

DESCRIPTION: The dense non-aqueous phase liquid (DNAPL) site paradigm developed in the 1990s has resulted in two competing site remediation approaches: (1) aggressive treatment and removal of DNAPLs and (2) long-term, low intensity containment with management of the DNAPL dissolution products. The objective of this research is to develop easy-to-use tools that will help the groundwater community decide which approach is appropriate at a given site. The project will develop an easy-to-use decision support system that will allow users to simulate the characteristics of a source zone, simulate the effects of various remediation alternatives, and estimate the resulting remediation costs/benefits and plume patterns over time. Specific objectives include (1) developing a new source evaluation methodology, based on a concept of generic "source settings" that will represent different types of DNAPL source; (2) generating a family of source concentration vs. time curves for each generic source-setting and for key site-specific input data; (3) developing a Source Remediation Cost and Performance Database; (4) applying this methodology to a 20-30 site source zone database; (5) generating a list of general rules regarding when and where various forms of intensive or partial site remediation are appropriate and cost-effective based on case study results and input from the expert panel; and (6) developing an easy-to-use Decision Support System.

BENEFIT: The Decision Support System will enable the groundwater community to: (1) apply the general rules derived from the detailed analysis of 20-30 sites to conduct a planning-level "Tier 1" evaluation of intensive source remediation strategies; (2) perform a more detailed "Tier 2" evaluation of the site by entering data, representing the source zone as a series of generic source-settings, using the software to visualize the change in the plume over time and evaluate the costs vs. benefits of source remediation; and (3) reference new research data in the form of a Source Zone Database, a Source Remediation Cost and Performance Database, and results from the source-setting analysis.

ACCOMPLISHMENTS: A draft questionnaire for the source databases was developed. Different distribution methods and methods to ensure high quality-responses were evaluated. Approximately forty DNAPL sites from the literature were reviewed, twenty-five of which had useable data. Information on four remediation technologies was compiled. Twelve preliminary source settings were developed, and three analytical models were developed on the Excel platform.

TRANSITION: To transfer the knowledge, the project will rely on two key products: (1) general rules derived from the detailed analysis of 20-30 sites, and (2) the Decision Support System, which will allow users to represent the source zone as a series of generic source-settings. The cost and predictive features will generate cost data and help users visualize the plume over time for various source treatment alternatives. The general rules, created from project results and input from the review panel, will be presented in the form of a simple table or graphic, and a short tech-transfer bulletin will be developed for distribution via the internet. Information will also be transferred through peer-reviewed journal articles, HTML files for use as web page, downloadable Source Zone Database and results of the application of the methodology to these sites, downloadable Source Remediation Cost and Performance Database, downloadable Decision Support Software and User's Manual, presentations at conferences, and information bulletins on commonly-used online groundwater groups and technology-transfer systems.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Assessment Tools for Evaluation of the Benefits of DNAPL Source Zone Treatment; CU-1293

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Linda Abriola; University of Michigan – Ann Arbor, MI

FY 2003 FUNDS: $185K

DESCRIPTION: Despite its importance to the evaluation of alternative site remediation and management options, relatively little research has been conducted to assess the post-treatment distribution, mass transfer, and biotransformation of dense non-aqueous phase liquids (DNAPLs) following in-situ treatments. This project is a multidisciplinary integration of laboratory, field, and modeling studies designed to provide a more comprehensive understanding of these issues and to develop tools and protocols for field monitoring and cost/benefit analyses. Various levels of treatment and remediation technologies/approaches will be investigated under heterogeneous subsurface conditions representative of known contamination sites. Application of the developed tools will be evaluated at selected DNAPL field sites. The research plan is organized around five tasks: (1) Bench-scale assessment of DNAPL recovery and contaminant fluxes following source zone treatment; (2) Evaluation of the potential for microbial reductive dechlorination in treated source zones; (3) Refinement, validation, and application of a numerical model for source zone flux prediction; (4) Field mass flux estimation protocol development and evaluation; and (5) Cost-benefit analysis tools development.

BENEFIT: Results will provide Department of Defense (DoD) site managers with tools and protocols designed to assess the effectiveness and cost-benefit potential of DNAPL source zone treatments. Anticipated project deliverables include: (a) field sampling and monitoring protocols to quantify pre- and post-treatment mass fluxes; (b) biological probe technologies to assess chlororespiring activity in source zones; and (c) cost analysis tools designed to provide simplified and detailed cost estimates for competing technologies. These tools are intended primarily for implementation within a pre-treatment decision process, in which several source zone treatment technologies would be evaluated.

ACCOMPLISHMENTS: Design work for the 2-D aquifer cell to be used in DNAPL recovery and flux studies was initiated, including evaluation of the use of light transmission as a means to quantify NAPL saturation and distribution. Preliminary experiments were conducted using a previously constructed cell to evaluate recoveries and post-treatment distributions of trichloroethene (TCE) following application of alternative surfactant-enhanced aquifer remediation (SEAR) approaches. Factors that control variability in microbial reductive dechlorination performance of *Desulfuromonas michiganensis* strain BB1 for free phase perchloroethene (PCE) in batch cultures were investigated. Preliminary 3-D geostatistical models were generated for the Bachman Road Site located in Oscoda, MI, and numerical modeling of DNAPL infiltration and entrapment for a simulated PCE spill in 2-D profiles extracted from these heterogeneity models was initiated. A multiple linear regression FORTRAN computer code was adapted to estimate the propagation of uncertainty through the mass flux equation for a 2-D section. Development of modular cost components for surfactant flushing beginning with the injection well system has begun.

TRANSITION: To reach site managers involved in source zone remediation and regulatory officers responsible for overseeing and approving such remedial actions, transition programs will be developed in cooperation with the State of Michigan Department of Environmental Quality (DEQ) and the U.S. Environmental Protection Agency (EPA). These may include monitoring and assessment at additional field sites, white paper(s) describing the implementation of the protocols, and workshop(s) involving regulatory officials at the state and national level, government agencies, and relevant industries.

PROJECT SUMMARY

PROJECT TITLE & ID: Mass Transfer from Entrapped DNAPL Sources Undergoing Remediation: Characterization Methods and Prediction Tools; CU-1294

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Tissa Illangasekare; Colorado School of Mines – Golden, CO

FY 2003 FUNDS: $199K

DESCRIPTION: Non-aqueous phase liquids (NAPLs) exhibit complex flow and entrapment behavior in naturally heterogeneous subsurface systems. Risk analysis to determine the effectiveness of remediation has to be conducted using the spatial and temporal distribution of NAPL concentrations in the contaminant plume. The physical process that is fundamental to determine both the pre- and post-remediation status of the contaminant plume is the mass transfer that occurs from the entrapped NAPL sources. The focus of this project is to understand, quantify, and model the process of mass transfer from source zones where DNAPL is distributed in complex configurations due to unstable behavior and natural geologic heterogeneity. A research study that involves batch and bench-scale experimentation, physical modeling in intermediate-scale laboratory soil tanks, and validation of the predictive modeling tools will be conducted. The research will aim to determine whether the existing site characterization techniques have the capability and refinement to determine the pre- and post-remediation distribution of NAPL mass within the entrapment zones (residual and pools) and whether the current understanding of mass transfer and mixing that occur within DNAPL source zones in heterogeneous subsurface formations is adequate to make predictions on how the dissolved contaminant plume behaves following remediation.

BENEFIT: The basic scientific knowledge gained in this research and the developed prediction tools and site characterization methods will help the Department of Defense (DoD) to make decisions on managing sites and to conduct cost/benefit analyses on the selection and implementation of different treatment technologies. The processes that govern mass transfer from complexly distributed DNAPL after application of three common source zone removal/destruction technologies will be characterized. The impact of properly selected source zone treatment technologies for long-term achievement of end-point DNAPL saturations will be acceptable downstream contaminant levels.

ACCOMPLISHMENTS: Perchloroethene (PCE) and trichloroethene (TCE) were selected as the primary DNAPL for the laboratory studies. In addition, DNAPL samples collected from an Air Force site in Texas will be used. Four tracers were selected. Determination of partitioning coefficients when the NAPL source is subjected to chemical oxidation and bioremediation was initiated. For use in the bio-treatment studies, a culture of *Desulfuromonas chloroethenicas* is being grown. A culture of *Pantoea agglomerans*, a facultative anaerobe that can degrade PCE and TCE to cis-DCE, has also been started. Finally, a mixed culture has been obtained for use in the event that the other two cultures are not successful. For use in the thermal remediation studies, thermal characteristics of the test DNAPLs were also determined. A set of experiments was conducted to determine the mass transfer coefficients under natural and surfactant-enhanced dissolution of PCE in both 1-D and 2-D flow systems. The data was used to test a numerical model that will be used in the development of upscaling methods and decision tools. Gamma ray and x-ray attenuation methods will be used to determine the NAPL saturations in the test tanks when the source zones are undergoing remediation. Development of the testing methods and calibration were initiated. A test tank that will be used to conduct large-scale simulations and a 3-D tank for the pilot scale testing of chemical oxidation were assembled.

TRANSITION: The team is directing another research project to improve the U.S. Army Groundwater Modeling System (GMS). The modeling tool developed in this work may be included in GMS.

PROJECT SUMMARY

PROJECT TITLE & ID: Impacts of DNAPL Source Zone Treatment: Experimental and Modeling Assessment of Benefits of Partial Source Removal; CU-1295

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. A. Lynn Wood; U.S. Environmental Protection Agency, Office of Research and Development – Ada, OK

FY 2003 FUNDS: $303K

DESCRIPTION: At the nearly 17,000 sites on Department of Defense installations potentially requiring environmental cleanup, there is a need for innovative source-zone treatment technologies that offer cost-effective risk reduction. Unfortunately, there is currently no consensus in the academic, technical and regulatory communities on the ecological or environmental impacts of dense non-aqueous phase liquid (DNAPL) source-zone treatment. The cost of source-zone treatment is high, and the anticipated benefits need to be understood before significant resources are committed to source-zone removal. Since it is not economically practical to remove all DNAPL mass from most source zones, the focus of this project is on the likely benefits from partial DNAPL mass removal using some aggressive in-situ technology (e.g., alcohol or surfactant flushing; steam flooding; air sparging; chemical oxidation). The primary objective is to develop a scientifically defensible approach for assessing the long-term environmental impacts (i.e., benefits) of DNAPL removal from source zones. The fundamental premise is that contaminant flux from the source, rather than contaminant concentration, should be used as the basis for evaluating the effectiveness of remediation. An integrated three-pronged approach, comprised of laboratory experiments, field observations and numerical simulations, will be used.

BENEFIT: This project will develop sufficient understanding of the linkage between source-zone remediation and its impacts on dissolved plume behavior to permit optimization of the remedial process by balancing mass removal with plume attenuation. The experimental data and modeling analyses will provide a basis for developing appropriate flux-based remediation endpoints at DNAPL sites and will help in the design of cost-effective remediation technologies. Thus, project results will facilitate more comprehensive risk assessments that include evaluation of benefits derived in terms of decreased adverse impacts on human and ecological receptors and will provide a scientific basis for developing regulatory and policy guidelines for DNAPL source-zone remediation.

ACCOMPLISHMENTS: Performance of a stochastic streamtube model for predicting DNAPL source remediation effectiveness is being tested with results from enhanced source removal technology demonstrations at the Dover National Test Site (DNTS). Also, soil cores have been collected from the DNTS site to better characterize the architecture of the residual DNAPL and the spatial variability of the hydrodynamic properties, providing input parameters for deterministic source remediation simulators. Contaminant mass discharge rates were measured at Hill AFB Operable Unit 2 prior to surfactant-enhanced removal of a DNAPL source outside of the containment slurry wall. Post-remediation discharge rates will be measured annually to assess the impact of DNAPL mass depletion on these rates.

TRANSITION: Results will be presented at national and international professional meetings and published in peer-reviewed journals. The team will also publish project findings in technical magazines, such as Pollution Engineering, Ground Water Monitoring Review, and other trade journals. At the conclusion of the project, two additional documents will be prepared for general distribution: (1) a technical document summarizing the findings of the research, and made accessible on the internet and in CD-ROM format; and (2) an executive summary document, written for lay audiences interested in obtaining a grasp of the research findings and their implications in hazardous-waste site management.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of a Surface Enhanced Raman Spectroscopy (SERS)-Based Sensor for the Long Term Monitoring of Toxic Anions; CU-1296 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Pamela Boss; SPAWAR Systems Center – San Diego, CA

FY 2002 COMPLETED PROJECT

DESCRIPTION: Long-term monitoring can be for process control, performance measurement, or compliance purposes and can last up to 30 years. Currently, monitoring is done by traditional methods of collecting aqueous samples from monitoring wells or by drilling and collecting soil samples. The collection and laboratory analysis of samples is both time consuming and costly. There is a need to develop new, long-term monitoring technologies that will measure contaminants of concern in-situ/on-site and will minimize sampling time and costs. This project developed an in-situ sensor that uses cationic-coated, surface-enhanced Raman scattering (SERS) substrates to detect perchlorate and chromate anions. The coating attracts the anions to the SERS substrate where they are identified and quantified by their characteristic Raman emission. The cationic coating stabilizes the SERS substrate, thereby extending its lifetime, and has a characteristic SERS spectrum, which can be used as an internal calibration. Besides specificity, simultaneous multicomponent analysis is possible due to the high resolution of Raman spectra. Raman spectra can be obtained remotely over optical fibers in real time and there has been significant advances in the development of inexpensive Raman spectrometers, charge-coupled devices, and diode lasers. Despite these advances, normal Raman spectroscopy is inherently an insensitive technique. In order to achieve ppb detection limits, the Raman signal needs to be enhanced.

BENEFIT: This long-term monitoring technology has several benefits including its ability to be used in-situ/on-site, decreased uncertainty with the analytical results, and reduction in sampling time and cost.

ACCOMPLISHMENTS: The SERS response of commercially available cationic thiols (cy, dma, dea, cys, cysm, cyse, atb, and mmp) to chromate and perchlorate was characterized. For perchlorate, silver substrates were used. The concentration response for perchlorate with the cationic coatings is described by a Frumkin isotherm. For chromate, gold substates were used. Results indicate that the only coating suitable to detect chromate is mmp. For both anions, the concentration response to 4-(2-Mercaptoethyl)pyridine (MEP) is described by a Frumkin isotherm. Using a 20 second acquisition time, 100 ppb chromate could be detected using this coating. The sensor module that houses the SERS substrate and fiber optic probe has been fabricated. The SERS substrate is either a thin gold or silver film on a soda glass substrate. Spectral data are obtained using a 'backside' configuration. The advantages of this approach are minimization of fluorescence interference and attenuation of the signal by water. When used in the stand-alone mode, the sensor module is immersed in samples obtained from monitoring wells. By inserting the sensor module inside a cone-penetrometer sampler probe, sampling of groundwater can be done at various depths. Either sampling approach will provide the required information in real-time without requiring the additional cost of an outside laboratory.

TRANSITION: Besides the detection of anions, this technology has the capability to detect volatile organic compounds (VOCs), metal ions, drugs, explosives, and agents used in chemical warfare. The technology fits into the areas of bioremediation, compliance, and monitoring. Consequently, it is believed that once the technology has achieved proof-of-concept, it will lead to more extensive follow-on development efforts within SERDP and future transition to DoD, other SERDP partners, and the private sector as a cost effective monitoring capability for the Environmental Restoration Program.

PROJECT SUMMARY

PROJECT TITLE & ID: Integrated Automated Analyzer for Monitoring of Explosives in Groundwater; CU-1297 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Yuehe Lin; Pacific Northwest National Laboratory – Richland, WA

FY 2002 COMPLETED PROJECT

DESCRIPTION: The closure and remediation of former ammunition plants and military facilities requires accurate characterization of soil and groundwater contamination. It has been found that the distribution of contamination is often highly heterogeneous, requiring numerous samples and analyses for these sites to be adequately characterized. The objective of this research was to develop a portable analytical system based on the on-line/on-chip coupling of a miniaturized, meso-scale sequential injection (SI) for fast and automated sample processing with a microfabricated capillary electrophoresis/electrochemical detector (CE/ECD) for fast separation/detection of explosives and their degradation products in groundwater at Department of Defense (DoD) sites that are undergoing closure and remediation. The full realization of the development of a portable analytical system was greatly dependent upon exploring and resolving specific technical issues, including the low concentration levels of analytes and the complexity of environmental sample matrixes, which makes sample preconcentration and purificaiton necessary prior to subsequent analysis. In this project, automated solid-phase extraction (SPE) and solid-phase microextration (SPME) techniques were used for sample preconcentration prior to capillary electrophoresis /electrochemical detection steps.

BENEFIT: The portable analyzer will allow fully automated sample pretreatment and fast separation/ detection of multi-components of explosives and their degradation products. Used for on-site/real-time analysis, the analyzer will be highly integrated, automated, and compact. Primary cost-savings are based on minimizing routine sampling and analysis of groundwater samples, resulting in significantly lower costs associated with sampling, disposal of purgewater, and analysis of samples collected. The total cost for long-term monitoring using this technique is estimated to be reduced by a factor of about 100.

ACCOMPLISHMENTS: The CE microchip was integrated with an electrochemical detector, with placement of the working electrode at the outlet of the separation channel. Relevant parameters of separation and detection processes were optimized in connection to a mixture containing 10 ppm of 1,3-dinitrobenzene (DNB) and 2,4,6-trinitrotoluene (TNT). All separation potentials result in well-defined peaks for both DNB and TNT. As expected, increasing the separation potential from 1000 to 4000 Volts (in 500 V increments) dramatically decreases the migration time of DNB and TNT. Subsequent work employed a potential of 1500 V, and both substances could be readily detected within less than one minute when rapid detection was concerned. The electrochemical detection of nitroaromatic explosives is based on their low-potential reduction process. Both DNB and TNT display similar current-potential profiles with defined waves. Amperometric work employed a potential of -0.5 V that yielded the optimal detection. The MEKC separation of neutral (nitroaromatic) compounds requires addition of a surfactant, dodecyl sodium sulfate (SDS). Work employed a 15 mM borate buffer solution (pH 9.2), containing 20 mM SDS. Additional parameters that were varied and optimized included the carbon ink (used for fabricating the detector), curing temperature, electrode material, and surface coating.

TRANSITION: The field-portable analyzer will be broadly applicable to many hazardous waste sites. Although the target analytes in this project are explosives, the analyzer can also be extended to other pollutants. Collaborators at the Engineer Research and Development Center (ERDC) will be responsible for field-testing of the prototype analyzer, if the project extends into a continued development effort.

PROJECT SUMMARY

PROJECT TITLE & ID: Long-Term Monitoring for Explosives-Contaminated Groundwater; CU-1298 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mark Fisher; Nomadics, Inc. – Stillwater, OK

FY 2002 COMPLETED PROJECT

DESCRIPTION: The research team, specializing in creating sensors for mobile and field applications, applied proven technologies to develop a sensor for monitoring explosives in groundwater. The core technology for this sensor is a polymer-based platform developed by the Massachusetts Institute of Technology (MIT) and Nomadics that has demonstrated the ability to detect TNT and related explosive compounds with far greater sensitivity than any other technology currently available. This technology has been implemented in a system for detecting landmines and has proven to be quite effective. As a platform technology, this sensor can be integrated into a number of system configurations, including downhole probes, cone penetrometers, *in-situ* monitors for remediation process streams, and other accepted methodologies for site monitoring. In this effort, the team performed a proof-of-concept demonstration using a prototype downhole probe for detection of trace amounts of TNT and related explosives. Based on experience in the field by Nomadics and the published results of others, it is clear that the soil in proximity to buried landmines contains energetic material. The material partitions between the soil, water, and air in ways that have been well documented. Some of this material is transported into groundwater, where it is detectable by the Nomadics polymer. The Nomadics amplifying fluorescent polymer (AFP)-based detection technology has primarily focused on nitroaromatic compounds. Some of these are associated with the explosive material itself, while others are associated with biodegradation and photochemical degradation of the explosives-related compounds (ERCs). The amplifying polymer responds well to electron-deficient components. Therefore, the ERCs that are most likely to be detected are those containing nitro groups on an aromatic ring such as 1,3-DNB, TNT, 2,4,6-TNB, 2,4-DNT, 2,6-DNT, 4-amino-2,6-DNT, 2-amino-4,6-DNT, and tetryl.

BENEFIT: This approach offers virtually real-time sensing of explosives with essentially no waste production at a greatly reduced life cycle cost over what is currently available. Because the sensor technology resides on a modular platform, the concept can be applied to a number of other analytes/ parameters by replacing the sensor mechanism. It may even be possible to develop probes capable of monitoring multiple analytes. In this way, the system would be useful for other environmental monitoring applications.

ACCOMPLISHMENTS: Development of a prototype instrument that detects low ppb levels of TNT in water pumped across the Nomadics/MIT AFP sensor was successfully completed.

TRANSITION: Taking a technology from the lab to commercialization is a complex process and demands far more than technology development skills. In particular, skills in licensing and intellectual property management are required as is experience in strategic partnering and collaboration. Nomadics anticipates that the system could be fielded for less than $3000 per probe. Considering that reports for the Department of Energy estimate water sample costs at $300-425 per sample, ten samples would recover the cost of a probe. The fully automated system would cost more; however, the costs would be offset in a scenario of long-term sampling, particularly through reduced dispatches of personnel.

PROJECT SUMMARY

PROJECT TITLE & ID: Identification of Metabolic Routes and Catabolic Enzymes Involved in Phytoremediation of the Nitro-Substituted Explosives TNT, RDX, and HMX; CU-1317

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jerald Schnoor; The University of Iowa – Iowa City, IA

FY 2003 FUNDS: $160K

DESCRIPTION: Manufacture of explosives and military operations as well as destruction of ammunition stocks have generated toxic wastes leading to contamination of soils and groundwater. Phytoremediation is an innovative technology capable of sustained prevention of migration of surface and near-surface soil contamination by energetic materials, which is applicable to large, potentially vegetated areas and directed to the long-term control of energetic materials. Although higher plants have been shown to take up energetic pollutants from groundwater and soil, little information is available about the fate of pollutants inside plant tissues. In the absence of further transformation and detoxification, metabolites will sooner or later return to the soil, resulting in a pollution transfer and a potential biohazard for the environment. The objective of this project is to explore the metabolic routes and the catabolic enzymes involved in the transformation and detoxification of the nitro-substituted explosives TNT, RDX, and HMX by poplar trees – a model plant for phytoremediation studies. A secondary objective will be to investigate the toxicity associated with nitro-substituted explosives and phyto-transformed metabolites, once taken up inside poplar tree tissues.

BENEFIT: Investigation of metabolic pathways, catabolic enzymes, and toxicity associated with the phytotransformation of energetic pollutants will contribute to a better understanding of the approaches needed to contain energetic contamination source zones on large vegetated areas over the long-term. Satisfactory results would lead to the application of practical phytoremediation strategies for the removal of RDX, HMX, and TNT by hybrid poplar trees.

ACCOMPLISHMENTS: Results obtained with small whole plants showed that poplar trees were able to actively take up TNT, RDX, and HMX from the hydroponic solution. The uptake rate of TNT was significantly greater than for RDX and HMX; however, while TNT or its metabolites accumulated in roots, RDX and HMX accumulated preferentially in leaf tissues. Degradation experiments using plant tissue cultures showed that plant cells are also able to metabolize TNT, RDX, and HMX. TNT was reduced to ADNTs and DANTs, which are known to be far less toxic than TNT. Plant-mediated transformation of RDX and HMX resulted largely in the formation of unknown products that consisted partly of soluble polar metabolites and, to a larger extent, non-extractable compounds. Results strongly suggest the early intervention of nitrate reductases or nitroreductases. Initial reduction of RDX and HMX breaks the electronic equilibrium of the molecule and leads to a fast breakdown of the heterocycle, associated with the generation of small molecular weight aliphatic or mineral products. While TNT is also easily reduced by reductive enzymes, the rate-limiting step in the TNT metabolism is the breakdown of the aromatic cycle, which requires the intervention of more powerful catabolic enzymes.

TRANSITION: This research will help to isolate the role of plants on energetic degradation. Besides the behavior of explosive pollutants inside plants specifically cultivated for phytoremediation purposes, the approach will allow the potential hazard associated with the existing vegetation naturally growing on nitro-substituted explosives-contaminated sites to be investigated. Finally, the study provides a general approach to investigate the relevance and the efficiency of any phytoremediation system. The project intends to select an actual training range for eventual design and demonstration of the process.

PROJECT SUMMARY

PROJECT TITLE & ID: Engineering Transgenic Plants for the Sustained Containment and In Situ Treatment of Energetic Materials; CU-1318

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Stuart Strand; University of Washington – Seattle, WA

FY 2003 FUNDS: $189K

DESCRIPTION: Containment of explosives in sites such as training ranges that receive periodic inputs of energetic materials using existing technologies continues to be demanding and very expensive. While it may be feasible to prevent horizontal movement using physical barriers, vertical migration of the more mobile compounds such as RDX and HMX is a matter of major concern. Phytoremediation is generating excitement as an economical and self-sustaining alternative for containment and cleanup of toxic compounds. Plants have been shown to promote uptake, degradation and sequestration of TNT, but the activities are low and RDX is generally only partially transformed with RDX residuals being bound to plant tissues. In addition, phytoremediation is limited by the phytotoxicity of TNT and other munitions pollutants. These limitations can be addressed by the use of genetic engineering, whereby genes that encode enzymes active against xenobiotic compounds are expressed in plants. The overall objective of this project is to engineer transgenic plants that can be used to contain and degrade energetic materials on testing and training ranges. Both fundamental and applied studies will be undertaken to express in plants genes for the transformation and degradation of explosives. Bacterial genes that detoxify RDX, DNT and TNT will be inserted and expressed in tobacco, as a model plant system, and in poplar, black locust, and aspen, trees that are well-suited for sustained remediation of testing and training ranges.

BENEFIT: Ultimately, the project intends to develop a toolbox of plants with unique abilities to take up, contain, and degrade compounds used in military explosives, especially TNT and RDX. These plants will be made available for trials on Department of Defense testing and training ranges. Phytoremediation using these transgenics promises to provide a nonintrusive, inexpensive, self-sustaining, easily confined, and environmentally friendly method for preventing contamination of groundwater from munitions compounds used on training ranges.

ACCOMPLISHMENTS: The bacterial gene for nitroreductase has been introduced into poplar. This gene imparts an increased ability to tolerate and remove TNT from media. Tissues are being incubated under selection conditions for transformed plants.

TRANSITION: Transition of results in three stages is planned, including greenhouse studies of tree metabolism in years three and four of this project, controlled field trials commencing after the completion of this project, then full-scale implementation on an active training range with monitoring.

PROJECT SUMMARY

PROJECT TITLE & ID: Genetic and Biochemical Basis for the Transformation of Energetic Materials (RDX, TNT, DNTs) by Plants; CU-1319

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jacqueline Shanks; Iowa State University – Ames, IA

FY 2003 FUNDS: $215K

DESCRIPTION: The energetic materials of RDX, HMX, TNT, and DNTs are possible sources of groundwater and surface soil (less than 1 foot) contamination at Department of Defense testing and training sites. RDX, in particular, is more mobile than the other compounds in groundwater. Phytoremediation is an inexpensive, self-sustaining treatment technology that may be suitable for prevention of contamination. Plants have the capability of transforming TNT, while RDX is primarily taken up and accumulated as the parent compound. However, the practicality of phytoremediation is limited by the fact that these chemicals are phytotoxic to plants. In addition, the ability to develop plant-based remediation systems is restricted by insufficient understanding of how plants uptake and/or transform and metabolize these energetic materials. The overall goal of this project is to construct a genetic and biochemical knowledge base for the transformation pathways of energetic materials by exploiting the fact that these chemicals are phytotoxic (approximately 5 ppm for TNT and 20 ppm for RDX). Specifically, the project will (1) screen mutagenized populations of the model plant, *Arabidopsis thaliana*, to isolate mutants that are resistant to RDX, DNTs and TNT, due to under- or over-expression of individual genes, (2) use transcriptome and proteome analyses to identify mutants, and (3) use metabolite analyses to select final mutants and link gene to function.

BENEFIT: This project will provide a knowledge base in the genetics, pathway structure, and operation of metabolism of energetic materials. Studies will facilitate selection and/or natural breeding of beneficial plant species, metabolic engineering of transgenic plants for phytoremediation, environmental impact assessment of suspected energetic materials-contaminated media, and design of phytoremediation processes for the treatment of contaminated media.

ACCOMPLISHMENTS: In one approach to obtain mutants, mutagenized populations that are resistant to RDX, TNT and DNTs were screened. Three libraries of mutant *A. thaliana* plants have been created, including 1.5 million T-DNA knockout mutant lines, 150 thousand Enhancer-Trap mutant lines, and 125 thousand EMS mutant lines.

TRANSITION: This basic research project will provide genes, genetic markers, and metabolic information that will be disseminated to several different entities including academic researchers and government labs for further development of the phytoremediation technology. Information will be shared when appropriate with other principal investigators whose projects are further "downstream" in the technology development process. A website of results will be maintained. More traditional routes of dissemination such as presentations at conferences and publications in journals will also be followed.

PROJECT SUMMARY

PROJECT TITLE & ID: Optimal Search Strategy for the Definition of a DNAPL Source; CU-1347

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. George Pinder; University of Vermont – Burlington, VT

FY 2003 FUNDS: $125K

DESCRIPTION: Locating a DNAPL source is very difficult because of its filamentous nature and the fact that it is, in general, a rather small target. The goal of this research is to use measurements that are relatively easy to make, such as soil gas or groundwater concentrations, to provide guidance in finding the source. The overall concept is to identify, prior to a detailed site investigation, where to initially sample the subsurface to determine the DNAPL source characteristics and then to update the investigative strategy in the field as the investigation proceeds. The approach exploits the concept that DNAPL is indicated by the presence of a DNAPL species concentrations in excess of a specified value attributable to dissolution as described by formulae based upon Raoult's law. A computer-based search strategy that uses groundwater flow and transport modeling under uncertainty, a linear Kalman filter, and an optimization algorithm will assist the groundwater professional in defining the DNAPL source. The algorithm will indicate where, and if necessary when, to sample groundwater quality in order to define the location of the DNAPL containing area identified with the pre-specified concentration of the target compound. The computer-based search strategy is interactive and will provide information on the location and approximate shape of the source and the plume simultaneously and in real-time. The objective of this project is to develop, test and evaluate a computer-assisted analysis algorithm to identify the location and geometry of a DNAPL source.

BENEFIT: The deliverable in this research is a computer-based search strategy that can be used by groundwater professionals to obtain, at least cost, information regarding a DNAPL source geometry and its location. Improved DNAPL source zone delineation and characterization has the potential to significantly reduce the duration and costs of remedial efforts.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION: One or more professional short courses attended by agency personnel will be held to transfer the information/concepts and associated user-friendly software in a formal academic setting to include hands-on experience. An operations manuals describing the concepts and utilization of the software will be prepared. In addition, results will be published in referred professional journals.

PROJECT SUMMARY

PROJECT TITLE & ID: Using Advanced Analysis Approaches to Complete Long-Term Evaluations of Natural Attenuation Processes on the Remediation of Dissolved Chlorinated Solvent Contamination; CU-1348

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Doug Downey; Parsons Engineering Science, Inc. – Denver, CO

FY 2003 FUNDS: $126K

DESCRIPTION: Within the last decade, the in situ treatment/containment effects of natural attenuation processes have been specifically integrated into hundreds of selected groundwater remedies for chlorinated aliphatic hydrocarbon (CAH) plumes across Department of Defense (DoD) facilities, either as stand-alone monitored natural attenuation (MNA) remedies or as part of multi-component remedial designs. Meaningful inclusion of site-specific CAH attenuation data into early remedial planning efforts was facilitated by the development of technical guidance documents that focused on the initial characterization and data-analysis approaches that should be employed to determine whether MNA could play a significant role in long-term groundwater remediation strategies. There is now a need to develop supplemental technical guidance that focuses on methods to quantitatively evaluate the long-term performance (or sustainability) of MNA at achieving remedial objectives and numerical cleanup levels. The objective of this project is to identify and compile available alternate and/or advanced analysis approaches, including both predictive and interpretive models, that may be applied to site-specific characterization and long-term monitoring data to more thoroughly evaluate the long-term efficacy of CAH natural attenuation processes. Monitoring data from several DoD sites where MNA is part of the core groundwater remedy for CAH contamination will be compiled and evaluated using a select number of the advanced data-analysis techniques to create a compendium of case studies on how these various analysis approaches could be reasonably implemented, at the discretion of the DoD environmental manager, to address the analysis topics that could be a part of long-term MNA performance evaluations. Emphasis will be placed on determining how best to define cause-and-effect relationships that influence time-of-remediation estimates. The supplemental technical guidance document to be developed for DoD environmental managers will include details on potential data analysis techniques, additional monitoring requirement recommendations, and the case studies developed.

BENEFIT: This effort will produce a technical guidance document that will assist DoD environmental project managers in thoroughly understanding and being able to quantitatively document the predicted long-term sustainability and cost-effectiveness of relying upon natural attenuation processes to treat and/or contain dissolved CAHs. Potential advanced analysis approaches that may need to be completed in order to meaningfully incorporate site-specific CAH natural attenuation data into long-term remedial decision-making will be defined. Significant savings for the DoD are possible by identifying how to use state-of-the-art analysis approaches to determine which CAH natural attenuation processes could be expected to be sustained, if any, to achieve reasonable remedial endpoints.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION: The final report for this project will be written as a technical guidance document, specifically for DoD environmental project managers. Results will be presented at conferences and published in peer-reviewed journals and military media. Together, these efforts and the continued interest in this type of information by regulators should help to transition proof-of-principle supporting data to more DoD activities and private contractors.

PROJECT SUMMARY

PROJECT TITLE & ID: Integrated Protocol for Assessment of Long-Term Sustainability of Monitored Natural Attenuation of Chlorinated Solvent Plumes; CU-1349

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mark Widdowson; Virginia Tech – Blacksburg, VA

FY 2003 FUNDS: $420K

DESCRIPTION: Under suitable conditions, monitored natural attenuation (MNA) can be an effective strategy for restoring aquifer systems contaminated with chlorinated solvents. However, a better understanding of factors controlling the long-term sustainability of natural attenuation is needed along with methods to characterize and assess the potential for sustained MNA at chlorinated ethene contaminated sites. The following three objectives will be addressed: (1) Develop integrated protocols to assess the long-term sustainability of biological and physical attenuation processes for chlorinated solvents in groundwater; (2) Implement the protocols and develop methods for practical site analyses using software tools and computer models in conjunction with routine field tests and monitoring regimes; and (3) Field-test the protocols and field methods on selected Department of Defense (DoD) sites and evaluate effects of controllable and uncontrollable parameter uncertainty on remediation outcomes.

BENEFIT: The outcome of this project will be a practical methodology to quantitatively evaluate feasibility and long-term sustainability of natural attenuation at chlorinated solvent sites while reducing cost and controlling risk. Technical guidance and integrated protocols for assessment of biotic and abiotic natural attenuation processes at chloroethene contaminated sites will be prepared. At project end, DoD will have quantitative tools for predicting the time of remediation, the sustainability of natural attenuation processes within this timeframe, and the degree of uncertainty associated with such results.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION: Results will be presented at conferences and published in peer-reviewed journals. Following extensive peer review, the technical guidance document and assessment tools will be disseminated through DoD service groups, participating DoD partner agencies, and using Virginia Tech internet resources. Further validation at additional sites will be pursued. New software products and updates to the SEAM3D model will be distributed through various DoD agencies and licensed to the private sector through the DoD Groundwater Modeling System. A short course will be developed to train DoD personnel (program managers and contractors) and regulators with federal and state agencies on MNA protocols and use of the software and the new version of SEAM3D.

PROJECT SUMMARY

PROJECT TITLE & ID: Decreasing Toxic Metal Bioavailability with Novel Soil Amendment Strategies; CU-1350

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Philip Jardine; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2003 FUNDS: $502K

DESCRIPTION: There are thousands of metal-contaminated sites on Department of Defense (DoD) lands that are awaiting possible cleanup and closure. At metal-contaminated sites where public access will not be restricted, the ingestion of contaminated soil by children is the exposure pathway that generally determines the required degree of site remediation. The overall objective of this project is to develop an improved understanding and predictive capability of the enhanced immobilization and decreased bioaccessibility of hazardous metals in soil as a result of novel chemical amendment strategies. Metals of interest will be those that drive risk-based remedial action at DoD facilities, namely arsenic, chromium, cadmium, and lead. The specific objectives of this investigation are to develop (1) an improved understanding of the rates and mechanisms of enhanced metal sequestration in soils that have been treated with various organic and inorganic amendment strategies, (2) remedial protocols that maximize toxic metal sequestration and minimize bioaccessibility for a wide range of soil types and mixed metal systems, (3) an improved predictive capability for evaluating sequestration and bioaccessibility of mixed toxic metal systems for various amendments and soil types, and (4) a spreadsheet-based computer model to determine optimum soil remediation strategies, testing programs, and costs to meet risk targets with a specific level of confidence.

BENEFIT: The experimental and numerical results from this research will provide knowledge and information in previously unexplored areas of enhanced toxic metal sequestration and decreased bioaccessibility in soils to support DoD's performance/risk assessment and decision-making process for site restoration. Since actual and relevant DoD soils from more than forty Army, Navy, and Air Force sites will be used, many installations will benefit directly from this research. This project will provide a practical and scientifically defensible tool to reduce remediation costs at thousands of other DoD sites nationwide. With the spreadsheet-based computer model, site managers and risk assessors will be able to make better estimates of baseline risk, to determine if additional testing is cost-justified, and to determine the optimum soil amendment regime to minimize cost.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION: Results of this research will be transitioned to DoD and Environmental Protection Agency cleanup activities through both broad-based information transfer and site-specific technology transfer. Easy-to-use, validated, peer-reviewed models will be produced to estimate enhanced soil-metal sequestration and decreased bioaccessibility in a wide range of DoD soils. Results will be transferred to specific site cleanup activities through model validation using contaminated soils at specific DoD sites. Results will be presented at conferences, made available on the internet, and published in peer-reviewed journals, which is essential to facilitate regulatory and community understanding and acceptance. Further validation of the results through some site-funded in vivo studies will be pursued.

PROJECT SUMMARY

PROJECT TITLE & ID: Soil Amendments to Reduce Bioavailability of Metals in Soils: Experimental Studies and Spectroscopic Verification; CU-1351

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. M. Katherine Banks; Purdue University – West Lafayette, IN

FY 2003 FUNDS: $263K

DESCRIPTION: Thousands of Department of Defense (DoD) sites require cleanup as a result of contaminated soil. Heavy metals are among the most common pollutants, particularly lead (Pb), cadmium (Cd), arsenic (As), and chromium (Cr). Pollution with these metals at DoD facilities can be extensive and complete removal is prohibitively expensive. The overall objective of this project is to significantly and measurably reduce the bioavailability and chemical mobility of As, Cr, Cd and Pb in contaminated soils through the addition of soil amendments that bind the metals in place. Specific objectives include the following: (1) Determine the impact of adding phosphorus, sulfur-based compounds, iron-rich composted organic matter, and limestone (individually and combined) on the aqueous solubility and extractability of contaminant metals; (2) Quantify the residual toxicity of amended, metal-contaminated soils using standard bioassays including earthworms, lettuce germination/emergence, nematodes, and soil microorganisms; (3) Measure the effects of soil amendments on plant uptake (both metal-sensitive and hyperaccumulating) of contaminant metals; and (4) Use spectroscopic and structural methods to study the local environment of metals and the solid-phases that bind them.

BENEFIT: This research will elucidate the efficacy of each soil amendment approach, the chemical mechanisms involved, and the potential of each as a long-term solution for metal-contaminated soils. Several soil amendments that have the capability to immobilize contaminant metals will be identified. Implementation of the results on DoD sites will begin during the field verification phase of this project. Prospective facilities will be contacted with the objective of treating soils on their sites with the selected amendments. Ideal sites will be those that have elevated concentrations to make them of regulatory interest, but soils with metal concentrations greater than 10,000 mg/kg could be problematic in applying enough amendments to control lability over the long term.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION: Results will be presented at conferences and published in peer-reviewed journals. A general guidance document will be prepared to augment the final report, which will thoroughly discuss the implications of the data gathered in each phase relevant to the development and implementation of an amendment plan. The project team will also work with the private sector to develop a plan for commercialization of products. The project intends to transition to the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Facilitated Immobilization of Heavy Metals in Soil by Manipulation with Plant Byproducts; CU-1352

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Teresa Fan; University of Louisville – Louisville, KY

FY 2003 FUNDS: $100K

DESCRIPTION: Soil organic matter (SOM) is expected to play a key role in in-situ bioremediation of both inorganic and organic pollutants because it regulates pollutant transport and bioavailability and can be readily manipulated by organic amendments and/or plant growth. Lignosulfonates (LS) may be well-suited for use as organic amendments in immobilizing metal ions in contaminated soils. They are relatively resistant to microbial degradation, interact readily with metal ions, are available at low cost, and appear to be "friendly" in terrestrial environments. However, the chemical mechanism(s) underlying LS functions in these applications are unclear. Nor is it known how LS aging or humification can be exploited for metal stabilization. This one-year proof-of-concept project will explore the use of LS for metal sequestration at the bench-scale and address the following two questions: (1) Can LS amendment and subsequent humification help sequester heavy elements in soils? and (2) Can the chemical sequestration mechanism(s) be understood?

BENEFIT: Improved understanding of the fundamental mechanisms of metal ion-SOM interactions is vital to soil bioremediation since it is the organic portion of soil that is amenable to rapid, engineered manipulation by organisms or amendments such as LS to achieve desired long-term stability of the sequestered metals. Once the bench-scale work is complete, the tools developed will be readily applied to pilot- or field-scale studies, which can lead to mechanism-based choice of organic amendments and design of processes for superior long-term immobilization of pollutant metal ions.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION: If successful, this project will serve as a foundation for further laboratory and field studies to provide unprecedented mechanistic information regarding SOM binding of metals, thereby facilitating the use of metal sequestration processes with organic amendments such as LS. Follow-on work will be pursued to apply the acquired knowledge to pilot-scale field tests, in partnership with the Air Force Base Conversion Agency at McClellan. Through such efforts, a new organic amendment-based technology for metal sequestration may be developed and ready for full-scale deployment.

APPENDIX B
Compliance Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Investigations of Improvements in Environmental Accountability, Safety, Process, and Training for New Technologies and Deconstruction Methodologies; CP-819

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Allan Roberts; National Environmental Education & Training Center – Indiana, PA

FY 2002 COMPLETED PROJECT

DESCRIPTION: New environmental technologies are often designed for efficacy with little consideration given to the safety of the technology to an operator, a maintenance worker or the community. As a result, significant time and energy is spent on re-engineering technologies to address health and safety issues. This project sought to assist development of maximal worker and environmentally protective processes and technologies. The goal was to produce efficient processes and technologies that are intrinsically safe and environmentally protective. The new processes and technologies were accompanied by upgraded information and training packages that foster safe, efficient implementation. The project focused on two specific areas, improvement of health and safety in new environmental technologies and development of more efficient processes in the dismantling and recycling of the Maritime Administration (MARAD) and United States Navy ships. Health and safety aspects included development of internet-based software that allow technology developers to incorporate safety in their designs and a series of field safety evaluations of environmental technology tests that result in the production of safety documents and an informational compact disk. The ship recycling project involved the cooperation of the Navy and private companies and investigated processes with a view towards improving them. Improvements involved process changes or technology introductions. Studies concerned actual cutting, recycling issues, improvements to planning, and development of more efficient training.

BENEFIT: The tools and data developed under this project, when coupled with existing "engineering design and management tools" will assist designers and technology implementors in evaluating and assessing health and safety issues in a focused, systematic way. It will lead to a consideration of worker and environmental safety and health implications associated with field (or production) use of innovative technology, and minimize the occurrence of health and safety concerns before and during end-user implementation. The ship dismantling project presents an opportunity to address the growing environmental problems posed by the MARAD and United States Navy inactive fleets, while creating jobs and spurring economic growth.

ACCOMPLISHMENTS: Information was collected on environmental and worker safety and health aspects of ship dismantling. Worker hazards along with appropriate OSHA standards requiring expenditures on personal protective equipment, training, and medical exposure testing were identified. These form the basis for defining specific variable safety and health costs. In addition, some preliminary information was collected on ship cutting technologies. The core objective of the project, namely, the development and checking of an alternative profit/cost model was accomplished. The model does provide a method for explicitly accounting for the impact of worker safety and health costs, environmental costs, and labor costs for different technologies on unit profit, within the general framework of cost and profit accounting for ship dismantling.

TRANSITION: Transition consists of full implementation of an expert system made available on the Internet or on diskette, demonstration at two technology development sites, and integration with a similar DOE program. Implementation of an outreach program via the Internet is also planned.

PROJECT SUMMARY

PROJECT TITLE & ID: Optimization of an Innovative Biofiltration System as a VOC Control Technology for Aircraft Painting Facilities; CP-1104

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kerry Kinney; University of Texas – Austin, TX

FY 2002 COMPLETED PROJECT

DESCRIPTION: Currently available VOC emission control technologies are costly at the high volumetric flow rates and low contaminant concentrations associated with the ventilation of aircraft hangars. This project developed an innovative, high flow-rate biofiltration method for treating VOC-laden air emissions. Biofiltration of painting off-gas streams currently is limited, not because of insurmountable technical problems but simply because current systems have not been designed to handle the operating conditions typical at these facilities. Innovative design features and biofilter configurations were investigated, tested, and applied to an actual Air Force paint spray booth.

The following innovative design features were investigated for their ability to improve biofilter performance for paint spray booth applications: (1) a recirculating inoculation method to shorten the bioreactor start-up period; (2) directionally-switching operation to improve biomass distribution and prevent clogging; (3) slip-stream feed to maintain high biomass activities during paint spray booth shutdown periods; and (4) an aerosol nutrient delivery system to efficiently deliver nutrients and moisture to the biofilm. Since bioreactor performance is strongly influenced by the contaminants being treated, the effectiveness of each design modification was determined under single (e.g., ethyl acetate) as well as multiple [e.g., methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), toluene] contaminant conditions representative of paint spray emissions.

BENEFIT: The project will provide a stable biofiltration system for paint spray booth applications that operate intermittently and emit varying quantities of VOCs. Typical biofilter problems, such as long acclimation times, slow response to load changes, and biomass clogging will be overcome. The innovative biofiltration process developed by this project will, therefore, be suitable for venting of aircraft hangars during application or removal of coatings. It has the added advantages of operating at ambient temperatures and minimizing the generation of secondary wastes.

ACCOMPLISHMENTS: The project demonstrated that optimized vapor phase bioreactors can achieve removal efficiencies of greater than 95% for representative paint mixtures. Several bioreactor configurations have been successfully tested at the lab scale including a biotrickling filter design, a foam-packed biofilter and a hybrid biotrickling filter/biofilter system. In all systems tested, the hydrophilic components of the paint mixture were readily removed while the degradation of the aromatic hydrocarbon constituents was found to control the overall removal efficiency achievable in each system. Nitrogen supply and microbial inoculation techniques were found to be critical operating parameters and were optimized to improve performance of the vapor phase bioreactors. Directionally switching operation, slip feed design and other operational strategies were also utilized to ensure stable performance. A paint booth was designed to supply actual DoD paint VOC emissions into the bioreactor unit.

TRANSITION: The primary users of the biofiltration technology will be DoD paint spray booth facilities; however, the technology also will be widely applicable to the private sector. Research results are being published in forums that reach a large audience of professionals in air pollution control including the Annual Meeting of Air and Waste Management Association. A web site also will be dedicated to the proposed research and will include brief statements related to research objectives and interim results.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of Particulate Emission: Size Characterization and Chemical Speciation; CP-1106

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Adel Sarofim; University of Utah – Salt Lake City, UT

FY 2002 COMPLETED PROJECT

DESCRIPTION: The objectives of this project were to develop advanced methods for the measurement of the size distribution and composition of particulate matter (PM) emitted from mobile and stationary sources and provide the DoD with the tools needed to characterize and control the emissions from DoD facilities. The data obtained during the evaluation of the instruments provide a measure of the relative importance of different DoD sources that are useful for guiding strategies for controlling the emissions from DoD facilities. The cost effectiveness of different measurement methods were assessed and recommendations made for the best protocols for measurement of fine particle emissions. Two innovative techniques for rapid measurement of fine particles were used in combination with a dilution sampler. The first is an aerosol time of flight mass spectrometer (ATOFMS) that measures the size and composition of individual articles. The second is a photoelectric aerosol sampler (PAS) which, in combination with a photoacoustic elemental detector (PED) for carbon, provides rapid measurement of the polycyclic aromatic hydrocarbon (PAH)-laden carbonaceous particles which dominate the emissions from combustion sources. These devices were applied in parallel with more conventional measurement techniques to establish their validity for characterizing the particle emissions from DoD sources. Multiorifice impactors (MOI) combined with chemical analysis were used to obtain chemical characterization sufficiently detailed to close material balances on the emissions. Optical particle counters (OPC) and differential mobility analyzers (DMA) were used to obtain detailed size distributions in order to calibrate the ATOFMS and PAS.

BENEFIT: The project will provide DoD with rapid measurement procedures for organic and inorganic particulate emissions at greatly reduced cost per analysis, as well as detailed chemical compositions of major particulate source categories by size. Assessments will be provided of the relative cost of alternative measurement strategies, ease of use, potential use for feedback control, reliability, and speed.

ACCOMPLISHMENTS: Exhaust emissions from a Stage II Minuteman rocket motor were collected and analyzed at the Hill AFB testing area by using two of the ATOFMS instruments that could size and chemically characterize particles between 3-250nm. Sampling was also conducted on wood and coal samples. Analysis of this data showed size and composition of ultrafine particles due to coal combustion and wood smoke, and the differences between the ultrafine and semimicron particles collected in previous source tests. The effects of operating a test engine on both diesel and JP-8 aviation fuels by use of the MOUDI were analyzed for particle mass, elemental and organic carbon and sulfate ion. Results indicated that emissions from the two fuels did not differ significantly. Final tests of the active diesel filter showed that the active filters reduced particulate matter by approximately 40-70%. This is significantly less than the passive filters, which reduced emissions by at least 90%.

TRANSITION: The techniques used in the advanced source test system will be evaluated in terms of ease of use, time of sampling to obtain data, time to analyze data, and capital and operating costs. Negotiations are in progress to produce a commercial version of the ATOFMS. The current project will have developed the calibrations necessary for producing quantitative emission measurements on DoD sources as well as provided a measure of the cost effectiveness of using this technology. Personnel from Hill Air Force Base and the Air Force Research Laboratory will evaluate the ease of transfer of the instruments to the field.

PROJECT SUMMARY

PROJECT TITLE & ID: Reduction of Particulate Emissions from Jet Engine Test Cells Using an Annular After-Reactor; CP-1126

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Norman L. Helgeson; Naval Facilities Engineering Service Center – Port Hueneme, CA

FY 2002 COMPLETED PROJECT

DESCRIPTION: This project developed a prototype Annular After Reactor (AAR) jet-engine attachment to reduce particle emissions from jet engine test cells (JETC). The AAR, positioned in the flow path of the jet engine exhaust tube, is simply a hollow pipe that delays mixing of exhaust gases with the surrounding air stream for a sufficiently long residence time to permit incineration of the particulate matter (PM), up to 90%, with minimum pressure drop. With a slight modification, the system may also be adapted for removal of NO_x, CO and unburned hydrocarbons.

The project was carried out in four phases: (1) analytical and computer studies to refine the basic AAR fluid dynamics model and establish design criteria for field tests; (2) intermediate-scale field testing to complete the AAR design; (3) full-scale AAR system fabrication and field testing at a California Naval Air Station; and (4) data reduction and analysis to provide the recommended AAR system for PM reduction. The most challenging technical aspect of this study was the efficient and rapid mixing, and combustion, of the injected natural gas within the AAR to achieve a proper temperature profile. Excessive pressure drops were expected to be eliminated by using a jet exhaust diffuser on the inlet to the AAR. The challenges of non-steady operating conditions were addressed by using a feed-forward control system to make required AAR adjustments in concert with programmed changes in engine operating conditions. By maintaining the temperature of the exhaust gases within the AAR at 2000 °F, the generation of nitrogen oxides within the AAR were insignificant.

BENEFIT: The DoD and DOE need new, cost-effective technologies to comply with the proposed, more stringent EPA National Ambient Air Quality Standards (NAAQS) for particulate matter below 2.5 microns ($PM_{2.5}$) for sources such as JETCs, and future National Emission Standards for Hazardous Air Pollutants (NESHAP) specific to JETC emissions. If demonstrated to be effective, the AAR is a minimum-capital-cost, minimum-operating cost approach for reducing PM emissions from JETCs.

ACCOMPLISHMENTS: Several runs of AAR to evaluate NOx reduction proved to be very smooth in operation: it ignited easily and burned stably, and uniform temperature environments were created in the AAR for PM burn-up. Test results seemed quite promising with good PM reduction at lower than anticipated temperatures - as low as 1800 F suggesting that PM reduction and NH_3/NOx reduction could be conducted simultaneously. However an increase in PM levels towards the end of each testing resulted in further investigation. Almost all of the testing was conducted with CH_4 fuel as opposed to a mixture of H_2/CH_4 which demonstrates the effectiveness of the combustor design.

TRANSITION: The Army, Navy, and Air Force have each expressed an interest in application of this proposed technology. In addition to JETCs, this technology has the potential to transition to other stationary and mobile sources of combustion emissions. An added benefit of the use of this technology is a reduction in noise of 15-20 dB.

PROJECT SUMMARY

PROJECT TITLE & ID: Distribution and Fate of Energetics on DoD Test and Training Ranges; CP-1155

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Judith Pennington; U.S. Army Corps of Engineers Engineer Research and Development Center, Environmental Laboratory – Vicksburg, MS

FY 2003 FUNDS: $1085K

DESCRIPTION: The primary objective of this project is to provide DoD with techniques to assess the potential for groundwater contamination from residues of high explosives at testing and training ranges. Determining the concentration of post blast residues will focus on identifying the appropriate analytes for various range firing activities, identifying major sources of explosives contamination, and overcoming the large spatial variability in the distribution of contamination on ranges. The effects of munition type, range activities, and geographical and climatic conditions will be evaluated by sampling on ranges located at various sites across the country. The extent of contamination from higher order detonations will be determined by sampling impact craters on active ranges and by conducting detonations on pristine snow. The extent of contamination from various degrees of low order detonations will be determined by creating low order detonations under controlled conditions where full recovery and analysis of contaminants is possible. Once the composition of post-blast residues is determined, environmental transport parameters will be developed and the distribution and concentration of the residues at ranges will be estimated. These data can be used to estimate site-specific source terms for use in risk assessment and fate and transport models.

BENEFIT: Project results will document activities at test and training ranges that have the potential to cause groundwater contamination by residues of high explosives. Immediate benefits will include guidance for characterizing contamination, tools for anticipating the potential for environmental impacts and for demonstrating responsible management of facilities to sustain their use for testing and training. These methods could result in substantial cost saving for site characterization, and sustained use.

ACCOMPLISHMENTS: Range characterization studies have encompassed seventeen locations including four Canadian sites and a site in Hawaii. Residues from high- and low-order detonations and firing points of heavy artillery have been characterized at eight U.S. and two Canadian installations representing a wide range of climatic and geological conditions. Results indicate contamination ranging from nondetectable to extremely low-levels distributed across these ranges and interspersed with hot-spots of higher concentrations around targets and low-order detonations. Composition, distribution, and concentrations of residues vary with range use (artillery, antitank, etc.). Distribution of residues is extremely heterogeneous. Results of various sampling strategies demonstrate that multi-increment composite sampling, careful subsampling in the laboratory, and the low detection limit GC-ECD analytical method are needed to adequately characterize these ranges. Residues of propellants were detected around firing points of heavy artillery. Results from the characterization of four hand grenade ranges reveal low concentrations of explosives residues that are more homogeneously distributed in a smaller area than residues on artillery ranges. These areas are amenable to periodic remediation. Controlled high-order detonations were performed on pristine snow at three test ranges. This test permits determination of the spatial distribution and concentration of explosives residues from the specific munitions tested. Controlled low-order detonations have been conducted at one site with two munitions, 81-mm mortars and 155-mm artillery projectiles. Results demonstrate the quantity of explosive residue generated with various low-order energy yields. Environmental fate and transport process descriptors have been determined to fill data gaps on explosives observed on training ranges. These included dissolution kinetics for three explosives formulations and the individual explosives comprising them, and partition coefficients and transformation rates for nitroglycerine, transformation products of RDX (MNX, DNX, and TNX), 2,4- and 2,6-DNT, nitrobenzene, and picric acid. These data contribute to a scientific database for modeling transport of explosives contamination from the surface to ground water and for determining the exposure component of environmental risk assessments.

TRANSITION: Programs in place at all of the performing organizations will facilitate future widespread application of the procedures to determine the distribution and fate of energetics on DoD test and training ranges. Researchers at the U.S. Army Corps of Engineers ERDC Environmental Laboratory and Cold Regions Research Environmental Laboratory, as well as Sandia National Laboratory (SNL) are actively involved in developing procedures to assess the fate and transport of explosives from UXO. The research team has been advising the National Guard on the complex problems with explosives at the Massachusetts Military Reservation. A demonstration program under the Environmental Security Technology Certification Program (ESTCP) can validate guidance with on-site evaluation and modeling that are developed in the proposed project with which ERDC and SNL have prior experience.

PROJECT SUMMARY

PROJECT TITLE & ID: Determining the Fate and Ecological Effects of Copper and Zinc Loading in Estuarine Environments: A Multi-Disciplinary Program; CP-1156

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. D. Bart Chadwick; Space and Naval Warfare Systems Command – San Diego, CA

FY 2003 FUNDS: $373K

DESCRIPTION: The objective of this work is to produce a method for estimating the impact of copper and zinc loading in estuarine environments. Copper and zinc species are incorporated in a hydrodynamic (physical) estuarine model that simulates the principal estuarine topography, tidally-driven currents, meteorology, and bottom characteristics. The model is used to compute water residence times in the estuary, the key physico-chemical variable against which all other rate-dependant processes are evaluated. Steady-state concentrations of metal species, including the steady-state concentrations of the "free" hydrated metal ion are computed from the hydrodynamic model, using known or experimentally measured input and sedimentation data for the estuary. The computed steady-state concentrations of copper and zinc species are then compared to the experimental data and the model is fine-tuned by adjusting interspecies reaction (rate) constants, until the model is optimized to reproduce the copper and zinc dynamics. The environmental impact of the steady-state concentrations of the toxic copper and zinc species are evaluated in laboratory tests, as well as through field observations. The principal investigators from this project are collaborating with the other two SERDP projects on copper and zinc in estuarine system (CP-1157 and CP-1158) and with other Navy projects working in this subject area in an effort to foster close cooperation and exchange of information. In addition, the three SERDP projects have developed unified sampling and analysis techniques.

BENEFIT: This program will benefit the Department of Defense (DoD) and broader environmental compliance by: (1) the methods and data developed will be important to the DoD Uniform National Discharge Standards Program (UNDS); and (2) the information from this project will be transitioned to DoD environmental managers dealing with facilities and dredging compliance issues. The science resulting from the project should provide a basis for DoD to work with Environmental Protection Agency (EPA) in developing water quality criteria which account for the importance of metal species and complexation on toxicity. Finally the scientific approach developed under this program can be used as a model for supporting development of reasonable criteria and standards for other metals and contaminants.

ACCOMPLISHMENTS: An assessment of the 1D model was carried out to determine the sensitivity to a range of input parameters including settling rates, partitioning coefficients, concentrations of metals and binding fractions such as total suspended solids (TSS). The sensitivity analysis was carried out based on the observed range of these parameters in the San Diego Bay study region, and the model was optimized based on a least-squares best fit analysis to the field data. Analytical efficiency was enhanced by setting up additional polarographic systems for the analysis of complexation capacity. Systems were implemented for the analysis of both copper and zinc complexation. Additional analytical capabilities have also been established at Scripps to support the evaluation of complexation capacity in relation to ecological conditions in San Diego Bay.

A complete second round of field surveys was conducted to evaluate seasonal/interannual variability of Cu and to evaluate Zn speciation in more detail. The Bay was mapped for copper and zinc species along with a broad range of potential controlling parameters including temperature, salinity, chl-a, pH, dissolved oxygen, etc. Discrete samples were collected for additional analysis of complexation capacity, toxicity, organic carbon, particulate matter, microbiology, etc. The sampling was carried out in close coordination with collaborators from University of Wisconsin, Scripps and Naval Research Laboratory. The copper results from this second round will provide the basis for a rigorous validation of the 2D speciation model capability, and for an initial assessment of the zinc 1D fate and transport model.

Initial development of a 2-D model for total copper in San Diego Bay was carried out. This development utilized loading and loss parameters that were optimized from the field data and the 1-D model. Tests of this 2-D model showed that it provided reliable predictions of the total copper distribution in San Diego Bay. The 2-D model provides significant improvement over the 1-D model in resolution of both spatial and temporal variations of copper.

Incorporation of speciation kinetics and equilibria into 2D model was also completed for the prediction of copper speciation. Again, the speciation parameters were based on optimization from the first year field data and numerous runs from the 1-D model. Initial runs from the 2-D model were completed for conditions simulating typical summer/fall loading and partitioning conditions in San Diego Bay. Simulated fractions included free copper, colloidal copper, and particulate copper.

During this period, researchers also incorporated and carried out standard EPA toxicity testing for Zn on ambient bay waters in San Diego Bay. The testing included samples from a range of spatial and seasonal conditions, and were conducted for multiple species. Initial results indicated that zinc levels in San Diego Bay are about one order of magnitude below typical response thresholds for toxicity.

TRANSITION: The products of this project will be transitionable to the Environmental Security Technology Certification Program with proposed joint funding from the Navy. Technology transfer will be through peer-reviewed journals, technical reports, and symposia. A workshop was held in November 2000, co-sponsored by the Navy Applied Research 6.2 Program, to address copper and zinc technical and regulatory issues.

PROJECT SUMMARY

PROJECT TITLE & ID: Speciation, Fluxes, and Cycling of Dissolved Copper and Zinc in Estuaries: The Roles of Sediment Exchange and Photochemical Effects; CP-1157

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Stephen Skrabal; University of North Carolina – Wilmington, NC

FY 2002 COMPLETED PROJECT

DESCRIPTION: The goals of this study were to: (1) quantitatively determine water column concentrations and benthic fluxes of total dissolved (TD) copper (Cu) and zinc (Zn), dissolved Cu- and Zn-complexing ligands, and ancillary parameters at two sites in the Cape Fear Estuary, NC; (2) determine changes in cycling, fate, and organic speciation of dissolved Cu and Zn that may occur during resuspension events, focusing on the role of photochemical reactions; and (3) examine the effects of a large-scale dredging project on the speciation, fate, and cycling of Cu and Zn in estuarine waters and sediments. Sediment and water sampling was conducted primarily at two sites, each of which were subject to shipping and berthing activities representative of Department of Defense (DoD) harbor facilities. Water column samples at the surface (~2 m depth) and near the bottom (1-2 m above the sediment surface) were collected and filtered in the field using a clean pumping and filtration system. Benthic fluxes of TD Cu and Zn, dissolved Cu- and Zn-complexing ligands, and dissolved organic carbon (DOC) were measured using a core incubation technique. Controlled photolysis experiments were performed on sediment suspensions. The principal investigators from this project collaborated with the other two SERDP projects on copper and zinc in estuarine systems (CP-1156 and CP-1158) and with other Navy projects working in this subject area in an effort to foster close cooperation and exchange of information. In addition, the three SERDP projects developed unified sampling and analysis techniques.

BENEFIT: The results of this project will be used to develop scientifically-based water quality standards for copper and zinc in the aquatic environment. The data presented by this project will provide information on the potential amelioration of copper and zinc by dissolved organic ligands in harbors and estuaries. This data can be used by the DoD to evaluate water quality compliance criteria that are based on environmentally-relevant impacts of metal discharges and hence to ensure that economic resources devoted to environmental monitoring and compliance are most efficiently utilized.

ACCOMPLISHMENTS: Benthic flux experiments were completed and several resuspension experiments were performed using natural sediments in estuarine water exposed to both light and dark conditions, and monitored for changes in Cu, Cu ligand, and dissolved organic carbon (DOC) concentrations over time. Further experiments were conducted in which sediment cores were subjected to a disturbance to observe how it affected metal, ligand, and DOC concentrations in the overlying water. An important finding from the Cu speciation work completed in Cape Fear was that concentrations of strong Cu complexing ligands are very conservative with respect to salinity in the estuary, similar to the behavior of DOC. The implication is that strong Cu-complexing ligand concentrations can be well predicted on the basis of DOC. Such a predictable relationship proposes to be a valuable water quality tool, because DOC is much easier to measure than Cu speciation.

TRANSITION: The data presented by this project will provide information on the potential amelioration of Cu and Zn by dissolved organic ligands in harbors and estuaries. This data can be used by DoD to evaluate water quality compliance criteria that are based on environmentally relevant impacts of metal discharges, and hence to ensure that economic resources devoted to environmental monitoring and compliance are most efficiently utilized.

PROJECT SUMMARY

PROJECT TITLE & ID: Speciation, Sources, and Bioavailability of Copper and Zinc in DoD Impacted Harbors and Estuaries; CP-1158

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Martin Shafer; University of Wisconsin – Madison, WI

FY 2003 FUNDS: $100K

DESCRIPTION: The overall goal of this project is to advance the current understanding of the fate and impact of copper and zinc in harbors and estuaries. Specifically, the project develops a quantitative understanding of the speciation, bioavailability and fate of important metal species transported to and found within Department of Defense (DoD)-impacted harbors. The objectives of this project are to: (1) apply and refine methods for speciation of copper (Cu) and zinc (Zn) in harbor and estuary waters; (2) assess the influences of environmental factors and processes on the speciation and fate of Cu and Zn; (3) interpret experimentally determined lability estimates of dominant metal-complexes in terms of time scales relevant to biological and physical processes in DoD impacted harbors; (4) compare modeled estimates of bioavailability of specific phases with biochemically determined exposure on experimental organisms; and (5) determine sources of Cu and Zn to harbors and estuaries using a multi-faceted approach of selective sampling, metal phase discrimination, and unique stable isotopic signatures to distinguish DoD sources of Cu and Zn from other sources to harbors and estuaries.

By isolating functionally distinct metal "pools" within harbor systems, the lability of Cu and Zn within these pools can be characterized. The nature and sources of ligands in specific pools are determined by chemical and biochemical means. Measurements of liability in specific pools, as defined by chemical and physical speciation techniques are complemented and validated by bioassays at both the molecular and organism level. Stable isotopes of Cu and Zn will be explored as tracers of source and source specific bioavailability.

The principal investigators from this project are collaborating with researchers working on two other SERDP projects studying copper and zinc in estuarine systems (CP-1156 and CP-1157) and with other Navy projects working in this subject area in an effort to foster close cooperation and exchange of information. In addition, the three SERDP projects have developed unified sampling and analysis techniques.

BENEFIT: These findings will allow the development of a method for the assessment of the potential of Cu and Zn to impact biological communities. This work, therefore, will have direct bearing on the establishment of water quality criteria in these systems. This study will provide a crucial test of the applicability of stable isotopes to aid in source reconciliation and bioavailability studies. Important parameters will be established from which the precision of source assignment can be assessed. Source tracing and apportionment using stable isotopic signatures should have broad applicability to both aquatic and terrestrial DoD sites and the exploratory work in this study will provide that assessment.

ACCOMPLISHMENTS: Methods for isolating Cu and Zn from seawater for stable isotope analysis were optimized. Researchers are obtaining end-member samples of geologic ores and processed paint/coating materials for Cu and Zn stable isotope analysis. Early data demonstrates that the isotopic signature of impacted harbor samples is similar to that of anti-fouling paint leachates but significantly different than seawater and certain copper containing salts. Comprehensive field studies of the San Diego and Norfolk estuaries and at the Cape Fear study system were completed. Researchers have demonstrated that Cu-binding ligands are found predominantly in the colloidal size fraction, and that algal pigment levels show a strong correlation with Cu-binding ligand concentrations, suggesting that strong ligands are derived from algal exudates. Levels of strong Cu-ligand are in large excess of Cu levels at both Cape Fear and Norfolk; however, in San Diego, concentrations of ligand and Cu are similar.

A preliminary model is under development, which relates chemical speciation to several bioassay endpoints - a tool which will greatly aid regulators and aquatic toxicologists in assessing potential impacts. The data/model demonstrates that Cu uptake into cells can be accurately predicted from levels of strong ligand. This development will also significantly advance the state-of-the-art of effects and speciation based regulation, rather than limit setting based on crude total metal levels.

TRANSITION: The technology underpinning the method of assessing the potential of Cu and Zn to impact biological communities should be readily transferable to DoD or DoD contractors. Data developed on Cu and Zn sources to, and within, the study systems will be used to construct or refine mass balances of metal loading. When coupled with information generated from this study, on source specific metal availability, appropriate resources can be directed to controlling inputs with the greatest potential for ecosystem impact. Recommendations along these lines will be prepared for DoD, which may then use these data in future permitting applications. DoD can use information from this project to determine whether stable-isotope technology should be applied to other impacted sites.

PROJECT SUMMARY

PROJECT TITLE & ID: A Predictive Capability for the Source Terms of Residual Energetic Materials from Burning and/or Detonation Activities; CP-1159

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Charles Kolb; Aerodyne Research, Inc. – Billerica, MA

FY 2003 FUNDS: $175K

DESCRIPTION: The overall goals of this project are to: (1) understand and quantify the major chemical and physical processes, such as afterburning effects, and formation and deposition of particles; (2) develop a Source Characterization Model (SCM) for predicting accurately the source terms resulting from the burning and detonation of munitions, including both gaseous and particulate species; (3) link the SCM output to appropriate fate and transport models in air, soil, or water medium; and (4) validate the final SCM against a few typical scenarios. This project is developing the SCM and related databases and linking them to available dispersion and transport models. The input to the SCM includes munitions or energetic identity and weight, ambient site conditions, and site-specific conditions for the open burn/open detonation (OB/OD) or use of munitions. The SCM includes algorithms, supporting databases, and a graphical user interface for the prediction of chemical identities and emission factors, particle size and deposition, plume buoyancy, and plume size at final rise. The output of the SCM is used as input conditions to existing transport and dispersion models in air, water, and the ground surface.

BENEFIT: The estimated benefits to the Department of Defense (DoD) are cost reduction by modeling of source terms and cost of incomplete responses to regulatory concern. The total cost of emission characterization by testing for an estimated 400 unique munitions could cost DoD from $0.5 billion to $1 billion. Assuming that only 1 in 20 munitions requires testing and the rest can be modeled, the savings from modeling could exceed $475 million. Typically an installation may spend up to $2 million monitoring groundwater and sampling soil in order to satisfy regulators and the public that munitions use or OB/OD has no impact to human health or the environment.

ACCOMPLISHMENTS: Research over the period between 2000 and 2002 focused on three major technical objectives: develop the SCM; develop an emissions database for HE explosives; and validate SCM predictions and impact assessments with available data.

Model development is based on a straightforward phenomenological description of HE explosive detonation and emissions dispersion that breaks the overall process into three distinct stages. Stage 1 refers to the detonation and rapid expansion of the initial explosive fireball to near ambient pressures. The largest uncertainties in model predictions are associated with the treatment of stage 1 processes and chemical emissions. Consequently, model development relied on available detonation test data obtained by the Aberdeen Test Center to compensate for modeling deficiencies. Stage 2 refers to subsequent dynamics and chemical interactions for the high temperature plume as it interacts with the ambient air. Stage 2 includes the buoyant plume rise and advection through to equilibration with the ambient atmosphere. Afterburning gas phase kinetics, particle interactions, and wet/dry deposition processes are included. Stage 3 refers to long time dispersion of emissions after the detonation plume has equilibrated with the ambient air. Emissions dispersion is dominated by atmospheric turbulence. A complete model for Stages 1 and 2 has been developed that outputs critical emission parameters that can be used as input to existing atmospheric dispersion models to treat Stage 3 processes.

Progress has been made on emissions database development and model testing and validation. The emissions data is a web-based archive of detonation products data for military-relevant munitions and explosives. SCM validation studies focused on emission factors for gas phase species reported as part of the Exploding Ordnance Emission Study at U.S. Army Environmental Center. A total of 5 test items were treated.

TRANSITION: The modeling capability developed by this project will be a public domain environmental assessment model. It will be reviewed for acceptance by applicable EPA offices involved in emissions modeling. Subject to EPA approval, it will be made available through the EPA regulatory support electronic bulletin board. The project results will be presented to potential users via journal articles, symposia, and technical reports. The potential users include all DoD, DOE, and EPA activities involved in OB/OD.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of $PM_{2.5}$ Dust Emissions from Training/Testing Range Operations; CP-1190

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Veranth; University of Utah – Salt Lake City, UT

FY 2003 FUNDS: $182K

DESCRIPTION: This project is conducting field measurements and laboratory analyses of windblown dust and road dust resulting from troop operations at arid sites in the western United States. The goal of this study is to provide installation-level environmental staff with scientifically validated information for developing emissions inventories, environmental assessments, and cost-effective dust control measures that are compatible with mission readiness. Source samples, laboratory analysis of these samples, development of advanced sample analysis techniques, theoretical modeling, and measurement of field emissions and receptor site particulates constitute the major components of this study. The study is based on two hypotheses developed from previous studies of dust emissions in arid climates. Only a small fraction of the dust that is initially suspended is actually transported long distances. Dust emissions from various sources potentially contain marker species that are present at higher concentrations than the regional background, and these markers can provide sensitive methods for quantifying the contribution of various source categories to the particulate collected at receptor sites. The experimental program tests these hypotheses with an integrated program of sampling dust at multiple locations and elevations above grade during selected troop operations on unpaved roads or cross-country trails.

BENEFIT: The direct products of this study will include (1) a critical evaluation and review of source characterization, dust emission inventory, and transport modeling technology applicable to training/testing range operations, and (2) technical papers regarding field measurement, sample analysis, and data reduction methods. Based on the detailed sampling and analysis in this study, specific recommendations will be made regarding appropriate methods for routine use in dust characterization studies.

ACCOMPLISHMENTS: The field sampling and laboratory analysis of fugitive dust source areas at military bases and areas near Class 1 receptor sites in the western United States has been completed and data reduction and preparation of a publication is in progress. Field experiments measuring dust transport were conducted at Dugway Proving Ground, UT and Ft. Bliss, TX. A conference presentation and a journal article have been prepared based on the near-source dust measurements from Dugway. Work on innovative dust sample analysis methods by microscopy and thermal desorption is in progress. A preliminary source-receptor study was conducted at Ft Bliss and the data will be used in the design of the Year 3 field study.

The SERDP-funded work has been leveraged by collaboration with a Western States Air Resources Council-funded study that considered whether adjustments should be made to current methods for modeling fugitive dust. This collaboration also serves as technology transfer to air quality regulatory agencies.

TRANSITION: The direct products of this study will include a critical evaluation and review of source characterization, dust emission inventory, and transport modeling technology applicable to training/testing range operations and technical papers regarding field measurement, sample analysis, and data reduction methods. This technology will be transferred to potential users by the investigators and by members of an advisory panel.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterizing and Quantifying Local and Regional Particulate Matter Emissions from DoD Installations; CP-1191

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Gillies; Desert Research Institute – Reno, NV

FY 2003 FUNDS: $178K

DESCRIPTION: Military activities on Department of Defense (DoD) installations in the southwest U.S. are potentially large contributors of wind-blown dust due to the presence of large expanses of fragile desert soils and via testing and training activities. Particulate Matter (PM) emitted by these activities impacts vehicle performance, and threatens the health and safety of military personnel due to inhalation of PM and loss of visibility. This project proposes a systematic, empirically based research approach that combines environmental monitoring and field experimentation to quantify and characterize PM emissions from testing and training. Contributions from dust and other sources is measured during a 1-year ambient air quality monitoring program at upwind and downwind boundary flux sites, combined with 14 days of intensive monitoring during periods of active training. An emission factor database is developed using upwind-downwind monitoring methods to measure vehicle-generated emissions using fast-response instrumentation. Potential long-range transport of the emitted PM will be assessed from field experiments. Potential visibility degradation off-post is determined with an intensive field measurement campaign.

BENEFIT: Specific benefits from the research include: (1) the development and demonstration of a methodology that will identify contributions of PM from specific on-post sources to the flux of PM exiting installation boundaries; (2) the development and demonstration of a methodology to define emission factors for military vehicles and an emission factor data base that can be used in a model to estimate the contributions from different sources within an installation for various testing and training scenarios; (3) a model to convert the horizontal emission flux to vertical emission flux that will allow the emission inventory data to be utilized in dispersion models to estimate the long-distance transport potential of the emitted PM; (4) the demonstration of the TRAKER approach to determine horizontal emission fluxes and its effectiveness to map the emission potential of different surface types with great economy; and (5) characterization and quantification of the emissions from the military activities.

ACCOMPLISHMENTS: This project has successfully carried out the air quality monitoring component of the study and is currently undertaking selection of source profiles and sensitivity testing with those profiles to be followed by chemical mass balance receptor modeling to attribute particulate matter to its sources. The road dust emission factors have been compiled and will be used by another SERDP-funded project, CP-1195, for testing in their GIS-based dust emission model. Data analysis on the transportable fraction of suspended particulate matter has been completed. The TRAKER data are being validated and analysis steps include: (1) calculating the relative particle loss within the sampling line as a function of particle size; (2) calculating collocated particle instrument variability; (3) calculating TRAKER signal for all sets of valid measurement; (4) relating TRAKER signal to particle flux on towers; and (5) relating TRAKER signal to variations in soil type across the Ft. Bliss range. Data from the April 2002 field experiment are being analyzed to quantify visibility and its impairment due to vehicle operation on unpaved roads. This analysis includes comparison with particle measurements nearby to check closure between these different types of measurements. In addition, researchers are integrating the in situ measurements with the HARLIE lidar data for calibration of the lidar signal to be used for estimating the visibility degrading potential of dust further downwind of the emission source.

TRANSITION: The acquired information can be transitioned to Integrated Training and Management (ITAM) personnel who may need to deal with certain aspects of the dust and PM emission problem.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of Scrap Metals for Mass Detonating Energetic Materials; CP-1194

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. James Phelan; Sandia National Laboratories – Albuquerque, NM

FY 2002 COMPLETED PROJECT

DESCRIPTION: This research project explored the concept of an automated screening process to help characterize scrap materials for the presence of mass-detonating energetic materials. The current practice of visually screening large amounts of scrap materials is inefficient and has misidentified mass detonating quantities of explosives causing significant equipment losses during scrap recycling operations. The concept of an automated screening process using chemical sensing technology has the potential to provide an efficient low cost method to discriminate whether scrap materials contain mass detonating quantities of energetic materials prior to entering a treatment process, and to verify decontamination of surface residues after treatment. The requirements for a chemical sensor for this application include high sensitivity and selectivity for the chemicals found in the energetic materials, and fast response time to allow real-time sorting. Using a novel amplifying fluorescent polymer (AFP) approach, the detection of TNT had been engineered into a sensor system by Nomadics, Inc. and researchers at MIT believe that they can design an AFP for RDX. The project proposed to complete proof-of-concept tests for determining mass detonating quantities of energetic materials. When successful, the magnitude of the vapor signature could be used to develop a conceptual design for a dynamic screening system. The research team determined the success of the technology by measuring and comparing the absolute sensitivity of the latest Nomadics sensor to vapors derived from water solutions and measured with preconcentrated samples. The team also performed bin tests and compared analyses from the Nomadics AFP sensor with the Tenax tubes or SPME samples, and extrapolated the data for use of the Nomadics AFP sensor in a dynamic conveyor system.

BENEFIT: This project determined the proof-of-principle of whether chemical vapor sensing could discriminate mass detonating energetic materials among scrap materials. This technology will be linked to conveyor belt sorting system to segregate portions of the scrap that likely contain mass detonating quantities of energetic materials, thereby, reducing the amount of scrap material requiring expensive inspection and treatment.

ACCOMPLISHMENTS: Sandia National Laboratories teamed with Nomadics, Inc. to evaluate the Nomadics FIDO vapor sensor to identify energetic material residues among scrap. Laboratory tests were completed that determined the vapor-sensing threshold to be 10 to 20 pptr for TNT and 150 to 200 pptr for DNT. Field tests with the FIDO demonstrated the proof of concept that energetic material residues can be identified with vapor sensing in enclosed scrap bins. Items such as low order detonation debris, demolition block granules, and unused 81-mm mortars were detected quickly and with minimum effort. Conceptual designs for field-screening scrap for energetic material residues include handheld vapor sensing systems, batch scrap sensing systems, continuous conveyor sensing systems and a hot gas decontamination verification system.

TRANSITION: Throughout the project DoD end users have been involved to ensure successful technology transfer to DoD applications including both the information and instrument (FIDO) development and demonstration.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of a GIS-Based Complex Terrain Model for Atmospheric Dust Dispersion; CP-1195

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. K. Jerry Allwine; Pacific Northwest National Laboratory – Richland, WA

FY 2003 FUNDS: $300K

DESCRIPTION: The objective of this project is to develop a fully tested and documented atmospheric dust dispersion modeling system for use by military staff to assess training/testing range contributions to local and regional air quality, to help manage dust-generating activities, and to help develop dust mitigation strategies. The dust dispersion modeling system must be robust, state-of-the-art, user-friendly, and most importantly, meet the needs of the staff responsible for addressing air quality issues from activities at military training/testing ranges.

This project characterizes dust emissions from range training/testing activities by: (1) analyzing existing dust characterization data, (2) conducting additional field studies, and (3) developing a geographic information system (GIS)-based complex-terrain atmospheric dispersion model. This modeling system has several uses including: (1) the near real-time tracking of dust movement given real-time meteorological data and dust generation information, (2) performing air quality assessments, and (3) planning and evaluating training operations and dust control measures under various meteorological scenarios. A primary focus of the proposed research is to develop dust emission factors for range activities and incorporate the dust emission formulations into a U.S. EPA approved air quality model. The GIS-based air quality model will be compatible with available military land management and operational models, and will be incorporated the effects of complex terrain on dispersion.

BENEFIT: The completed modeling system will allow military personnel to specify training/testing activities using a GIS interface, run the atmospheric dispersion model, and then graphically view the dust impacts using a GIS. The model will also have the capability to provide real-time dust dispersion for those sites maintaining real-time weather measurement data. This capability will allow graphic, GIS-based representation of current and projected PM transport and concentration that will enable military staff to modify activities or locations to minimize health and environmental impacts of airborne dust and/or obscurants. With the emphasis on user needs and input during the development of the model, transition to installation operation and use of the model should be greatly facilitated.

ACCOMPLISHMENTS: The major accomplishments during FY 2002 were: (1) incorporating two EPA-recognized atmospheric models (CALPUFF and CALGRID) into the modeling system with the existing PGEMS atmospheric model, (2) converting the modeling system from running under the ArcView 3.2 GIS to the ArcView 8.1 GIS, (3) formulating a dust emission module for military vehicles based on results from SERDP field studies, and (4) finalizing a preliminary version of the modeling system for review and use at military training facilities.

TRANSITION: The product (dispersion model and dust characterization techniques) will be transferred to military land managers and operational leaders for use during testing and training exercises and operation in order to reduce the generation of dust. The end product of this product will also include a field deployable time-tagged particle sampler and a documented measurement method for rapid, cost-effective assessment and mapping of roadway dust generation with high spatial resolution.

PROJECT SUMMARY

PROJECT TITLE & ID: A Field Program to Identify TRI Chemicals and Determine Emission Factors from DoD Munitions; CP-1197

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Chester Spicer; Battelle – Columbus, OH

FY 2003 FUNDS: $736K

DESCRIPTION: At present, published emission factors for munitions activities have been focused on tests conducted for open burning and open detonation (OB/OD) disposal of energetic materials. DoD needs a technology that would allow emission factors for Toxic Release Inventory (TRI) chemicals to be developed for munitions usage during routine testing and training activities. The overall objective of this program is to demonstrate a methodology for measuring emissions of TRI chemicals from DoD munitions activities and facilities under realistic conditions. A specific objective is to assemble and test an instrumentation package capable of measuring pertinent TRI chemicals at DoD sites. A second specific objective is to measure "point of discharge" TRI chemical emissions from a variety of munitions used in training activities. A third objective will be to measure "point of impact" TRI emissions from a wide range of DoD munitions at an outdoor testing range. The major focus of the project is the field campaigns. The first will focus on emissions from the discharge of weapons (point of discharge studies) and the second on emissions from explosion on impact (point of impact studies). The field campaigns are conducted at the Aberdeen Test Center (ATC). The point of discharge campaigns make use of an indoor facility which permits firing weapons with capture of the discharge emissions. The point of impact studies are carried out at one of ATC's outdoor ranges.

BENEFIT: The proposed program is designed to work closely with DoD services to: (1) identify important munitions activities and sites; (2) use existing data and chemical principles to develop a list of target TRI chemicals that will be measured in the field; (3) recommend and deploy innovative state-of-the-art field monitoring technologies; and (4) collect real world data on munitions emissions for important munitions activities under a range of actual field conditions at field sites. These data will advance the state of knowledge of the nature and quantities of emissions from munitions activities and will help DoD meet its EPCRA reporting requirements by providing more accurate estimates through the DDS. In addition, the accurate characterization of emissions from these activities will assist DoD in setting priorities for emissions reduction strategies.

ACCOMPLISHMENTS: Researchers have conducted an extensive review of past studies of munitions emissions, and reviewed the compositions of numerous munitions items to select target TRI chemicals for measurement. They have identified 124 TRI chemicals or chemical groups as potential emissions from munitions. Following the identification of potential target chemicals, researchers performed a modeling analysis to estimate the detection limits that will be needed to measure the target chemicals under realistic conditions on a testing range. Based on this analysis and the estimated detection limits of the potential measurement methods, the team identified six measurement methods and 75 TRI chemicals for measurement during emissions testing. The types, usage, and chemical composition of a large number of munitions items was reviewed and used to identify and prioritize items for emissions testing. Once target chemicals and measurement methods were identified, sampling plans for emissions testing was developed at the point of discharge and the point of impact. The plan for the point of impact tests specified test conditions, levels of test replication, criteria for a successful test, and measurement methods for the TRI chemicals. The test plan also described methods to account for dilution, which will be needed to convert chemical concentrations into emission factors. The approaches selected to account for dilution include two chemical tracer approaches (carbon mass balance and xenon spiking) and two approaches for estimating the volume for the emissions cloud during sampling (aerosol lidar and 3-D photogrammetry). Because of the critical importance of the dilution estimate, researchers conducted 25 field tests of these four approaches on a test range at Aberdeen

Test Center (ATC). The results confirmed the ability to account for dilution in future outdoor range testing. Most recently, they optimized and evaluated the six measurement methods for the TRI chemicals and prepared ancillary instrumentation to monitor other critical variables during emissions testing. For example, optimization of one of the methods, atmospheric pressure chemical ionization tandem mass spectrometry, demonstrated the ability to monitor 11 of the more difficult TRI chemicals in real time, with high specificity, and with detection limits better than 100 pptr for 10 of the chemicals. At the end of FY02, the research team deployed the instrumentation for the TRI chemicals and other important variables in a mobile laboratory for a 2-week set of Point of Discharge emissions measurements at ATC. The data and samples from these tests are currently being analyzed, but all indications point to a very successful conclusion to those tests.

TRANSITION: There is a broad interest within DoD in developing a credible method to measure the emission factors that are used to estimate annual emissions, and in applying the method to measure emission factors from significant munitions activities.

PROJECT SUMMARY

PROJECT TITLE & ID: Measurement and Modeling of Energetic Material Mass Transfer to Pore Water; CP-1227

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. James Phelan; Sandia National Laboratory – Albuquerque, NM

FY 2003 FUNDS: $100K

DESCRIPTION: Ordnance detonation during military testing and training operations leaves unreacted energetic materials on and in near-surface soils. Transport of these energetic materials in soils is initiated by a mass transfer process to soil pore water. This project is analyzing this mass transfer process using laboratory measurement and numerical simulation to produce an energetic material source function linked to weather cycles. This effort will involve two phases of experimentation and model development. Phase I will consist of an initial series of experiments designed to determine the critical parameters affecting the mass transfer of energetic materials to pore water and the derivation of a mathematical function that incorporates the most significant factors. Phase II will evaluate in more detail the factors that have the greatest impact in mass transfer process and evaluate actual post-blast residue in soil obtained from test or training ranges. Mass transfer rate data will be collected in an unsaturated or saturated column test apparatus allowing variation in parameters representative of environmental condition in near surface soils. Actual range soil and post-blast residue will be used to assess the accuracy of the mass transfer function.

BENEFIT: The inclusion of an energetic material source release function in a soil solute transport simulation code will create a new predictive ability to assess the migration potential of energetic materials left by military testing and training operations.

ACCOMPLISHMENTS: Experiments that measured the energetic mass transfer process as a function of certain soil, precipitation and energetic material attributes were completed. Most notable was the observation that under most circumstances, the effluent concentrations of RDX and TNT were very high, near the maximum controlled by temperature dependent water solubility. This implies that low order detonation residues are a significant pollution source and that weather cycles will drive the impact to groundwater. The experimental data was used to develop an energetic material source release function in the computational simulation model T2TNT. Further experimental and model development work will continue. The inclusion of an energetic material source release function in a soil solute transport simulation code has created a new predictive ability to assess the migration potential of energetic materials left by military testing and training operations. This will support range managers for improved decisions on management of this challenging problem.

TRANSITION: Modelers can use this source release function as part of a solute transport simulation code to predict the fate and transport of energetic material in soil pore water. In addition, this work can be extended to evaluate groundwater impact and range management strategies by implementation through the Army Environmental Center.

PROJECT SUMMARY

PROJECT TITLE & ID: The Development of Spatially-Based Emission Factors from Real-Time Measurements of Gaseous Pollutants Using Cermet Sensors; CP-1243

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Natalia Meshkov; Argonne National Laboratory – Argonne, IL

FY 2003 FUNDS: $290K

DESCRIPTION: The Department of Defense (DoD) needs to identify and characterize emissions of trace air toxic compounds, especially persistent organic pollutants, from operations and activities at its facilities. This information is used to estimate emission factors used in environmental risk assessments. Currently, ambient air toxic concentration data for most urban air toxics (UATs) and mobile source air toxics (MSATs) are not available.

This project aims to (1) develop miniature sensors and portable sensor arrays capable of rapidly detecting and characterizing trace air toxic compounds in near-real time, (2) integrate pollutant data into spatial and temporal emission profile models correlated with specific DoD activities, and (3) produce high quality emission factors for targeted pollutants released during various activities. Cermet (ceramic-metallic) electrocatalytic "smart" microsensors that monitor emissions in near-real time will be used. These sensors are capable of operating over a wide temperature range (approximately -40 °C to 500 °C). Voltammetric analytical techniques employed during sensor operation allow for both a wide variety of gaseous constituents and a wide range of analyte concentrations to be detected (from parts per billion to percent levels). Advanced pattern recognition techniques are used to resolve composite signals from a mixture of gases into individual components. TiO_2 photocatalytic properties are used to develop new microsensors that complement voltammetric devices. By combining existing and experimental microsensor technologies, more capable comprehensive microsensor arrays (a micro-miniature electronic nose) for selected emission constituents are developed. The new microsensor arrays are used to efficiently produce improved emission characterization profiles associated with DoD activities and to estimate and validate emission factors.

BENEFIT: The project provides DoD new sensing systems for detecting and characterizing trace air toxic compounds. These systems are portable, small, and inexpensive. Operating from a laptop computer, these systems can provide near-real-time analysis and feedback. UATs, MSATs and a spatial profile of air pollutants will be provided. The information gained from this project will advance the efforts for control of pollutants, the fate and transformation of pollutants, and transport modeling of pollutants.

ACCOMPLISHMENTS: Three types of photocatalytic microsensors were fabricated, each employing different forms of TiO_2, and using different geometries. The photocatalytic sensor apparatus was reduced in size by incorporating a miniature high-intensity ultraviolet (UV) light emitting diode (LED), comparable in size to the sensor, to replace the external UV reactor as a light source to induce photocatalytic reactions. A new miniature test chamber has been designed to support the operation.

After an assessment of expected atmospheric contaminants at Yuma Proving Grounds, researchers focused primarily on gases resulting from diesel exhaust. Specifically, tailoring the scope of work to focus on the decomposition products of formaldehyde along with the four other significant mobile source air toxics at YPG from diesel exhaust gases: benzene, 1,3-Butadiene, acetaldehyde, and acrolein. The Department of Transportation Argonne Engine Test Facility was secured for use. The new data-acquisition (DAQ) system was tested by performing experiments with the ANL-designed/commercially manufactured yttrium stabilized zirconium (YSZ) electrocatalytic sensor and three concentrations of oxygen in nitrogen (0.1%, 1.0%, and 10.0%) to evaluate the sensor's response to various experimental parameters controlled by the new software. Experiments were also performed and the new (DAQ) system on chlorinated compounds, chosen because they have been more difficult to detect than non-chlorinated compounds. Trichloroethylene (TCE) and perchloroethylene (PCE) were tested in an air matrix at concentrations of approximately 30 ppm, 300 ppm, and 3000 ppm. Distinct reproducible signatures were obtained for each compound and concentration.

Data acquisition equipment, needed to implement the updated microsensor voltammetry operation was reviewed, evaluated, selected. The new data acquisition hardware and experimental control software was completed and a series of laboratory shake-down tests were performed. The neural analysis tool has been tested and verified. All of the code has been tested with several different microprocessors and models of PCs to insure universal operation. All challenges to the hardware/data acquisition software have been completed - only minor improvements and tailoring are anticipated as the project moves into the more intensive gas testing stages.

TRANSITION: Results from this project will enable the identification and characterizing of the emissions of trace air toxic compounds produced from activities at DoD operations. Actual data from the research could be of direct interest of DoD facilities and to the U.S. EPA since future regulations will be based upon the results of this research effort. An effective transition plan will include constant contact with colleagues at EPA and DoD and marketing of the results at conferences and working groups of regulatory agencies.

PROJECT SUMMARY

PROJECT TITLE & ID: Harmful Algae, Bacteria, and Fauna Transported by Department of Defense Vessels; CP-1244

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. JoAnn Burkholder; North Carolina State University – Raleigh, NC

FY 2003 FUNDS: $163K

DESCRIPTION: Ballast water is thought to represent the primary vector of marine non-indigenous introductions into the U.S. and elsewhere. There is concern that existing and proposed regulatory measures designed to control such introductions could translate into severe restriction for DoD vessels, unless this aspect of ship operations is more fully characterized and managed.

In order to identify and quantify harmful or non-indigenous species of algae, bacteria, and microfauna transported via ballast water on representative DoD vessels, samples will be collected at the Norfolk and San Diego Naval Stations. Plankton samples will be analyzed using phase contrast light microscopy. Scanning electron microscopy will be used for positive identification of species of particular interest. The potential of flow cytometry and molecular screens as rapid tools for identification and enumeration of selected taxa in ballast water will be investigated. The data are subjected to exploratory statistical analyses, followed by appropriate determinative measures to identify relationships between environmental or ship-related variables and the biological evidence. Species of taxonomic groups and harmful/noxious species discovered during the sampling surveys are exposed to various heat regimes in order to assess the efficacy of using excess engine heat as a control treatment.

BENEFIT: Results of this study will fill a critical data gap by providing information on the abundance and diversity of aquatic species found in ballast waters from DoD vessels. The characterization of communities in the ballast water of DoD vessels, including ‘harmful species,’ together with bench-scale heat treatment experiments, will assist the DoD in determining the measures necessary to reduce the risk of non-indigenous introductions to U.S. harbors and estuaries by ballast water. This project is coordinating these research efforts with CP-1245.

ACCOMPLISHMENTS: Standard operating procedures were finalized, covering the sample kit preparation, sampling procedures, preservation, fractionation, shipment and distribution of samples for analysis. Two sampling events were completed in San Diego with samples collected and shipped to the lab for concentration and distribution for analysis. Chemical and biological analyses are being conducted on the samples collected. A draft design of the project’s database was completed. This included the field and data attributes listing, table relation structure, design of electronic entry forms and production of draft report/query products. Functionality will include linkage to organism image libraries enabling project atlas development and ballasting data export to GIS applications for linking biological observations to specific geographic information/voyage routes.

TRANSITION: Results from this project will support the activities of the Unified National Discharge Standards (UNDS) program. This program will analyze discharges from DoD vessels and develop performance standards for pollution control devices employed to treat these discharges. Non-indigenous species have been identified as a constituent of concern for several of the discharges examined. The data we obtain will guide the formulation of scientifically-defensible treatment standards under the UNDS program, and the development of effective pollution control devices, by providing information on the abundance and types of organisms found in ballast water and as fouling on hulls.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of Aquatic Non-Indigenous Species for Department of Defense Vessels; CP-1245

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Eric Holm; Naval Surface Warfare Center, Carderock Division – West Bethesda, MD

FY 2003 FUNDS: $345K

DESCRIPTION: In order to develop a better understanding of the role DoD operations may play in the introduction of invasive aquatic species, ballast tanks of various classes of Navy and Army vessels will be sampled at two Naval Stations (i.e., Norfolk, and San Diego), and an Army installation (i.e., Fort Eustis). The sampling plan concentrates on the size fraction of planktonic organisms for which invasions are well documented. Samples will be taken with a plankton net and preserved upon collection for enumeration at a later date. The physical and chemical characteristics of the ballast water will also be determined. Data will be obtained on the volume, loading location and management of ballast on board. The concentration of organisms and diversity of the ballast tank communities will be related to the characteristics of the ballast water, loading location, management practices, type of vessel, and date of sampling. Vessels will be sampled for spatial extent of fouling and species richness. Hull fouling communities will be sampled using a remotely-operated vehicle. Divers will collect hull samples to estimate species richness in the fouling community, and to identify any invasive species. Analysis of maintenance practices, including coating type, will be conducted for Navy vessels using the hull inspection database maintained.

BENEFIT: Data to determine if and how discharges from DoD vessels contain aquatic invasive species, and how these vessels should be managed will be the immediate outcome of this project. This effort will lead to the development of cost-effective, environmentally-compliant treatment and monitoring technologies or management strategies, designed to control the spread of invasive organisms, and meet the unique operating requirements of DoD vessels without jeopardizing operations or ship safety. This project is coordinating these research efforts with CP-1244.

ACCOMPLISHMENTS: The USNS Kaiser, a Military Sealift Command (MSC) oiler, was the first vessel to be sampled. Equipment and procedures were tested and modified. Two ballast tanks were successfully sampled. Analysis of the samples is currently underway. Experience with the USNS Kaiser led to minor modifications of the sampling plan. In the future, additional methods will be employed to sample for zooplankton, including light traps and a hand pump. These methods will allow the team to more effectively sample tanks with little water in them, or tanks with very low concentrations of organisms. Plans have been made to sample MSC vessels on both coasts. In the future, sampling of MSC and Army vessels will be continuous as ships arrive to US waters.

TRANSITION: Results from the proposed research will support the activities of the Unified National Discharge Standards (UNDS) program. This program is intended to analyze discharges from DoD vessels, and develop performance standards for pollution control devices that may be employed to treat these discharges. Non-indigenous species have been identified as a constituent of concern for several of the discharges examined. The data we obtain will guide the formulation of scientifically-defensible treatment standards under the UNDS program, and the development of effective pollution control devices, by providing information on the abundance and types of organisms found in ballast water and as fouling on hulls.

PROJECT SUMMARY

PROJECT TITLE & ID: Temporal and Modal Characterization of DoD Source Air Toxic Emission Factors; CP-1247

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Brian Gullett; U.S. Environmental Protection Agency – Research Triangle Park, NC

FY 2003 FUNDS: $579K

DESCRIPTION: Air toxic emission factor data are lacking, in part, due to the inability of current methods to address pollutant- and source-specific sampling and analytical challenges. This is particularly true for any kind of emission factors that adequately reflect the use mode and temporal nature of air toxics. This project will develop an integrated methodology for measurement of trace organic and metallic air toxics using modified conventional measurements, state of the art laser-based technologies, and optical path monitoring to develop and test a sensitive, time-resolved methodology for detection of trace toxics that can be applied to mobile and stationary sources. This combination of three measurement methods (laser-based, conventional, optical path) provides a triangle of overlapping, confirmatory analyses that cover the broad range of organic and metallic air toxics. The project approach will combine three supportive measurement technologies into a method for assessing multiple source type air toxic emission factors under use-mode and temporally relevant conditions. Because the technologies overlap in terms of pollutant types, temporal spans, and modal relevance, this project can develop pollutant-to-pollutant correlations. Resonantly Enhanced Multiphoton Ionization (Jet-REMPI) and Laser-Induced Breakdown Spectroscopy (LIBS) use a common seed laser source (Nd:YAG), providing an integrated, common platform for detection of most organic and metallic air toxics.

BENEFIT: Data from these efforts will be used to determine source- and mode-specific emission factors for use in the Air Force's Air Permit Information Management System (APIMS), an emission inventory system currently used by Hill AFB and being adopted DoD-wide, as well as to improve EPA's AP42 emission factor system. DoD will benefit from understanding how its base operations contribute to levels of ambient air toxics, both from a standpoint of being able to minimize impacts of potential operating restrictions as well as understanding how to limit occupational exposures (so called "hot spots"). Source identification and emissions characterization, coupled by an understanding of how specific modes of source sampling lead to emissions, will provide DoD with an effective tool for emission impact minimization.

ACCOMPLISHMENTS: Preliminary laser assessment tests on a new compact, fieldable laser have been conducted. A compact time-of-flight mass spectrometer has been reviewed and determined to be applicable to this field unit. Samples for ARL LIBS analyses have been taken at EPA on a rotary combustor. These samples consist of multiple trace metals in an ashy matrix. Source #1 has been selected, a tactical quiet generator (TQG). The Quality Assurance Project Plan has been drafted and includes anticipated sources, relevant sampling methods, measurement means, available air toxic emission factors, and data quality indicators. A study of LIBS analyses of metallic particles in a gaseous flow has been initiated. This work is aimed at characterizing the LIBS technique with regards to real-time, in-situ particle analysis. A flow was seeded with particles containing Al and Mg including micrometer-sized, oxidized metallic particles.

TRANSITION: This project's methods and technologies will be published in peer reviewed literature and promoted through establishment of a Project Advisory Council (PAC). The project will work with the EPA Emission Inventory Group and the Air Force APIMS program for incorporation at DoD facilities. The combined technical expertise, military involvement, and multi-office EPA involvement ensures that the project output will receive broad and accepted use.

PROJECT SUMMARY

PROJECT TITLE & ID: Application of MALDI-MS to Identification of Phytoplankton in Ballast Water; CP-1248 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Dana Woodruff; Pacific Northwest National Laboratory – Richland, WA

FY 2002 COMPLETED PROJECT

DESCRIPTION: Non-indigenous species are increasingly conspicuous in marine and estuarine environments throughout the world as invasions linked to ballast water transport. Innovative methods are needed to quickly and accurately identify the presence of and speciate non-indigenous and/or harmful phytoplankton in ballast water. Recent advances in ionization techniques such as matrix-assisted laser desorption/ionization mass spectrometry (MALDI-MS) have allowed detection of intact biomolecules within ballast samples. This project developed and demonstrated the use of MALDI-MS for detecting and monitoring non-indigenous phytoplankton species in ballast water. The first step involved modifying MALDI-MS bacterial identification techniques currently being developed at Pacific Northwest National Laboratory (PNNL) for phytoplankton analysis. Mass spectral "fingerprints" of this species were examined for reproducibility using statistically-based algorithms. The second step evaluated the reliability of MALDI-MS for identifying the target phytoplankton species in ballast water of Navy vessels. Ballast water was spiked with the target phytoplankton and analyzed using MALDI-MS.

BENEFIT: The development of MALDI-MS for detecting and monitoring non-indigenous phytoplankton in ballast water will provide a streamlined, cost-effective approach to assessment and management of microorganism transport in ballast water.

ACCOMPLISHMENTS: Progress was made on culturing phytoplankton and preparing the samples for MALDI in order to modify existing methods of bacterial species identification to obtain useful MALDI mass spectra from phytoplankton. To assess various sample prep. conditions for MALDI analysis, the following samples of *Isochrysis* were prepared and shipped to Richland by the project subcontractor: growth stage (healthy and senescent), matrix (filtered sterilized seawater and NH_4Cl), and storage (frozen and lyophilized), as well as samples of *Gymnodium catenatum* and *Rhodomonas*. Generation of *Gymnodium* cysts is ongoing, as well as antibiotic trials with new cultures to eliminate bacteria. Culturing of *Pseudo-nitszchia* spp. was initiated, including *P. australis, P. multiseries*, and *P. pseudodelicatissima*, and were tested in November. Using a pure strain of a representative phytoplankton species, an appropriate MALDI matrix material was determined that is compatible with the analyte sample. "Fingerprints" of several representative diatoms and dinoflagellates were developed.

TRANSITION: Potential follow on studies after the "proof-of-principle" phase would include: (1) additional testing of environmental and ballast water samples from other geographic regions; (2) expansion of the MALDI-MS spectral library with other representative phytoplankton species from other geographic regions worldwide; (3) combining the phytoplankton MALDI-MS library to the existing MALDI-MS library of bacterial species; (4) refinement of sampling and preparation techniques for automated sample extraction/concentration from complex environments; and (5) application to other marine species including zooplankton, pahtogenic bacteria and viruses, and examination of increasingly complex mixtures.

PROJECT SUMMARY

PROJECT TITLE & ID: Adaptive Grid Modeling and Direct Sensitivity Analysis for Predicting the Air Quality Impacts of DoD Activities; CP-1249 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mehmet Talat Odman; Georgia Institute of Technology – Atlanta, GA

FY 2002 COMPLETED PROJECT

DESCRIPTION: Air pollutants emitted from DoD facilities may directly interfere with military activities such as training exercises, or in some cases even threaten life and property. Through long-range transport and transformation processes, these emissions may contribute to regional air-quality problems. Air quality simulation models are needed that can help determine the air quality impacts of various types of emissions from military installations. The primary objective of this project is to bring current air quality models to a level where they can be used to predict the impact of air pollutants emitted from military installations on the surrounding environment. The project will try to improve the models' ability to capture source-receptor relationships between emissions at local scales and air quality at regional scale by using prescribed burning emissions from Fort Benning as a case study.

The project incorporated adaptive grid modeling and direct sensitivity analysis techniques that have been recently developed into one of the current air quality models (CMAQ or MAQSIP). While adaptive grid modeling will improve the air quality model by filling the gaps between local to regional scales, the direct sensitivity analysis will allow discerning the impacts of specific sources from cumulative effects on regional air quality. Simulations were conducted to determine the air quality impacts of the prescribed burning operation at Fort Benning. In particular, the project team estimated the sensitivity of ozone levels in the Columbus metropolitan area to NO_x and VOC emissions from the fires. Title V Air Emissions Inventory, which includes emissions of criteria pollutants (CO, NO_x, PM, and VOC) by source, type and quantity, will be used. For the prescribed burning operation, the inventory is detailed enough to yield emission factors by litter type per acres burnt. These emissions will be processed for use with the CB-4 chemical mechanism. Simulation of a historic episode enabled a comparison of model results with observed air quality to determine if the modeling system was functioning properly.

BENEFIT: The techniques that were tested are applicable to other military operations. Other types of emissions could be targeted, for example, from aviation, ship, or coastal operations at various locations. Once the concept is proven, the techniques can be used for the general purpose of predicting the fate of air pollutant emissions from various military sources. Products can be developed that can assist site managers in responding to immediate needs, as well as being able to plan future emissions that will minimize the impact on the environment.

ACCOMPLISHMENTS: Acquisition of prescribed burning emissions data was obtained. MAQSIP was selected as model framework and the adaptive grid and direct sensitivity analysis techniques were incorporated into this model. Model verification is ongoing.

TRANSITION: The development of the proposed impact analysis approach has many potentials. The techniques will be implemented in the current generation of air quality models that are already in the public domain. Software and hardware requirements are not envisioned to entail any significant cost. Application of the model to other DoD operations may require further research. If the concept can be proven in this project, development of a user-friendly product tailored to DoD needs, along with a detailed plan for the transfer of this technology to DoD facilities may be addressed in a follow-on project.

PROJECT SUMMARY

PROJECT TITLE & ID: Developing Molecular Methods to Identify and Quantify Ballast Water Organisms: A Test Case with Cnidarians; CP-1251 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Brian Kreiser; University of Southern Mississippi – Hattiesburg, MS

FY 2002 COMPLETED PROJECT

DESCRIPTION: The objective of this exploratory research was to describe molecular markers and refine the methods necessary to identify cnidarian taxa in ballast water samples. The need for this work was based on the difficult and time-consuming task of using morphology alone to identify ballast water organisms. Furthermore, full identification of certain taxa is not always possible, leading to an underestimate of the diversity of organisms present. All the molecular methods employed are standard techniques. The novel aspect of this work required experimentation and optimization in developing protocols that apply these techniques to detect, identify, and quantify ballast water organisms. The basic protocol developed in this project can be briefly summarized in four steps. First, the bulk DNA (from all the organisms present) was extracted from a sample. The polymerase chain reaction (PCR) was used to amplify a specific target gene from a specific group of organisms (cnidarians in this case). The PCR products were then cloned as a means of isolating the contributions of each species present. Finally, identifications were made by screening these cloned PCR products using a variety of techniques including size variation, restriction fragment length polymorphisms (RFLPs) and selective amplification by PCR. The development of the molecular protocol was conducted in three phases. The first phase characterized the markers needed to identify various cnidarian species. This involved determining which genes in the genome provided the appropriate level of taxonomic resolution. The second phase conducted lab tests of the marker's ability to detect the presence of specific cnidarian taxa at a variety of concentrations in mixed samples. As a "proof-of-principle" project, the bulk of the effort was expended on the first two goals involving the development and laboratory evaluation of the techniques. However, in the third phase the technique will be tested on actual ballast water samples.

BENEFIT: Successful completion of the work outlined in this project will provide a powerful and versatile protocol that will be available to any worker with basic skills in molecular biology. One area that warranted investigation was the use of the identifications derived from this protocol as a means of determining if ballast water exchange took place.

ACCOMPLISHMENTS: Progress was made on the initial goals of specimen acquisition and the identification of suitable molecular markers. Specimens have been acquired and DNA successfully extracted from a total of twenty-two species representing the four classes of cnidarians. DNA sequence data have been obtained from 106 additional species of cnidarians from GenBank (a database funded by two federal agencies - NIH & NLM). Research focused on the 18S rRNA gene, its internal transcribed spacer (ITS), and two genes within the mitochondrial genome (16S rRNA and cytochrome oxidase I). The sequences are currently being used to identify regions of these genes that provided adequate taxonomic resolution in the protocols.

TRANSITION: Full implementation of this protocol will require several additional steps that will be straightforward to pursue once the initial methodology has been refined. A full characterization of all cnidarian species that may be present in ballast water is beyond the scope of this project. However, the only requirement for a complete taxonomic coverage is to acquire voucher material from around the world, particularly from ports visited by DoD vessels. This will allow workers to fully characterize the assemblage of cnidarians that may end up in ballast water. Of course, cnidarians represent only a fraction of the organisms present in ballast water as crustaceans, annelids and mollusks are by far more numerous. The power of this protocol is that it is versatile enough to be adapted to any taxonomic group.

PROJECT SUMMARY

PROJECT TITLE & ID: Automated Image Processing/Image Understanding Coupled with Artificial Neural Network Classifier for Detection of Non-Indigenous Species on Ship Hulls; CP-1252 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Stephen Lieberman; Space and Naval Warfare Systems Center – San Diego, CA

FY 2002 COMPLETED PROJECT

DESCRIPTION: Invasive (or non-native) species (NIS) have been introduced inadvertently into many marine and fresh waters via ship movements. Major transport pathways that have been identified include ballast water, tank sediments and ship hull fouling. To date, most information on invasive species hull fouling organisms is based on diver inspections of hulls which is costly, potentially dangerous, and often subjective. The project team evaluated the feasibility of developing automated image processing and understanding algorithms coupled with an artificial neural network classification scheme for quantitative measurement of the abundance and diversity of hull fouling organisms and to detect and classify NIS. The proposed automated quantification and classification system for complex shapes such as fouling organisms will make use of four processing modules: (1) image acquisition, (2) image pre-processing, (3) feature extraction, and (4) object classification. Estimates of fouling organism abundance (quantitative spatial coverage) will be derived from the digital images using image pre-processing and feature extraction techniques. Fouling organisms can be discriminated from unfouled hull based on differences in selected characteristics. The feasibility of developing artificial neural networks to automatically classify various types of fouling organisms isolated via the digital image processing procedures described above were evaluated.

BENEFIT: The capability developed with this effort could be adapted to the Remotely Operated Vehicle (ROV) for Underwater Hull Evaluation that is currently under development at the Naval Surface Warfare Center (NSWC) Carderock Division. By combining high-speed digital image processing with the in-situ imaging and 3-D positioning capability provided by the ROV, a methodology would emerge for rapid assessment of fouling organisms on ship hulls. This would represent a significant improvement over the current practice. An automated system would also be useful to evaluate the effectiveness and condition of different hull coatings and for quick evaluation of hull condition to access ship readiness for operations.

ACCOMPLISHMENTS: Considerable efforts have been expended collecting and archiving images of hull fouling and invasive marine organisms. Images were collected from online sources, books, reports and other printed sources and hull fouling studies at NSWC Carderock. An effort was launched to put test panels in San Diego Bay and to image these test panels on regular basis to generate an image database for the development of the neural network classification algorithm. A total of 129 high quality images have been collected that track the progressive fouling of the panels.

Preliminary results from neural network classification algorithm efforts were presented at the 11th International Marine Corrosion & Biofouling Congress held July 21-26, 2002 in San Diego. The paper entitled: “Use of automated image processing coupled with an artificial neural network based classifier for identifying fouling organisms on ship hulls” presented results from studies in which artificial neural networks were developed for classification of images of mollusks and selected invasive species.

TRANSITION: The image processing/image understanding algorithms developed here could be transitioned to NSWC Carderock to enhance the capability of the Remotely Operated Vehicles (ROV) for Underwater Hull Evaluation currently under development.

PROJECT SUMMARY

PROJECT TITLE & ID: Development and Validation of a Predictive Model to Assess the Impact of Coastal Operations of Coastal Operations on Urban Scale Air Quality; CP-1253

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Alan Gertler; Desert Research Institute – Reno, NV

FY 2003 FUNDS: $434K

DESCRIPTION: Many east and west coast U.S. urban areas, classified as non-attainment for ambient air pollutants, are home to major DoD facilities. DoD operations can be significant sources of air pollutants and their precursors. However, there is considerable uncertainty associated with emission inventories of these coastal areas. This project aims to develop and validate a prognostic modeling system capable of assessing the impact of coastal DoD operations on air quality. Included in this objective are the determination of primary and secondary pollutant concentrations, as well as their spatial and temporal variation. The goal is to develop a tool that helps in the design and implementation of effective strategies to reduce the impact of DoD operations on air quality in coastal urban areas. This project uses a method that links state-of-the-art meteorological, transport, and chemical modules by coupling a Lagrangian random particle dispersion model with an Eulerian chemical model. The impact of emissions inventory and meteorological parameter uncertainty on the model predictions are estimated. The model system is validated using real-world data obtained from a series of aircraft measurements performed in the San Diego area.

BENEFIT: The result of this study will enable DoD to: (1) Predict the impact and influence of coastal DoD facilities on urban and regional air quality; (2) Assess the contribution from individual sources to primary pollutant (directly emitted from sources) and secondary pollutant (formed by chemical reactions in the atmosphere) levels; (3) Estimate the impact of new technologies, fuels, and activity patterns on air quality; and (4) Design effective abatement strategies for primary pollutants and secondary pollutant precursors.

ACCOMPLISHMENTS: The San Diego County Emissions Inventory was obtained from the California Air Resources Board (CARB). In order to add additional temporal resolution to the inventory, the SMOKE model is being applied to the CARB inventory. A microscale inventory from the Barrio Logan (San Diego) CARB experiment has also been obtained and is being merged with the county inventory. Fuel specific emission factors and activity data for DoD operations in the San Diego area have been obtained. Work has also begun on the Lagrangian Transport module, Emissions module, and Eulerian Chemical module. Tracer data from the August Barrio Logan Experiment were obtained and has been used to evaluate the performance of the Lagrangian Transport module for the San Diego region. Meteorological data needed to drive the Lagrangian model was obtained from the Naval Postgraduate School (NPS). Evaluation of the NOAA/HYSPLT-Chemistry and UK Met Office/NAME methods to link the Lagrangian and Eulerian modules has begun. The aircraft sampling protocol was completed.

TRANSITION: The model will be transferred to San Diego area military installation environmental personnel for application and to other coastal areas. The approach will be communicated and the model possibly transferred to other potential users.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmental Fate and Transport of a New Energetic Material, CL-20; CP-1254

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Roman Kuperman; GEO-CENTERS, Inc. – Aberdeen Proving Ground, MD

FY 2003 FUNDS: $385K

DESCRIPTION: The primary objectives of this research are to: (1) determine transport and fate of CL-20 using a standardized intact soil-core microcosm system; (2) quantify the toxicity of CL-20 to soil invertebrates and plants in soil supporting high chemical bioavailability, and to aquatic biota; and (3) examine the effect of a simulated weathering/aging process on CL-20 toxicity. The research will be conducted in two phases. In phase one, the toxicity of CL-20 to soil invertebrates, terrestrial plants, and aquatic species will be quantified. The range of CL-20 concentrations tested will provide a continuum of exposure concentrations from "no effect" to "bioaccumulation levels" to "lethal levels," ensuring investigation of biological and chemical relationships across orders of magnitude in exposure concentration. In phase two, transport and fate of CL-20 using standardized intact soil core microcosms will be characterized. Concentration levels will be determined from the results of the definitive toxicity tests conducted in phase one, and will include at least one safety factor of five above the EC50 level. Transport and fate will be assessed in the soil layers, plant and invertebrate materials, and leachates throughout the study period. Aquatic toxicity assays will be conducted with leachates to supplement information on potential toxicity of CL-20 in groundwater following transport through the vadose zone. This project along with CP-1255 and CP-1256 will develop collaborated methods for CL-20 analysis.

BENEFIT: The results of these studies will provide potential cost savings to both risk assessment and remediation processes. In the past, chemicals similar in nature to CL-20 were released into the environment without knowing the fate and effects of these compounds. Millions of dollars and thousands of man-hours have been spent on risk assessment and remediation of previously released energetic compounds. By determining the chemical and physical fate of CL-20, as well as toxicological thresholds in aquatic and terrestrial environments, production, training, and disposal operations may be designed to avoid sensitive soils or ecosystems.

ACCOMPLISHMENTS: A coordination meeting was held among research leaders to determine the environmental and physical properties of CL-20. The Standard Analysis Protocol for use by all participating groups was finalized. Sassafras sandy loam (SSL) soil was collected and processed for toxicity testing. The SSL soil was spiked with various concentrations of CL-20 and subjected to a simulated weathering/aging process. Range finding toxicity tests with soil invertebrates and terrestrial plants using various concentrations of CL-20 have been completed. Preliminary aquatic toxicity tests with *Ceriodaphnia* were conducted to determine treatment concentrations for the range finding tests with CL-20. Several protocols have been completed to include; Algal Inhibition, the *Ceriodaphnia* 7 Day Chronic Reproduction, and fish protocol.

TRANSITION: This research project was designed to generate toxicity data for CL-20 that can be used directly for the development of screening levels according to the draft "Ecological Soil Screening Level Guidance" (US EPA) and protective benchmarks for aquatic species. The data transition to US EPA will be facilitated because project personnel are associated with the Eco-SSL National Task Group for developing Soil Invertebrate and Plant Eco-SSLs. Information developed in this project will be provided to munitions managers.

PROJECT SUMMARY

PROJECT TITLE & ID: Factors Effecting the Fate and Transport of CL-20 in the Vadose Zone and Groundwater; CP-1255

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Szecsody; Pacific Northwest National Laboratory – Richland, WA

FY 2003 FUNDS: $291K

DESCRIPTION: Hexanitrohexaazaisowurtzitane (CL-20 or HNIW) is a promising replacement for existing propellants and explosives, since it releases more energy on ignition and is more stable to accidental detonation than energetic materials that now are being currently used. Wastes associated with DoD energetic materials constitute a major fraction of the Department of Defense (DoD) hazardous waste inventory. Therefore, it is critical that DoD consider the environmental fate and reactivity of CL-20 in sediments and in groundwater before it is replaced with currently used energetic materials. The objective of this project is to characterize the fate and transport of CL-20 in subsurface sediments by focusing on the identification and quantification of geochemical and microbial reactions of CL-20 in sediments, the effects of weathering, and the influence of transport on these reactions in the subsurface environment. Geochemical and microbial reactions, coupled effects, and effects of sediment weathering and flow are investigated using simple (e.g., uncoupled batch experiments) to more complex systems that represent field-scale transport (e.g., 1-D unsaturated/saturated transport, coupled reactions in natural sediments). Geochemical reactivity in batch systems is used to quantify sorption mass, rate, and reversibility, and the abiotic degradation pathway and rates. Anaerobic biodegradation of CL-20 and coupled geochemical microbial reactions and effects of aging are investigated. Individual and coupled reactions during unsaturated and saturated transport are quantified. A mechanism-based reactive transport model is used to predict CL-20 fate for a range of theoretical scenarios of CL-20 releases into the subsurface environment. This project along with CP-1254 and CP-1256 will develop collaborated methods for CL-20 analysis.

BENEFIT: By characterizing the fate and transport of CL-20 in the subsurface, the DoD has the ability to determine the appropriateness of CL-20 as a replacement for currently used propellants and explosives that are known to contribute to DoD hazardous waste inventory.

ACCOMPLISHMENTS: Degradation of CL-20 to specific mineral surfaces and natural sediments was further investigated to address dominant reactive sediment components. The biological fate of CL-20 was examined under aerobic and anaerobic conditions using batch microcosms with a variety of environmental samples, including surface and subsurface soils from the firing range at Ft. Bliss, Texas. Experiments testing CL-20 reactive transport through sediment under high influx rates and under highly reducing conditions were completed.

TRANSITION: Information from the results of this proposed work will be disseminated to the scientific community through peer-review publications. There will be an interlaboratory comparison of data to assess risk to the environment relative to other energetic compounds. Results of this proposed work, along with other CL-20 projects, will additionally be disseminated to DoD program managers through briefs and workshops for the purpose of providing information of CL-20 impact in the environment.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmental Fate and Transport of a New Energetic Material, CL-20; CP-1256

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jalal Hawari; Biotechnology Research Institute, NRC – Montreal, Quebec, Canada

FY 2003 FUNDS: $160K

DESCRIPTION: High density polynitropolyaza-caged compounds contain high energy that attracts the military to use them as high energetic explosives and propellants. A typical energetic chemical of this family commonly known as CL-20 is being considered a potential replacement for existing propellant and explosive materials. However, it has been recognized that the potential environmental fate and impacts of this compound must be understood prior to its adoption as a common use energetic material. Previous practices involving explosives such as RDX and HMX, including manufacturing, waste discharge, testing and training, demilitarization, and open burning/open detonation (OB/OD), have resulted in severe soil and groundwater contamination. Furthermore, it has been shown that both RDX and HMX are modestly toxic to aquatic organisms and indigenous soil microorganisms. Future wide military practices with CL-20 (manufacturing, storage, testing, and training) may also result in environmental contamination of soil and groundwater and thus in adverse effects to the environment. The project is addressing the following objectives: (1) investigate the transport, and the biotic and abiotic degradation of CL-20; and (2) study the lethal and sub-lethal environmental effects of CL-20 on terrestrial higher plants, soil invertebrates, soil microorganisms, and avian and aquatic species. Very little environmental data are available on CL-20. A one-year feasibility study was performed to collect preliminary data on its (bio)degradability, interactions with soil, and toxicities to some selected ecological receptors. This project, in collaboration with SERDP projects CP-1254 and CP-1255, will develop methods for CL-20 analysis.

BENEFIT: Scientifically sound and convincing environmental data (transport, transformation and ecotoxicological effects) generated on CL-20 from this project will provide military personnel and other site managers with a knowledge base to help understand and predict the fate and environmental impact of CL-20.

ACCOMPLISHMENTS: Researchers developed a SOP method for the analysis of CL-20 in soil and water. Two methods based on HPLC and capillary electrophoresis were developed for the analysis of the energetic chemical and its degradation products. The stability of CL-20 was investigated in water and in water/acetonitrile solutions and its solubility was measured at different temperatures. Researchers determined the octanol/water partition coefficient (K_{ow}) and the sorption coefficient of CL-20 with topsoil. The determination of K_{ow} and Kd parameters can be used to predict soil adsorption, migration through subsurface soil, and bioaccumulation in terrestrial and aquatic biota. Preliminary data were obtained on the degradability of the compound by photolysis, hydrolysis, and soil microbial degraders. Finally, encouraging preliminary data was obtained on the toxicity of CL-20 towards various aquatic, terrestrial, and avian organisms.

TRANSITION: The knowledge of (bio)degradability and ecotoxicity of CL-20 generated from the laboratory work will allow the prediction of its environmental fate and effects in the field. This information can be used by the DoD to help make implementation or deployment decisions on CL-20. If CL-20 is adopted, this information can also be used by site managers and engineers to help design any possible remediation plans at contaminated sites. Besides, successful laboratory bench-scale microcosms for the degradation of CL-20 can provide the fundamental data for pilot-scale demonstration work and for optimizing the engineering parameters for field applications.

PROJECT SUMMARY

PROJECT TITLE & ID: Advanced Acoustic Models for Military Aircraft Noise Propagation and Impact Assessment; CP-1304

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kenneth Plotkin; Wyle Laboratories – Arlington, VA

FY 2003 FUNDS: $643K

DESCRIPTION: Current environmental noise models used by the Department of Defense (DoD) to assess the impact of military aircraft operations are not appropriate for the new generation of fighter aircraft with high performance engines and vectored thrust capabilities. This shortcoming has the potential to lead to restrictions in flight operations at airbases and within training airspaces. New models, which take advantage of today's computer computational capabilities, are needed to provide legally defensible noise assessments of current and future aircraft operations in protecting bases and airspace for training purposes and in minimizing restrictions based on noise. The objective of this project is to provide environmental specialists with tools, based on the latest technology, for assessing and mitigating the noise impact around bases and on ranges of the new generation of fighter aircraft operating under all possible weather and terrain conditions. The research effort will consist of two main elements. The first will be a series of numerical, laboratory, and field studies to develop practical models for nonlinear generation and propagation of noise from high-thrust, vectored jet engines. The second element will be development of computer simulation procedures for the visualization of the resultant dynamic noise fields. The product will allow planners to incorporate a completely new set of operational scenarios and features, such as non-linear propagation and dynamic visualization of noise exposure, not available in current models, that will assist in public presentation and understanding of potential noise impacts and their mitigation.

BENEFIT: The information developed under this study will represent a significant advance in the understanding of non-linear propagation from high-level noise sources and in the measurement of aircraft source noise levels. This will allow DoD to more accurately estimate the noise environment from aircraft operations and provide a scientific foundation for installation commanders in responding to criticisms from knowledgeable citizens on the appropriateness of these estimates. These tools will assist DoD in being responsive to the requirements of the National Environmental Policy Act of 1969 (NEPA) while protecting operational readiness from unreasonable restrictions based on today's limited knowledge of nonlinear noise effects.

ACCOMPLISHMENTS: Work has been initiated on the survey of non-linear propagation models and existing data that can be used for comparison with the algorithms is being explored. Work on the instrumentation and analysis system requirements for the first field measurements is underway.

TRANSITION: One of the main deliverables of this project will be a new aircraft noise model for the assessment of community and environmental impacts. This will provide planners and environmental analysts with the best tools in a short amount of time. It is expected that a DoD agency will assume primary responsibility for the maintenance and distribution of the program as it is made available to end users.

PROJECT SUMMARY

PROJECT TITLE & ID: Impacts of Fire Ecology Range Management (FERM) on the Fate and Transport of Energetic Materials on Testing and Training Ranges; CP-1305

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Rob Hinchee; Battelle Memorial Institute – Columbus, OH

FY 2003 FUNDS: $120K

DESCRIPTION: There exists a growing concern that the accumulation of unexploded or unconsumed energetic compound residues in soils on military testing and training ranges represents a threat to human health and the environment. These residues, which can take the form of discrete "chunks" or very fine particles, may dissolve and leach into groundwater or be carried offsite in runoff. This illustrates the need for range management practices that effectively reduce inventories of energetic residuals, thereby avoiding costly environmental cleanup projects and disruptions in DoD training activities.

The objective of this project is to determine the degree to which prescribed burning reduces surface and near-surface energetic residuals in range soils. Variables such as burn intensity, soil depth, and vegetation density will be measured to quantify the conditions necessary to optimize reduction of energetic residuals. The observed energetic contaminant destruction will be assessed in terms of mass loadings of energetic compounds in surface water runoff from controlled test plots. Results from this study will be used to develop burn scenarios that help reduce the inventory of energetic contamination on ranges without compromising the benefits of burning to achieve specific land management objectives. The final report will examine the impact prescribed burning has on the fate and transport of energetic residuals. Specific attention will be devoted to the relationship between energetic residuals and native plant species, and how that relationship can be exploited to enhance the destruction of the energetic contaminants.

BENEFITS: Documenting the impact prescribed burning has on energetic residuals can serve as a basis for developing prescribed burning strategies that maximize the destruction of energetic residuals, thereby minimizing the likelihood of widespread environmental contamination. The long-term potential benefit to the DoD will be the deployment of a range management tool that may prevent the need for costly environmental cleanup projects and help avoid interruptions in training activities caused by environmental and/or regulatory concerns.

ACCOMPLISHMENTS: The primary focus of the efforts to date has been range selection. Battelle has been working with the University of Rhode Island (URI) and the Air Force Center for Environmental Excellence (AFCEE) to outline criteria for range selection and has been in contact with potential bases (e.g., Eglin AFB, FL; Ft. Lewis, WA) to determine their suitability and willingness to participate in the project. Once a range has been selected and range soils collected, the URI can begin laboratory testing with those soils.

TRANSITION: Project team members will work cooperatively with members of the DoD user community to accomplish project objectives. In addition, findings will be presented at various professional symposiums and submitted for publication to peer-reviewed journals. Finally, this work may lead to the development of a guidance document that describes the use of prescribed fire to mitigate hazardous caused by energetic residuals.

PROJECT SUMMARY

PROJECT TITLE & ID: On-Range Treatment of Ordnance Debris and Bulk Energetics Resulting from Low-Order Detonations; CP-1330

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Philip Thorne; Applied Research Associates – South Royalton, VT

FY 2003 FUNDS: $119K

DESCRIPTION: Low-Order Detonation (LOD) debris is poorly characterized and a potential source of contamination to groundwater beneath live-fire testing and training ranges.

This project aims to complete development of a low-cost, fieldable process for the rapid decontamination of energetic materials (EM) from bulk compositions and LOD debris. The on-range process will use rapid decomposition, dissolution and hydrolysis to separate EM from metallic debris and destroy it. Data will be aquired to evaluate chemical processes for treating the decontamination solutions on-site so that no hazardous wastes require disposal will be acquired. Ordnance debris with visible EM residues and "chunks" of EM compositions will be collected manually or robotically and segregated. The contaminated items will be placed in tanks containing polyglyme(polyethylene glycol dimethyl ether)/sodium hydroxide solution which will be re-circulated until the EM residues decompose and dissociate from the scrap. The scrap can then be removed and sent off-range for recycling. Dissolved EM will be hydrolyzed and the polyglyme/hydrolysate chemically destroyed using combustion or hydrothermal oxidation. Simple field colorimetric analysis will be used to determine when enough of the EM has been hydrolyzed so that thermal treatment can be safely performed.

BENEFITS: The flexibility (applicability on different scales), safety, simplicity and low costs associated with this decontamination technology will facilitate its use by site personnel. The capability for handling LOD debris and "chunk" energetics will reduce the amount of hard-to-handle UXO that must be processed by site personnel, resulting in improved safety and lower disposal costs. Some costs may be offset by using the decontamination solution as a co-fuel. By dealing with the most contaminated materials, implementation of the new process is also likely to reduce the need for wide-area decontamination, which again will reduce cleanup costs.

ACCOMPLISHMENTS: Tests of the aqueous/acetone decontamination solution that was developed during the SEED project were conducted with larger pieces of bulk energetic compositions. At this scale the dissolution rates were quite slow and the capacity of the solutions low. Polyglyme, a glycol ether, was substituted for the aqueous/acetone for further tests. Dissolution of TNT and Composition B was rapid. Polyglyme also supported concurrent base hydrolysis of these energetics. Thus, it appears that several pounds of these energetics can be dissolved and hydrolyzed/gallon of polyglyme. Planning is underway to test small batches of this solution on-range with low-order detonation debris.

TRANSITION: The technology will be introduced at several ranges as the first transition step. It is expected that familiarity with the process and its performance will encourage those ranges to adopt the technology for full-scale remedial clean-ups and for the more extensive routine clearances that will be required once the LOD debris problem is fully recognized. Applied Research Associates is well positioned to supply decontamination systems and support to end users. The intent is to commercialize the technology through both the sale of systems and decontamination services.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of Off-Road Diesel Emissions of Criteria Pollutants; CP-1336

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Watson; Desert Research Institute- Reno, NV and Wayne Miller; University of California – Riverside, CA

FY 2003 FUNDS: $623K

DESCRIPTION: As a result of their reliability and fuel economy, diesel engines have become the preferred power source for many activities at Department of Defense (DoD) facilities. Emissions from these activities are currently not well understood, making it difficult for environmental staff on military installations to provide emissions information needed for state and regional planning. Quantification of PM, NO_x, sulfur dioxide (SO_2), volatile organic compounds (VOC), and other chemicals from diesels in military use is needed to develop effective policies that will achieve current and future air quality standards. The primary objective of this project is to develop source-, use-, and fuel-specific emission estimates for representative DoD mobile and stationary diesel equipment, most of which is not extensively used on paved public roadways. These estimates must meet the minimum requirements of the Consolidated Emissions Reporting (CER) rule for emission rates of carbon monoxide (CO), NO_x, VOC, PM_{10}, $PM_{2.5}$, SO_2, and ammonia (NH_3). A second objective is to develop, test, and apply new methods for quantifying non-road emissions that more efficiently and realistically represent actual operations than engine dynamometer certification tests. The final objective is to integrate these results into U.S. EPA non-road emissions and source profile software and to create an emissions modeling system that permits quick and efficient estimates to be made for military installations.

BENEFITS: The project will provide the DoD with new emission measurement technologies and improved emission inventories for use in assessing progress toward improving air quality and assessing progress for national air quality standards and visibility goals.

ACCOMPLISHMENTS: This is an FY03 New Start.

TRANSITION: The products of this research are: modern non-road exhaust test methods; documented data bases of emissions measurements for many different fuel/engine/use combinations; integration into national NONROAD and SPECIATE software; and an easy to use emissions model tailored to military applications. Data sets and models will be available via the internet, and one training course will be organized and conducted. Measurement technology will be commercialized, when possible.

PROJECT SUMMARY

PROJECT TITLE & ID: Tailpipe Emission Estimation for DoD Off-Road Sources; CP-1338

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Michael Kemme; U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory – Champaign, IL

FY 2003 FUNDS: $187K

DESCRIPTION: Emissions from tactical equipment engines contribute to local and regional air pollution during training activities. Although many of these sources are exempt from regulations that limit these emissions from comparable civilian sources, DoD installations still must be able to answer regulatory questions about the impacts these sources have on air pollution problems.

The proposed project will develop a database of DoD diesel engine powered off-road equipment. The database will contain information about fuels, equipment, engines, inventories, usage, and fuel consumption. Detailed tactical equipment information such as age, mileage, use, etc., will ensure that equipment tested represents a larger population of the equipment type. The fuel consumption data allow an estimate of engine use independent of hours-of-operation estimates and will justify the specific fuels used for emission tests. The work will integrate data from many disparate sources into a single database that is useful for prioritizing emissions research or as an easily accessible source of information for estimating emissions. The database will be designed so that it can be modified through a user interface or by automated batch procedures that capture data from known sources. The database will also contain sets of useful queries and reports to provide output useful for data analysis.

BENEFITS: The primary benefit of this research will be its contribution to the development of a tool to accurately estimate engine emissions for DoD off-road sources. This capability will be useful to DoD environmental staff, installation managers, and designers of military training ranges to estimate environmental impacts of off-road diesel emissions and to develop recommendations for reducing these emissions. The database of DoD off-road sources and activity levels will also be a useful tool for researchers investigating other environmental impacts related to off-road diesel engine use.

ACCOMPLISHMENTS: This is an FY03 New Start.

TRANSITION: All the products of this research will be approved and provided to the U.S. EPA for their dissemination. Military personnel will be able to obtain the emission estimation technology through the U.S. EPA or through commonly visited Internet sites (i.e., Defense Environmental Network and Information eXchange-DENIX).

PROJECT SUMMARY

PROJECT TITLE & ID: Assessing the Impact of Maneuver Training on the NPS Pollution and Water Quality; CP-1339

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Steichen; Kansas State University – Manhattan, KS

FY 2003 FUNDS: $200K

DESCRIPTION: Military training maneuvers have the potential to significantly alter land surfaces in a manner that promotes Non-Point Source (NPS) pollution, preventing military installations from meeting water quality standards and the decline of training lands. In order to avoid training operation restrictions, proactive management plans must be developed to give commanders the information they need to assess the environmental cost of training and management practices that reduce the environmental impact.

Investigators will assess the impact of two major sources of NPS pollution on surface water quality at Fort Riley, Kansas: (1) erosion from upland training areas and (2) channel erosion at stream crossing sites. These objectives will be met through a comprehensive analysis of military activities, climatic factors, and environmental response. Researchers will use a watershed water quality model in conjunction with remotely sensed information and a geographic information system (GIS) to assess the impact of training on water quality, in particular on the amount of soil erosion. Particular attention will be paid to linking weather, vegetation stage, and training activities to water quality. A matrix of training intensity and weather will be created to give commanders a tool for assessing the environmental cost of training maneuvers. Researchers will instrument three buffer sites with runoff samplers to determine the effect of vegetated buffers for controlling NPS pollution. A complete survey characterizing the buffer, including vegetation and soil characteristics, will be conducted at each field site. The Riparian Ecosystem Management Model (REMM) will be adapted to each site and provide a tool for determining the optimal buffer width to control soil erosion caused by military maneuvers. New real-time data collection systems will be developed and installed at Low Water Stream Crossings (LWSCs) to assess the impact of vehicle crossings on stream water quality and erosion dynamics.

BENEFITS: Land managers will benefit from the design guidance that will assist them in maintaining and enhancing riparian filter areas for water protection. An environmental decision support tool will allow Commanders to guide their decisions on the use of training lands and the potential for environmental damage

ACCOMPLISHMENTS: This is an FY03 New Start.

TRANSITION: A better understanding of the characteristics of sediment-laden runoff and the effectiveness of riparian filter strips will be useful for many installations. Results from this study will culminate in a model for assessing the impact of military training and weather on NPS pollution and TMDL compliance. Fort Riley is representative of several maneuver posts located in the central United States. Project results will be transferred to military installations by workshops and field trips at an ITAM Workshop sponsored at Fort Riley near the end of the project.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of an Adaptive Framework for Management of Military Operations in Arid/Semi-Arid Regions to Minimize Watershed and Instream Impacts from Non-Point Pollution; CP-1340

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mark Wigmosta; Pacific National Northwest Laboratories – Richland, WA

FY 2003 FUNDS: $200K

DESCRIPTION: To ensure adaptability in managing training operations while minimizing impacts on watersheds, the Department of Defense (DoD) needs to identify activities that contribute to non-point source (NPS) pollution, and strategically locate and schedule training operations to minimize impacts. Decision tools are needed that provide information to articulate tradeoffs between alternative management actions and resultant impacts and/or benefits to training range or adjacent downstream water bodies. A set of decision tools, process models, and GIS databases will be assembled, linked and integrated as an adaptive management framework that will allow DoD to minimize constraints on training exercises while ensuring protection of watersheds and compliance with Total Maximum Daily Load (TMDL) targets. The decision tools will assist in optimizing design and implementation of operations, management plans, and policies while accounting for uncertainties. They will be supported by state-of-the-art watershed/erosion models and GIS models linked to tailored remotely sensed and conventional databases. NPS pollution resulting from military training activities will be identified using advanced pattern recognition techniques to characterize spatial variability and changes in soil and vegetation. The level of impact will be quantified in the form of hydrologic model input parameters. The framework will be accessible via the Internet. The practical utility of the adaptive management framework for managing training operation environmental impacts in arid/ semiarid regions will be demonstrated at the Yakima Training Center, WA.

BENEFITS: DoD will benefit from an adaptive management tool for more effective, streamlined, and integrated operational and environmental planning at military bases in arid and semiarid regions. Improved management of training lands will help maintain sustainable training facilities, protect water quality and the natural resource base while avoiding violations of TMDL and other regulations.

ACCOMPLISHMENTS: This is an FY03 New Start.

TRANSITION: The adaptive framework to be developed under this project will be demonstrated/ transferred and made fully operational for use at the Yakima Training Center (YTC) on YTC computer systems. YTC staff will be fully instructed in the use of the framework. Materials produced for this technology transfer process will be designed to facilitate broad transfer to other military facilities as well.

APPENDIX C
Conservation Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Emerging and Contemporary Technologies in Remote Sensing for Ecosystem Assessment and Change Detection on Military Reservations; CS-1098

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Randall Karalus; U.S. Army Corps of Engineers Engineer Research and Development Center, Topographic Engineering Center – Alexandria, VA

FY 2002 COMPLETED PROJECT

DESCRIPTION: Federal land managers need accurate and affordable ways to assess the health and availability of their training lands. This research was designed to develop techniques that relate ecological concepts of carrying capacity, vegetation dynamics, critical thresholds, habitat fragmentation, ecosystem response and recovery, and land degradation to the response of remotely sensed spectral indicators, and ultimately, to training and testing upon military installations. The objective was to apply spatial and temporal change detection methods over a range of geographic scales using contemporary and emerging remote sensing technologies and traditional field surveys to identify and monitor land degradation.

The approach for this project was essentially a composite of: (1) mapping the installation or selected components thereof; (2) correlating the fundamental attributes of disturbance, vegetative cover, and plant succession; (3) analyzing, retrospectively, the ecological history of each installation in relation to land use; and (4) assessing high resolution systems to identify the sensor attributes necessary to monitor changes in plant species composition along disturbance gradients and plant succession stages.

Two types of analyses were conducted: retrospective analysis, and ecotone and degradation gradient analysis. The purpose was to consider ecosystems in terms of their temporal and spatial characteristics, respectively. The retrospective analysis is a combination of (1), (2), and (3) described above. Whereas, the ecotone and degradation analysis is a combination of (1), (2), and (4). Analyses were conducted at three facilities: Camp Williams, Utah - Army National Guard; Fort Bliss, Texas - U.S. Army; and, Marine Corps Air Ground Combat Center (MCAGCC), Twentynine Palms, California. Each of these facilities represented three of the four types of desert ecosystems in the U.S.: the Intermountain Cold Desert, Chihuahuan Desert, and Mojave Desert.

BENEFIT: Installation managers will benefit from standard techniques for cost-effective environmental change detection and extrapolation of field data through the use of remotely sensed data. The capabilities produced by this research will significantly improve the accuracy and cost/time-effectiveness of data collection, monitoring, and modeling for military land management.

ACCOMPLISHMENTS: Over the course of several years, this project has developed remote sensing-based protocols and tools to assess and monitor the status of military landscapes in arid and semi-arid environments. The project completed the processing and analysis of images from the bases listed above for both the ecotone and temporal research aspects of the effort. Concerning the retrospective part of the project, the team has analyzed imagery and related the data to the ecology of the system. An inventory was completed on all raw, intermediate, and final images for the study sites. The relationship between Landsat derived SAVI temporal fluctuations at Camp Williams and LCTA results was investigated. A project website was established (http://www.gis.usu.edu/~doug/SERDP/) that contains information on the project such as objectives, field sites, performers, papers, and data. Also part of the website are tutorials specific to each PIs primary research objective. For example, one of the tutorials assesses environmental damage/change on military installations with remotely sensed imagery. This tutorial introduces environmental remote sensing derived from this project through descriptive and interactive examples.

TRANSITION: The project will acquire an impressive, and to a large degree unprecedented, array of imagery data types for three military facilities in the southwestern U.S. University of Nevada - Reno (UNR) constructed a web site (http://www.ag.unr.edu/serdp) to facilitate data transfer. The website will be integrated with University of Illinois at Urbana and Utah State University's websites in 2002. The data will provide a baseline against which installation managers can compare future inventories and interventions. This database will not only be available for the installation managers and their environmental staff, but will also be available for further research and adaptation by other research organizations. Deliverables include: models for change detection of land use on military reservations; methods for scale transitions; relationships between hierarchical scheme of spectral and spatial resolution to ecotone/biological thresholds/degradation; protocols for data extrapolation from remote sensing imagery; and a better understanding of ecosystem response and recovery in relation to disturbance (land use).

PROJECT SUMMARY

PROJECT TITLE & ID: Improved Units of Measure for Training and Testing Area Carrying Capacity Estimation; CS-1102

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Alan Anderson; U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory – Champaign, IL

FY 2002 COMPLETED PROJECT

DESCRIPTION: This project proposed to significantly improve the Army Training and Testing Area Carrying Capacity (ATTACC) methodology. The focus of this project was to develop quantitative units of measure to estimate training and testing land carrying capacity, extend the spatial and temporal scale of the methodology to include individual training areas and changes in training and land condition throughout the year, and validate the improved methodology. The enhancements that were incorporated into the ATTACC model include: (1) revised water erosion model; (2) wind erosion model; (3) plant species composition; and (4) time varying climatic factors. The unit stream power approach for estimating the topographic factor of Revised Universal Soil Loss Equation (RUSLE) was incorporated into the water erosion model to account for complex topography typical of military lands. Existing wind erosion models were evaluated to determine which were most applicable to military lands based on data requirements and model assumptions. The results from the completed SERDP project on Terrain Modeling and Soil Erosion (CS-752), were used to improve estimates of land condition and can be extended to off-site impacts (sedimentation and water quality).

BENEFIT: By providing an improved methodology, mission impacts can more accurately be matched to the ecological capability of military lands to support those activities resulting in decreased land maintenance costs, maintaining realistic training conditions, and increasing land use capacities.

ACCOMPLISHMENTS: The Army's Integrated Training Area Management (ITAM) Army Training and Testing Area Carrying Capacity (ATTACC) software was modified to include additional measures of land condition to better assess the capacity of installation lands to support training activities. The software was used to develop data for use in several Stryker environmental impact statement (EIS) assessments. In addition, Hawaii, the Alaska and Fort Polk Stryker Brigade Combat Team also included these methods in their site EISs. The Ecological Dynamics Simulation (EDYS) model was utilized to incorporate species composition into the ATTACC model. A sub-model was developed for the EDYS model that translates training/testing activities into changes in soil and vegetation processes. Existing DoD impact studies were used to estimate the primary impacts of military activities on soil and vegetation processes. Also, components of the ATTACC model were modified to incorporate time varying climatic factors.

Vehicle monitoring and impact assessment methods developed to collect field data to support implementation of ATTACC carrying capacity methods are being used at Fort Lewis and Yakima Training Area. Data from the field studies are an integral part of the installation's cultural and natural resources management plans. The field methods allow installations to monitor and assess vehicle impacts and adapt management policies and practices to evolving training doctrine and training loads.

TRANSITION: Researchers have been actively involved in the Army Corps of Engineers' Land Management System (LMS) initiative and have participated in the Fort Hood LMS Military Demonstration and activities of the LMS Integration Team. Project activities were coordinated with several DoD user groups including (1) the ATTACC Wind Erosion Advisory Group, (2) ITAM Installation Steering Committee, and (3) ATTACC Working Group. Team members were also asked to serve on the United States Department of Agriculture (USDA) WEPS advisory group.

PROJECT SUMMARY

PROJECT TITLE & ID: Identify Resilient Plant Characteristics and Develop a Wear Resistant Plant Cultivar for Use on Military Training Lands; CS-1103

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Antonio Palazzo; U.S. Army Corps of Engineers Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory – Hanover, NH

FY 2003 FUNDS: $150K

DESCRIPTION: Wear-resistant plants are needed to mitigate environmental impacts and improve the use of Department of Defense (DoD) training lands. Knowledge of the relationships between military training and plant injury, regrowth, and wear resistance is limited. Plant and soil data will be combined allowing land users to make knowledgeable choices concerning plant selection and site-rehabilitation procedures to reduce soil erosion. This project intends to use several collections of resilient and other plants to breed new, more resilient cultivars. A second objective is to conduct field and greenhouse studies to quantify the degree of compaction that occurs during training and relate soil condition to root injury in plants with known resilience.

The technical approach identifies and develops training-resilient plant cultivars. The greenhouse study is on soil compaction and plant root growth. Three species are being studied (Reliant hard fescue, Blackwell switchgrass, and western wheatgrass) and three compaction levels in six soils. The field study is evaluating a naturalized cultivar and two native cultivars which were seeded in mixtures and in several different row-space combinations.

BENEFIT: This project will provide DoD guidance for mitigation methods in restoring training lands and will provide more resilient plant species that will help to increase training opportunities on existing training areas. This guidance will assist land managers and trainers in making choices on training schedules and in estimating cost and time requirements for maintaining military readiness.

ACCOMPLISHMENTS: Using plant materials existing on western military lands, new germplasms were selected and developed with the desired traits of rapid germination and establishment, tiller and rhizome development, reduced seed dormancy (early spring growth), and tolerance to abiotic and biotic stresses. The desired plant materials were selected from multiple sources, giving the new germplasms a wide genetic base to increase the plants' ability to adapt to future environmental and man-made stresses. To date, four new germplasms have been released: CD-II crested wheatgrass, Tetra-1 Russian wildrye, RoadCrest crested wheatgrass, and P7 bluebunch wheatgrass. In 2002, three-to-five year large-scale demonstrations of the new germplasms were established at Camp Guernsey, Wyoming, and Yakima Training Center, Washington. Along with developing the new germplasms, this project has: (1) studied the effects of tracking on soil compaction and root growth; (2) investigated seeding techniques to further improve the establishment rates of the improved SERDP-select native grasses; and (3) began to market the new plant materials.

TRANSITION: The results and findings of this project can be expanded to include the development and testing of additional plant species on a variety of soil types. This will provide opportunities for widespread application/demonstrations of this information to other testing and training ranges. This project will provide valuable information for organizations outside of DoD who deal with plant resiliency and soil compaction problems, as well. A business plan has been written to market and release the new germplasms and a major marketing effort was conducted in 2002 with a workshop at Fort Carson and the U.S. Air Force Academy on the new germplasms and methods of controlling invasive weeds and establishing native grasses.

PROJECT SUMMARY

PROJECT TITLE & ID: SERDP Ecosystem Management Program (SEMP); CS-1114

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. William Goran; U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory – Champaign, IL

FY 2003 FUNDS: $2432K

DESCRIPTION: The SERDP Ecosystem Management Program (SEMP) was established as an outgrowth of the 1997 SERDP Management Scale Ecological Research Workshop during which it was determined that the DoD should establish a long-term ecological monitoring program at a military base with possible expansion to some other bases in the future. The overall program objective of SEMP is three-fold. First, SEMP directs and selects DoD relevant, ecosystem management research initiatives. Secondly, it manages a long-term ecological monitoring system to support these research efforts while also fulfilling some of the host installations monitoring requirements. Finally, SEMP facilitates the integration of results and findings of research into DoD ecosystem management practices. The SEMP is managed by a separate Program Manager with the assistance of a Technical Advisory Committee (TAC).

Under the Ecosystem Characterization and Monitoring Initiative (ECMI), a team works with the host installation to gather, assess and document historic and current ecological data sources and monitoring efforts. In addition, this team is responsible for long term ecological monitoring. Data from the characterization effort, the monitoring efforts and the research teams all flows into the common data repository, shared by all research teams and the installation managers.

Selected research teams work in a collaborative context -- sharing field sites and approaches, entering data into a common repository, reviewing each other's findings, and contributing to common technology transfer mechanisms. Three research groups were initiated in FY99 to examine ecological indicators. The objectives are to identify indicators of ecological change at multiple spatial and temporal scales, and to establish relationships between ecological indicators and land use. In FY00, two research teams initiated the identification of ecological disturbance from military land use with the objective being to develop the knowledge to implement ecosystem management approaches for military lands.

BENEFIT: DoD's Conservation user community is directed to implement an ecosystem approach to land management issues. However, there is a critical need for scientific information to support this approach, especially as it relates to integrating ecosystem management with mission concerns. The success of user plans will depend on the capabilities and increased knowledge generated by research investment. SEMP will facilitate a number of studies that can be sufficiently planned and funded to allow a full array of remote sensing, ground truth experiments, modeling, cause-effect studies, etc. to be integrated to address complex problems. This contributes to data sharing, leveraging, and joint publications, supported by major experimental findings. Focused development of an ecosystem research plan, appropriate instrumentation and monitoring to support this research, and identification and selection of the most effective, technically sound research efforts to answer user needs will all contribute to the science and understanding necessary for an ecosystem approach to land management.

ACCOMPLISHMENTS: The SEMP program management coordinated an annual research coordination meeting including SERDP-funded and non-SERDP research teams associated with Fort Benning studies. This meeting was instrumental in integrating efforts and initiating collaboration among the researchers supporting resource management at Fort Benning, Georgia. The SEMP Technical Advisory Committee met throughout the year to provide recommendations to the program manager on the technical approach and progress of each of the SEMP research projects. Two special reports were published by the program management. The first is a report titled "The SEMP Approach" which covers the history of the SEMP effort and how the research results will be integrated and helpful to Fort Benning resource management staff. Additionally, the Proceedings of "Partners Along the Fall Line: Sandhills Ecology and Ecosystem Management Workshop" was published and made available to participants of the workshop to facilitate continued regional coordination.

The ECMI team provided the software and training to the Fort Benning resource management staff to download near real-time meteorological data through the SEMP repository to assist in day-to-day management decisions on the installation. The stream gauges were adapted to accommodate the current drought conditions and subsequent low stream flows. Water flow, level, and temperature are now monitored with automated stations. Water quality parameters are being monitored via manual sampling at six sites on a bi weekly basis. Ground water data are being collected hourly and entered into the repository on a monthly basis. Riverine habitats on the base are being characterized through the aquatic monitoring protocols. A second land cover map was developed using Land SAT ETM data from 2001. The erosion/deposition measurements were implemented during 2001 and the first re sampling occurred during 2002. Using data from the Fort Benning Forest Inventory, estimates of woody productivity have been derived. Fort Benning was confirmed as a MODIS (Moderate Resolution Imaging Spectroradiometer) ASCII (American Standard Code for Information Interchange) site in the fall of this year. A suite of MODIS land products will be assisting the SEMP research teams by providing critical measurement including: photosynthetic active radiation, net primary photosynthetic production, and vegetation indices.

The SEMP data repository stores most of the available data that are associated with the current research efforts. All teams have contributed at least one set of data/metadata to the repository. Several modifications to the SEMP data repository have been made. These include monthly notification to all users of all new data added, automatic notification of success to users when they submit data for upload, and links to the SERDP and SEMP web sites.

Under the research project **Determination of Indicators of Ecological Change**, Dr. Ramesh Reddy, University of Florida, continued the effort to identify relationships among ecological indicators and land condition following soil and vegetation sampling of 300 sites over a broad area encompassing a range of military and non military land use and anthropogenic disturbance (low intensity sampling). Multivariate data analyses were completed on Phase I and II biogeochemical data. Hyperspectral analysis was conducted on Phase I soil samples to determine the relationship between biogeochemistry and spectral reflectance. A study of ground cover vegetation for different recovery times after clear cutting was conducted. Soil water content measurements were obtained and used to estimate the total water storage and spatial movements of water content within the Bonham catchment. Watershed hydrologic monitoring continued, including precipitation monitoring, stream flow gaging, throughfall measurements, and soil-, ground- and stream-water sampling.

Under the research project **Development of Ecological Indicator Guilds for Land Management**, Dr. Anthony Krzysik of Prescott College continued the investigation of ten ecological indicator systems to assess and monitor landscape conditions and trends on the basis of ecologically relevant metrics and unbiased statistical methods. Nine study sites were selected at Fort Benning that represented three replicates each in low, medium, and high disturbance landscapes. Important ecological indicator systems were developed to characterize the disturbance gradient in the Sand Hills of Fort Benning, Georgia. The depth of the A Horizon and soil compaction were determined to closely and clearly characterize the entire disturbance gradient. Other systems identified were general ground cover, soil chemistry, and the ground/litter ant community. Preliminary analyses indicated that the woody ground cover community and microbial community also appear to be promising indicators. Plant developmental instability and physiology were assessed as possible ecological indicators as well.

Under the research project **Indicators of Ecological Change**, Dr. Virginia Dale of Oak Ridge National Laboratory has calculated and analyzed the landscape metrics for Fort Benning. The potential aquatic indicators at Fort Benning were narrowed to: (1) suspended sediment and nutrient (NH_4, NO_3, PO_4) concentrations (baseflow, storms); (2) diurnal dissolved oxygen profiles (in stream metabolism); (3) streambed organic matter content (habitat); and (4) macroinvertebrate communities (various metrics at population and community levels). The historical reconstruction of the 1827 forest types was prepared based on Land Office records. Field studies have determined the understory characteristics of sites with different training intensities, found that microbial biomass in the soil decreased with increasing levels of disturbance, examined macroinvertebrarte community structural changes as related to disturbance, and developed comparisons of stream sediment and dissolved mineral concentrations across a spectrum of disturbance and discharge regimes.

Under the research project **Disturbance of Soil Organic Matter and Nitrogen Dynamics: Implications for Soil and Water Quality**, Mr. Charles Garten, Oak Ridge National Laboratory continued the investigation of thresholds associated with natural and/or anthropogenic disturbance that establish the potential recovery of soil quality on disturbed lands. In the area of field sampling, data analysis, and interpretation, the research team completed pre-disturbance soil sampling at the K 11 study site, soil sampling along a long leaf pine chronosequence, analysis of soil samples for soil carbon and nitrogen concentrations and stocks, and resampling of selected field sites to track recovery of measures of soil quality following site restoration activities by Natural Resources Conservation Science (NRCS) at Fort Benning. Significant progress was made on a multi compartment model to predict soil carbon and nitrogen dynamics and thresholds in soil quality to recovery and sustainability of forest ecosystems at Fort Benning.

Under the research project **Thresholds of Disturbance: Land Management Effects on Vegetation and Nitrogen Dynamics**, Dr. Beverly Collins, Savannah River Ecology Laboratory, monitored initial edaphic and vegetation responses to 2 year prescribed burns and compared these with unburned (4-yr) sites. Fire resulted in a modest, short term temperature increase at 1 cm soil depth and the organic layer loss was roughly in proportion to the pre-fire condition. Also, there was either no change or an increase in the extractable nitrate and ammonium following the prescribed burns. A reduction in the number of naturally established seedlings and sprouts suggests frequent fire could limit regeneration of canopy species.

Numerous publications and presentations have resulted from these projects. More information on SEMP can be found on the website: www.cecer.army.mil/KD/SEMP

TRANSITION: The goal of SEMP is to provide knowledge, tools, and techniques to contribute to understanding and enhancement of the ecological role of military installations within their ecoregions. Project results and findings will be integrated into DoD ecosystem management policy and procedures to provide DoD land managers the necessary guidance and tools for a sustaining future military training and testing. The monitoring and research results will also be available to other Federal land managers.

PROJECT SUMMARY

PROJECT TITLE & ID: Diagnostic Tools and Reclamation Technology for Mitigation Impacts of DoD/DOE Activities on Arid Areas; CS-1131

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. W. Kent Ostler; Bechtel Nevada – Las Vegas, NV

FY 2002 COMPLETED PROJECT

DESCRIPTION: This project was designed to overcome current gaps in diagnostic capabilities needed to distinguish between various degrees of sustainable and non-sustainable impacts due to military training and testing activities in desert ecosystems. Additionally, the project developed and evaluated new and cost-effective techniques for rehabilitation and restoration of such disturbed habitats. For diagnostic techniques, new rapid detection methods were developed using hand-held digital cameras and Hi-8 camcorders to record selected ground data. Combinations of innovative revegetation techniques developed at sites in the Mojave Desert were applied to disturbed lands at Fort Irwin. The approach included the establishment of plots of land representing 5 to 10 classes or degrees of disturbance ranging from light disturbance to very heavily disturbed sites (non-vegetated). Plots were treated at Fort Irwin with revegetation techniques. Vegetation and site conditions were documented in representative areas for each degree of disturbance. Ground data from the sites were correlated with remote sensing data. Field data was taken over a four-year period by the image collection techniques previously described.

BENEFIT: Approximately 70% of all U.S. military training lands are located in arid areas that will benefit directly from these technologies. Under current technology, it is estimated that up to 35% of revegetation projects will fail. Applying the results of this project will increase the success of the restoration and possibly save DoD as much as $5 million annually. These diagnostic tools will enable management to maximize utilization of limited training environs and thus increase operational readiness.

ACCOMPLISHMENTS: This project had many major accomplishments over the course of several years. Specifically, under the task of Reclamation Techniques, this research team (1) designed, implemented, and monitored more than 300 treatment plots; (2) designed portable, modular irrigation systems; (3) designed laboratory studies to determine factors controlling germination; (4) developed new seed priming technologies for enhancing germination; (5) determined cost-effectiveness of new reclamation techniques; (6) went to many installations to introduce new techniques to DoD, DOE, and EPA scientists; and (7) completed a Reclamation Technologies user's manual and workshop to facilitate transfer of successful technologies. Concerning Diagnostic Techniques, this project (1) evaluated conventional remote sensing applications for arid lands with low vegetative cover; (2) evaluated high resolution image capture for obtaining photo coverage of desert landscapes; (3) applied image processing techniques often used in medical research to digital aerial photographs and then developed user protocols to apply these techniques to DoD/DOE lands; (4) tested the application of Laser-induced fluoroscopy imagery and Laser-induced fluoroscopy spectrophotometry technology to detect stress from military activities on desert vegetation; and (5) completed a Vegetative Change Analysis user's manual and workshop to facilitate transfer of successful technologies.

TRANSITION: Technologies developed by this program can be used for a variety of applications currently needed by government agencies with land management responsibilities in both arid and moist environments. The primary applications include: (1) evaluating and monitoring the site's ability to recover from various levels of impacts, (2) rapidly assessing shrub density, height, diameter, size class and percent canopy cover (to control erosion), and (3) developing cost-effective revegetation techniques. Results from this project will be integrated into land management decision support tools to provide DoD land managers the necessary guidance for mitigation methods that will help to increase training opportunities on existing training areas.

PROJECT SUMMARY

PROJECT TITLE & ID: Application of Hyperspectral Techniques to Monitoring and Management of Invasive Weed Infestation; CS-1143

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Susan Ustin; University of California – Davis, CA

FY 2003 FUNDS: $356K

DESCRIPTION: The rapid spread of non-native invasive plant species, including noxious weeds is causing irreparable damage to the natural resources on military installations. This project aims to develop and demonstrate a new remote sensing methodology using hyperspectral imaging (HSI), for mapping invasive weeds. Seven bases have been selected that have different weed types, intensities, and patterns of environmental disturbances from the southeast, southwest, and northwest ecoregions of the U.S. to demonstrate, refine and validate the proposed methodology. Appropriate airborne flightlines that include a range of types of weed problems on the base, intensity of invasive weeds, and encompass a range of land use conditions will be identified. These data will provide a basis for demonstrating and assessing the benefits of HSI data for mapping various species of weeds under the diverse conditions existing at each of these military bases. New support vector machine learning tools will be used to characterize the habitats and identify weeds in the HSI imagery. The Hierarchical Foreground Background Analysis (HFBA) is one example of a multi-scale resolution analysis that is used to link the spectral variation for each pixel with variation in the spatial domain. The HFBA decomposition is coupled with a wavelet-based, multi-scale resolution in the spatial domain. This method addresses three issues (spectral redundancy, the span and completeness of a supervised classification, and a mechanism for producing an automatic classification) regarding spectral features which are not addressed by standard methods of image analysis. The combination of HSI tools for analysis of field spectra and images will provide a robust protocol for monitoring ecosystems that can be applied, even when the specifics of the location and the nature of the invasive species changes.

BENEFIT: The immediate benefit of this project will be a better understanding of the distribution of major invasive weeds on military bases and the environmental conditions associated with their distributions and spread. The long-term benefit will be in developing a cost-effective method for mapping weeds that can be used to monitor spread of weeds to new locations.

ACCOMPLISHMENTS: This project has acquired high resolution (~4m) AVIRIS hyperspectral image data over Vandenberg AFB, Camp Pendleton, Yuma Proving Ground, Aberdeen Proving Ground, and Fort Benning. GIS databases have been acquired from all bases in support of the image analysis and the ecological modeling. Ecological surveys have been conducted on all bases except Aberdeen and Eglin AFB and field remote sensing spectral data on all bases except Yakima Training Center. This project has succeeded in mapping iceplant and Pampas grass at Vandenberg and Arundo from Camp Pendleton from AVIRIS data. Recent results have found that both physiological indices and factor analysis can be used as classifiers for Arundo, iceplant and Pampas grass. This indicates that common analytical methods may be successful across a range of invasive weeds. This project has prepared the SAMS software, Spectral Analysis Management System), a tool for analyzing and processing field spectra, for distribution in the technology transfer aspect of the program and are working with Vandenberg AFB and Camp Pendleton to conduct training on the field and image analysis methods.

TRANSITION: Demonstrations of the tools will be provided to site personnel and written technology transfer documents and a web based training course as part of the technology transfer objectives will be developed. The image analysis and other software tools to be developed are compatible with GIS based management protocols and compatible with LMS software.

PROJECT SUMMARY

PROJECT TITLE & ID: Exotic Annual Grasses in Western Rangelands: Predicting Resistance and Resilience of Native Ecosystems Invasion; CS-1144

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jayne Belnap; U.S. Geological Survey, Canyonlands Field Station – Moab, UT

FY 2003 FUNDS: $277K

DESCRIPTION: This project is examining what controls a system's susceptibility to invasive species. While physical disturbance appears to play a role, many disturbed areas are not invaded, while many undisturbed areas have been invaded. This project proposes to (1) determine if the current distribution of cheatgrass (*Bromus tectorum* - an invasive species) and other annual grasses can be predicted on a landscape and regional level using soil chemistry; (2) construct a model that predicts which soils are resistant or susceptible to annual grass invasion for a large watershed; (3) investigate positive feedback loops that may perpetuate annual grass dominance, such as altered soil organic matter, litter, or chemistry; and (4) examine ways to favor native plant re-invasion by altering soil chemistry.

The initial focus will be the random selection and sampling of sites. These sites will represent major habitat types (based on vegetation and soil types). At each site, slope, aspect, elevation, soil type, past and present anthropogenic disturbance and distance to roads will be noted. Cover of vascular and non-vascular vegetation will be estimated. Soil depth and stability will be assessed along with chemical properties. Soil food webs will be analyzed as well. Magnetic properties, which indicate the presence of windblown dust, will be measured. Regression analyses will be done to see what factors best predict the presence of *Bromus*. If nothing is found to predict cheatgrass presence, the above will be repeated in an area of winter-rain only.

BENEFIT: This project will aid installation managers in predicting what soils are susceptible to invasive species and facilitate re-establishment of lost habitat. In addition, understanding how annual grass invasion changes natural ecosystem processes, such as nutrient availability, water availability, and soil microbial systems and how these changes affect re-establishment of native perennial plants, will enhance efforts to restore lost habitat. Specifically, the information resulting from this project will help prevent *Bromus* invasion, and therefore, sustain valuable military training and testing lands.

ACCOMPLISHMENTS: This research team has conducted surveys of soil chemistry, soil type, parent material and surficial geology on the Colorado Plateau and in the Mojave desert. Results have found that surficial geology, reflecting soil texture, does an excellent job of predicting the presence of annual grasses (*Bromus* spp., *Schismus* spp.). Greeenhouse trials have been conducted and show that zeolite, CaO, and NaCl greatly reduce germination of *Bromus* while only slightly affecting the native grass *Hilaria*. In a subsequent drought year, it was found that zeolite significantly reduced *Bromus* germination. However, repeating this experiment will make certain that results are applicable to more normal years. Also being examined in this study is the role of microhabitat in the success of *Bromus*. The effects of *Bromus* on native plants and nutrient cycles has been studied and the five-year presence of *Bromus* has still not resulted in the death of any natives.

TRANSITION: The projects resulting from this project will include datasets, metadata, technical reports, scientific publications and field consultations with land managers. Printed and digital media will be distributed. The project results will have impact on directing the specific management actions relative to *Bromus* invasion.

PROJECT SUMMARY

PROJECT TITLE & ID: Integrated Control and Assessment of Knapweed and Cheatgrass on Department of Defense (DoD) Installations; CS-1145

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mark Paschke; Colorado State University – Fort Collins, CO

FY 2003 FUNDS: $383K

DESCRIPTION: The objective of the project is to develop a strategy for the control, monitoring and prediction of knapweed and cheatgrass infestations at two military installations in the Western U.S. The technical approach evaluates the combined effects of (1) biological control using insect pathogens, (2) fire, (3) manipulation of soil N availability, (4) seeding with native late-seral species, and (5) restoration of the soil community. A replicated partial factorial arrangement of test plots in established communities of cheatgrass and knapweed are being used. The results of these manipulations on plant community composition will be monitored over a four-year period in order to evaluate success. Results from our study will be incorporated into an existing ecological dynamics simulation (EDYS) model. The EDYS model will be calibrated to each of the field study sites to assess the direct and indirect effects of treatments on ecosystem dynamics at multiple spatial scales, and to project potential effects of treatments on long-term successional dynamics. Remote sensing methods will be used to test the effectiveness of these methods for monitoring population densities of weed species over a large area.

BENEFIT: This project will provide a new effective methodology for controlling non-indigenous invasive plant species. The overall long-term benefit will be reduction of knapweed and cheatgrass populations on military installations and other lands, and a return of native plant communities to provide more realistic training areas and thus improve mission readiness.

ACCOMPLISHMENTS: Research plots were established at Fort Carson (FC) and Yakima Training Center (YTC) in the spring of 2000. Experimental treatments for the control of annual brome and knapweed were initiated immediately following baseline data collection in 2000. These treatments included release of insect biocontrol agents for knapweed, burning of annual brome stands, seeding with desirable plant species, control of soil N availability, and introduction of late-successional soil communities. Post-treatment data have been collected during the summers of 2001 and 2002 for each of the 160 research plots. These data include plant community biomass composition, soil fungal community assessment, soil nitrogen availability, and knapweed biocontrol population assessments. Populations of insect biological control agents released in 2000 have become established in the plots (*Larinus minutus* at YTC and *Cyphocleonus achates* at FC). Density of knapweed plants, seedheads, and insect populations were quantified in spring and late summer of 2001 and 2002. Treatments to reduce soil nitrogen availability (sucrose amendments) have continued to date. The effectiveness of this treatment for reducing soil N availability in the research plots has been demonstrated using in-situ ion-exchange resin (IER) bags. The DOE Remote Sensing Lab (RSL) has completed remote sensing tasks of research plots at YTC each year. The Ecological Dynamics Simulation (EDYS) model has been implemented and calibrated for the test sites at the two military installations using both existing information and the plot-specific data collected in 2000 and 2001.

TRANSITION: Resulting methodology for controlling these weeds will be made available to others by the means of peer-reviewed journal articles, web pages, and presentations at scientific meetings and symposia. The project results will directly serve to facilitate current management actions at military installations.

PROJECT SUMMARY

PROJECT TITLE & ID: Developing Biological Control of Garlic Mustard; CS-1146

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Bernd Blossey; Cornell University – Ithaca, NY

FY 2002 COMPLETED PROJECT

DESCRIPTION: Garlic mustard (*Alliaria petiolata*) is one of the most serious invasive species in the Eastern and Midwest United States replacing native spring wildflowers in forest communities. Physical, mechanical, and chemical means have failed to provide long-term control. The development of biological control appears the only viable option for ecologically sound management of garlic mustard. This project focused on the development of a standardized long-term monitoring plan to assess the impact of released biocontrol agents on target plant and associated plant communities. Personnel at the CABI Bioscience Center in Switzerland undertook detailed investigations on the ecology, life history and impact of 5 potential biocontrol agents for garlic mustard native to Europe and determine their host specificity. An important focus of the investigations was to observe changes in plant growth or biomass allocation of garlic mustard in response to different densities of control agents. In addition, the influence on plant performance as a result of attack by single or multiple species (i.e., on above and below ground plant tissues) was assessed in the field and in common garden experiments. These studies of herbivore interactions helped to determine whether the introduction of multiple agents is warranted or should be avoided.

To assess the impact of the release of biocontrol agents on garlic mustard and native plant communities, a standardized monitoring protocol was developed. Long-term monitoring sites were established. Data was collected on garlic mustard performance and abundance at sites in North America and in Europe. Basic site specific parameters (exposure, overstory species, soil types etc.) were recorded to evaluate the influence of habitat types on the control success.

BENEFIT: The development and implementation of biological weed control programs, e.g., the introduction of host specific herbivores from the native range of a non-indigenous plant species, offers an ecologically sound, cost-effective, long-term management strategy that will help protect native species and their habitats.

ACCOMPLISHMENTS: This project has conducted host specificity tests at CABI in Switzerland using plants provided from North America and additional species available in Europe. Experiments investigating the impact of two stem mining weevils and of the root mining weevil on performance of garlic mustard were completed. A protocol for monitoring the effect of insects after their potential release in North America has been field tested. As part of the project technology transfer, a workshop was held at Cornell University to introduce land managers to the garlic mustard monitoring protocol. Participating agencies included Fort Drum, West Point, Army Environmental Center, Army Corps of Engineers, National Stockpile Center, Invasive Plant Control, Cornell Plantations, NJ Department of Agriculture, Indiana Department of Natural Resources, National Park Service, and US Fish and Wildlife Service.

TRANSITION: This protocol will be used by researchers and natural resource managers at military installations and other agencies to monitor the success of control agents after their release in North America. Workshops and manuals will be used to introduce resource managers to the application of biological weed control and in the use of the monitoring protocol.

PROJECT SUMMARY

PROJECT TITLE & ID: Acoustic Monitoring of Threatened and Endangered Species in Inaccessible Areas; CS-1185

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kurt Fristrup; Cornell University – Ithaca, NY

FY 2003 FUNDS: $223K

DESCRIPTION: Large parcels of known or suspected TES habitat are in areas that are inaccessible to ground personnel because of operational restrictions or unexploded ordnance. Because biologists are unable to use traditional ground-based survey methods in these areas, this project will develop an airborne monitoring system for taking censuses of acoustically active species from the air.

The monitoring system will consist of three components: (1) a microprocessor-controlled digital data recording system that can be deployed either on the ground or on an airborne platform; (2) a helium-filled lift vehicle that can carry the recording system aloft for drifting or tethered deployments; and (3) a software package for automatic extraction, identification, and localization of sounds of interest. All three components represent plausible extensions of technologies that have been successfully implemented by the Cornell Bioacoustics Research Program and its affiliates. The completed system will enable long-term or wide area acoustic monitoring, with fully automatic data reduction. Post-deployment processing will be capable of producing a map of sound source locations and a log of species and time of call for all detections of interest. Summary statistics regarding call density, the estimated density of animals, and measures of the uncertainty of these estimates will be produced. Fully functional systems will be provided to Fort Hood, Texas, for surveys of golden-cheeked warbler (GCWA), black-capped vireo (BCVI), and Bell's vireo.

BENEFIT: This project will result in deployment of a fielded system that will enable natural resource managers at Fort Hood to obtain data on the presence and distribution of the endangered GCWA and BCVI within the 60,000-acre live fire area. Such data have previously been either sparse or non-existent because of access restrictions to this area. In the long term, application of the tools to be developed in this project should reduce the cost and operational impact of conducting biological surveys in areas where such surveys interfere with military operations. The resulting data will support the development and implementation of management plans to protect TES and their habitats while minimizing impacts on the military mission.

ACCOMPLISHMENTS: This project has made an extensive collection of ground-based recordings of black-capped vireos, using microphone arrays and autonomous digital recorders at Fort Hood. These recordings are being used to (1) provide training and test data for the development of automatic song detection algorithms, (2) develop robust estimates of the range at which songs can be detected by ground-based and airborne monitoring systems, and (3) quantify diurnal and seasonal variation in temporal singing patterns. Prototype software was developed to automatically detect songs of black-capped vireos and golden-cheeked warblers. Preliminary statistical models relating balloon drift rate to probability of detection of singing birds were produced. Six test flights of a balloon-based acoustic monitoring system were conducted and all flights ended with recovery of intact recording instruments and successful recordings of bird songs. The flight telemetry has been used to improve the altitude control system.

TRANSITION: The equipment and methods to be developed in this project will be applicable to monitoring acoustically active TES that occur at other DoD installations, such as the red-cockaded woodpecker (Fort Bragg, Fort Benning, Fort Stewart), Mexican spotted owl (Fort Huachuca), and least Bell's vireo (Camp Pendleton).

PROJECT SUMMARY

PROJECT TITLE & ID: Riparian Ecosystem Management at Military Installations: Determination of Impacts and Restoration and Enhancement Strategies; CS-1186

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Patrick Mulholland; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2003 FUNDS: $314K

DESCRIPTION: Military activities can have negative impacts on riparian ecosystems. DoD recognizes the critical importance of riparian ecosystems as habitat and controls on adjacent aquatic ecosystems. To help DoD better balance land stewardship with its training missions, this project is designed to increase understanding of riparian functions and stresses, and the ecological effects of specific riparian restoration strategies. Two objectives will be addressed: (1) the identification of impacts of upland (erosion) and riparian disturbances (denudation, fire) on riparian functions; and (2) the evaluation of the effects of riparian restoration involving woody debris additions and revegetation to channels. Impacts of current stresses on riparian functions will be based on measurements and comparison of these measurements in catchments at Fort Benning, Georgia. Both reference catchments and disturbed catchments that represent a range of disturbed conditions will be monitored and characterized. The degree of disturbance or disturbed condition of a catchment is determined by the percentage of denuded land. Riparian and stream characteristics and processes will be quantified in each catchment. Soil and vegetation measurements will be used to define riparian processes. Stream measurements include hydrologic, nutrient and sediment concentrations, metabolic, and periphyton and macroinvertebrate communities. The restoration phase of this project involves woody debris additions in ephemeral channels and 1st/2nd order streams of highly disturbed catchments. Revegetation, using native grasses and woody vegetation, will be conducted in highly disturbed ephemeral channels. The efficacy of the two riparian management restoration strategies (i.e., woody debris additions, and revegetation) to relieve stresses and improve riparian ecosystem functioning will be evaluated.

BENEFIT: The long-term benefit of this project is an increased understanding of riparian ecosystem functions, how military training activities can impact those functions, and how land management activities at military bases can be designed to reduce or eliminate these impacts. The results of this research will provide managers with the information needed to make better land management decisions and more effective restoration plans that can sustain military base ecosystems and the training missions they support.

ACCOMPLISHMENTS: One full year of sampling of riparian vegetation, stream chemistry and metabolism, stream benthic organic matter, and stream macroinvertebrates and periphyton communities have been completed for the eleven study sites. An index was derived to quantify the disturbance level in each of the study catchments. This disturbance index is based on the percentage of the catchment in bare ground on slopes > 3% and roads as determined by remote imagery, a digital elevation model, and a GIS-based mapping of roads and trails. Preliminary analysis of the data indicates that riparian forest biomass, litterfall, and root biomass are all reduced by disturbance resulting from sedimentation. Stream suspended sediment concentrations are higher and baseflow phosphate and dissolved organic carbon concentrations are lower in more highly disturbed catchments. Stream gross primary production and total respiration rates are reduced in some seasons in more highly disturbed catchments. Stream benthic organic matter, several measures of macroinvertebrate density, and algal levels are reduced in more highly disturbed streams.

TRANSITION: This project will provide prioritized and simplified riparian assessment metrics and protocols which can be used to facilitate the development of riparian restoration and adaptive management support tools for land managers and military trainers. Additionally, project findings and data will be integrated into SERDP's Ecosystem Management Project (CS-1114), a long-term monitoring and research initiative at Fort Benning, Georgia.

PROJECT SUMMARY

PROJECT TITLE & ID: Acoustic Response and Detection of Marine Mammals Using an Advanced Digital Acoustic Recording Tag; CS-1188

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Peter Tyack; Woods Hole Oceanographic Institute – Woods Hole, MA

FY 2003 FUNDS: $380K

DESCRIPTION: This project will quantify the probability of passive detection of marine mammals in Navy range waters which is currently hindered by an absence of information regarding the vocalization rate, level, and spectral characteristics for many marine mammals found in Navy range waters, especially deep-diving whales. The second objective is to evaluate the short- and long-term impacts of Defense activities on marine mammals. Woods Hole Oceanographic Institution (WHOI) has developed a miniature digital acoustic tag, the DTAG, that provides high fidelity, on-animal recordings of vocalizations and ambient sound. The tag also includes orientation and dive sensors, and provides a uniquely direct means for establishing the behavioral response of a whale to an impinging sound. This project will perform a series of field experiments combining surface observations with on-whale recordings using the DTAG. Focal follows of tagged animals will produce a database of vocalizations from whales with identified species and behavior. These data will be used to estimate vocalization rates. The second experiment involves simultaneous recordings of vocalizations at a tagged animal and at range hydrophones. The result will be a set of reference recordings from animals of known position and species, which can be used to evaluate, and enhance, passive detection, localization, and classification algorithms. Finally, controlled exposures of Navy-related sounds will be made to tagged animals to determine if, and under what conditions, deep-diving whales react to man-made sounds.

BENEFIT: The project research on short-term impacts of naval sound sources will provide critical data for developing protocols for operating these sources in ways that comply with federal environmental laws. Without this information, there is a risk either that these sounds may adversely impact protected populations or that protective measures taken as a precautionary measure because of ignorance may impact naval operations. Once passive acoustic monitoring has been tested and validated, it offers a non-invasive, cost-effective method to monitor vocal behavior and distribution of vocalizing animals for months before an operation, during the operation, and for months after the operation.

ACCOMPLISHMENTS: This research team has worked on two Navy ranges: AUTEC and the East Coast Shallow Water Test Range in Onslow Bay. During 2002, a very successful cruise was conducted at AUTEC, and vocalizations from tagged whales were analyzed for distribution to NUWC and AUTEC. Onslow Bay surveys added to the sighting and acoustic data from this area. The refinement of the DTAG and attachment techniques yielded a critical accomplishment when the team successfully tagged beached whales, thereby obtaining the first dive data from this species.

TRANSITION: The results of this project will transition into the Navy's marine mammal protection program. The data will provide vocalization databases required to assess the probability of detecting animals on Navy ranges. In addition, the team will work with range acousticians and signal processors to provide a biological perspective.

PROJECT SUMMARY

PROJECT TITLE & ID: Acoustic and Visual Monitoring for Marine Mammals at the Navy's Southern California Off-Shore Range; CS-1189

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Hildebrand; University of California, San Diego – La Jolla, CA

FY 2003 FUNDS: $340K

DESCRIPTION: The Southern California Off-Shore Range (SCORE) is a region where naval operations are frequently conducted and where marine mammals are known to be abundant. The technical objective of this project is to compare methods for actively monitoring marine mammals within the SCORE region using the following four techniques: (a) Aerial surveys (visual), (b) Ship-based transect surveys (visual), (c) Sonobuoy-based mobile acoustic surveys, and (d) Continuous fixed-site acoustic surveys.

Simultaneous application of these techniques will allow their comparison to determine the combination of methods most suitable for long term monitoring of the SCORE range. In addition, this project will investigate the contribution of environmental factors, such as sea surface temperature, to make an environmentally based model for marine mammal presence. This research will allow for better understanding of marine mammal presence within SCORE and improve techniques for studying marine mammal presence at other sites of naval interest.

BENEFIT: There is a high priority Navy requirement for data on marine mammal locations and seasonal densities within areas of frequent naval operations. The acoustic population estimation techniques developed by this project offer the potential for efficient and economical monitoring of marine mammals. These techniques are a first step in understanding the impact of sound on marine mammal behavior. This is an area of intense research by the Office of Naval Research and the Chief of Naval Operations (N45) with respect to environmental compliance issues.

ACCOMPLISHMENTS: The accoustic and visual monitoring of the Cortez and Tanner Banks within SCORE for marine mammal presence continued. Aerial surveys have been flown on a bi-monthly schedule, and shipboard surveys, including the use of sonobuoys, have been conducted. Autonomous Recording Packages (ARPs) have been deployed to acoustically monitor baleen whales, resulting in 298,000 blue whale call detections during 35,000 hours of recording. A diurnal calling pattern has been observed with 30% more calls at dawn and dusk than at other times of the day. An acoustic tag was attached to a calling blue whale in 2002, and revealed an unexpected calling behavior. Aerial survey data suggests that there is a mismatch in the seasonality of blue whales detected visually and those detected acoustically. More whales are visually detected early in the summer, while acoustic detections peak late in the summer. The acoustic population estimation techniques developed by this project offer the potential for efficient and economical monitoring of marine mammals. In addition, several dolphin species have been recorded on sonobuoys during ship-based acoustic surveys.

TRANSITION: Research findings will transition for use by SCORE personnel as a real time system for marine mammal detection and classification, as a database of seasonal marine mammal presence within SCORE, and as a predictive model for marine mammal association with environmental conditions. Marine mammal density estimates, as a function of both time and location as produced by this project will be integrated into a planning tool for use by the Navy. Development of acoustic techniques for marine mammal population assessment will also transition into the larger marine mammal science community. Passive acoustic monitoring can be applied as a complimentary technique to traditional visual survey such as those conducted by the National Marine Fisheries Service (NOAA).

PROJECT SUMMARY

PROJECT TITLE & ID: The Evolving Urban Community and Military Installations: A Dynamic Spatial Decision Support System for Sustainable Military Communities; CS-1257

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Brian Deal; U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory – Champaign, IL

FY 2003 FUNDS: $250K

DESCRIPTION: Extreme urban growth and the resultant patterns of development outside military installations are undermining the military community's ability to maintain mission focus. Some military installations' economic and environmental contributions to the local community are becoming outweighed by perceived incompatibilities such as noise, dust, shared resource competition, land use, land value, and land availability. These arise as the local community expands and available resources become scarce.

This project will quantify the current and future impacts of urbanization on the operations and sustainment of military installations. A Spatial Decision Support System (SDSS) is used to identify the factors and variables that contribute to land-use transformation and the subsequent conflicts that can arise between the military establishment and adjacent private sector communities due to conflicting land-use goals. The SDSS includes the development of spatial, societal and environmental impact assessments. The creation of indicators of installation sustainability, using both mission and ecological oriented criteria, will be established. The SDSS will be applied to identify military installations most at-risk from rapid exogenous urbanization.

BENEFIT: This project will help elucidate where the threat of urban growth may negatively impact the military mission. Obtaining clearer understanding of the dynamic and spatial interactions between the military community's mission and land use needs, and the adjacent community's goals, planning policies and probable spatial growth patterns is an important step toward resolving some of these issues. Evaluating the urban transformations near military installations can illuminate future conflicts for military land use and resource managers.

The military can benefit from better planning tools for predicting exogenous and endogenous land use needs and their conflicts with installation mission requirements. While several urban systems models are available that could provide a basis for such a tool, they are either not explicitly spatial or they do not model the interacting systems in any significant or dynamic way. In many cases, the emphasis is on modeling simple changes in land-use patterns and not the underlying systems and the interactions that produce these patterns. This project focuses on the development of a dynamic and military specific Spatial Decision Support System (SDSS) that will improve the decision-making processes and land management practices of the military installations and adjacent private sector communities. The fundamental purpose of this work is the discernment of possible approaches to planning solutions that can help sustain the military missions and environments within the communities in which they exist.

ACCOMPLISHMENTS: Progress has been made in the risk assessment and mLEAM model development and the team continues to develop a sound modeling technique and visualization of the model results, improving the statistical certainty in model outputs. All DoD properties have been spatially coded in terms of risk assessment and the project has been working with USAF, the Navy, Marine Corps and Civil Aviation Authority to narrow the focus and identify more critical properties. A methodology for determining risk and the dimensional characteristics of installation risks has been identified. An Installation Risk Assessment (IRA) framework using a stressors-state-respond methodology has been developed.

The adaptation of the LEAM framework toward military specific applications is underway. A test site – Fort Benning, Georgia has been selected in order to leverage other SERDP related data collection efforts. Preliminary data collection and LEAM model runs have been completed. The spatial extent of the Fort Benning mLEAM model has been determined to include 5 counties at 1 30x30 m resolution encompassing 8 million cells. This has necessitated the porting of the model onto super computers at the National Center for Super Computing Applications at the University of Illinois. This has dramatically decreased model run times and enabled smoother and more efficient model scenario runs. In addition, leveraged funding through the CHSSI program will enable mLEAM to ported to DoD high performance computers at to be linked to other spatially explicit DoD impact assessment models.

TRANSITION: The outcome of this project will provide MACOMs with an analytical and visually oriented methodology for determining where the threat of urban growth might negatively impact the military mission, how this threat will impact military operations, and possible strategies for mitigating these impacts.

PROJECT SUMMARY

PROJECT TITLE & ID: Alternative Future Scenarios: Phase 1 Development of a Modeling System; CS-1258

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mary Cablk; Desert Research Institute – Reno, NV

FY 2002 COMPLETED PROJECT

DESCRIPTION: Due to the number and variety of unintended consequences, urban development on lands adjacent to installations is currently among the most pressing challenges to military installations. These consequences include safety risks; noise; impacts to plants, animals, and cultural resources; dust emissions, and other air and water pollution; and installation-specific issues. The Department of Defense (DoD) has investigated the use of alternative future scenario modeling (AFSM) to predict and remediate potential impacts of civilian development on military bases. To improve transferability of this technology to military land managers, this project developed an information system, a tool for simulating alternative future scenarios. The information system significantly reduces the complexity of the AFSM process by making the modeling component interactive, portable, iterative, and user-friendly. Ultimately, land managers and other decision makers will have a user-friendly tool that they can use to (1) identify variables that may conflict with the sustainability of military operations and (2) predict and evaluate environmental impacts and assess risks under alternative land use change scenarios.

BENEFIT: There are several immediate benefits from this project. First, an evaluation of existing models or programs (OO-IDLAMS, mLEAM, LUCAS) relative to the overall AFSM process is exceedingly valuable for appropriate application of these models. The evaluation will serve to highlight the strengths and weaknesses of each as well as allow us to identify where efforts have been concentrated, where they have been successful, and where key components still need research and development. Components of these models may prove useful in the development of our AFSM tool. A second immediate benefit is that research into statistical and mathematical modeling for developing alternative futures that includes translation of user-input into functions to revise outputs demonstrates proof-of-principle. This same research contributes to the understanding of key processes, specifically the relationship between landscape level spatial data and potential or predicable urban development. The proposed alternative futures information system (AFIS) will be designed to minimize potential and negative impacts of urban development outside of installation boundaries.

ACCOMPLISHMENTS: In order to identify common variables that drive patterns of development, a comprehensive statistical analysis was conducted for the Coachella Valley, CA. Results indicated that the driving variables behind urban development vary significantly with location to include distance to roads and the distance to existing development. The largest likelihood of new development (~10%) have the areas closest to the existing development, with about 6% of new development occurring within 60 m, 23% within 200m and 70% within 1 km from the existing development. An extensive review of existing models revealed that there are elements already in existence that can be used to build an AFSM suitable for evaluating encroachment to installations.

TRANSITION: The Phase I advances to the AFIS will increase the transferability and usability of this technology to help installation managers make critical land management decisions related to urban development surrounding their installation. Another set of advancements (Phase II) to make this tool more user friendly is needed to fully transfer this tool to an installation management staff.

PROJECT SUMMARY

PROJECT TITLE & ID: RSim-A Regional Simulation to Explore Impacts of Resource Use and Constraints; CS-1259

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Virginia Dale; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2003 FUNDS: $317K

DESCRIPTION: The need for applying ecosystem management approaches to military lands and regions that contain them is critical because of the unique resources on these lands and the fact that conservation issues may jeopardize military missions if not appropriately managed. This project will address this critical need by enabling application of ecosystem management approaches to military lands and surrounding regions. The objective is to develop a spatially-explicit simulation model that will enhance the abilities of military planners to understand the implications of external land-use change, resource use and future development policy on the sustainability of military land and missions.

A Regional Simulation Model (RSim) will be designed to integrate environmental effects of on-base training and testing and off-base development and other decision. Effects to be considered include changes in air and water quality, noise conditions, and habitats for threatened and endangered species and game species. The simulation environment will build upon on existing land-use change model and will be designed to be available to users via a web interface. The model will be provided in a gaming mode so that users can learn about the potential environmental repercussions of military and land-use decisions. The RSim model will be developed and applied to the region around Fort Benning, Georgia because of the large amount of data available for the installation and surrounding region and the cooperation offered by the base in developing and testing the model. However, the model will be designed so that is broadly applicable to DoD's environmental management concerns. A risk assessment approach will be used to determine impacts of and integrated risks.

BENEFIT: This effort is developing new ideas on: (1) Developing an approach that integrates processes that operate on very different temporal and spatial scales. Such an approach is critical for the management of diverse environmental resources required of DoD and other agencies. (2) Incorporating feedbacks between different aspects of the environment that operate at different scales is one of the biggest challenges of interdisciplinary research and resource management. (3) Optimization. Environmental research has been constrained by efforts to meet single criterion (e.g., protection of one species or keeping particulates below a certain level). Our approach allows consideration of several criteria at the same time dealing with air, water, noise and species. Acceptable land uses for DoD are those that maintain standards within all these categories, and we are devising a procedure for verifying that standards are maintained. (4) Advances required within each module. Improvements in the state of the art of assessing land-use changes on water quality, noise, air quality, and species and their habitats. (5) A regional perspective. Historically, environmental concerns have focused on impacts within the installation due to onsite activities. Impacts will be examined of the region on the installation, of the installation on the region, and of potential feedbacks.

ACCOMPLISHMENTS: This project has explored the quality and accessibility of land-cover and other data for the region around Fort Benning in order to determine our goal region for the study. Based on the planned model structure as well as the data, the study region has been defined based on political boundaries within which socio-economic and other factors affect environmental changes in the region. The region for our analysis has been selected to be the five counties in Georgia of Harris, Talbot, Muscogee, Chattahoochee, and Marion. This area encompasses the middle reach of the Chattahoochee River basin; Columbus, Georgia municipality and smaller communities; agricultural, forest, industrial and residential lands; and Fort Benning. An interface diagram and protocol was developed to implement the major flow paths of information flow and serves as a means of communication between the computer scientists, geographic information specialist, and biologists on the project. A web site has been established for the project (http://www.esd.ornl.gov/programs/SERDP/RSim/index.html), which serves as a means for communicating with others about the RSim project.

TRANSITION: At the completion of this project, land managers and planners will be able to use this user-friendly tool at Fort Benning to help understand the implications of external land-use change, resource use and future development policy on the sustainability of military land and missions. Transition of this tool to other installations is dependent on the type and amount of data available in and around an installation, however, the methodology will remain relatively the same.

PROJECT SUMMARY

PROJECT TITLE & ID: Detection and Identification of Archaeological Sites and Features Using Radar Data; CS-1260

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Ronald Blom; NASA / Jet Propulsion Laboratory – Pasadena, CA

FY 2003 FUNDS: $184K

DESCRIPTION: Application of aerial and satellite radar data for archaeological inventory and evaluation has been limited for two reasons: (1) most cultural features are too small to be identifiable given the resolution of imagery produced from the radar data using current processing and post-processing protocols, and (2) until recently, imaging radar data have been only collected at a single frequency/polarization combination. This project will provide a nearly ideal environment in which the archaeological interest can be systematically determined, thus providing and characterizing protocols for data processing and interpretation adequate to detecting and characterizing archaeological sites. This project will identify the radar wavelengths, polarizations, and angles of transmittal that are most effective in detecting and characterizing a variety of archaeological sites and features under conditions that fall within environmental parameters common to much of the western U.S. Airborne radar data will be collected with a multi-band, NASA/JPL multi-polar radar instrument (AIRSAR) over San Clemente Island, CA. The resulting understanding of the behavior of radar in response to archaeological targets will provide the basis for the formulation of effective, transferable protocols for detection and evaluation of cultural resources on military installations in the western U.S.

BENEFIT: The protocols developed by this research will demonstrate and prove the utility of synthetic aperture radar to finding and evaluating archaeological sites. Those most readily identified by the refined technologies and protocols will be among the most important and challenging from a cultural resource management point of view: structural sites, sites with middens, and sites that have been occupied over an extended period of time or reoccupied repeatedly with the result of altering soils chemistry and vegetative pattern. Processes for radar bands and polarizations will be much better understood so that they can be better applied to finding and characterizing archaeological sites. The protocols will be in effect produce a pilot scale system for this application of synthetic radar technology to cultural resource management.

ACCOMPLISHMENTS: The JPL AIRSAR (Airborne Synthetic Aperture Radar) platform was flown over San Clemente Island, utilizing both TOPSAR (Topographic Synthetic Aperture Radar) and POLSAR (Polarimetric AIRSAR) mode. From data collected in the TOPSAR mode, digital elevation models have been produced with an accuracy of one to three meters. These digital elevation models were used to orthorectify all images produced in POLSAR mode. Field testing indicated that the precision of the orthorectified CVV image was in the meter range. Subsequently, all other images were orthorectified using this method. Other data sets collected and added as layers to the project GIS include: (1) ASTER, (Advanced Spaceborne Thermal Emission and Relection Radiometer), multi-spectral data; (2) High altitude AVIRIS (Airborne Visible/Infrared Imaging Spectrometer), hyperspectral data; (3) Color ortho photos, which were accurate to about one meter when obtained; (4) False color infrared aerial photos; (5) Black and white aerial stereo pairs, taken in 1951; (6) Vegetative, soil, geologic, hydrologic, slope, and elevation data; and (7) Locations of archaeological sites in four half-kilometer square survey plots.

TRANSITION: If successful, the protocols developed will be transitioned to cultural resource managers to inventory archaeological sites in environments similar to those of San Clemente Island. Preliminary characterization of detected sites is also feasible. The next step in transitioning the technology is to modify the protocols for more heavily vegetated areas.

PROJECT SUMMARY

PROJECT TITLE & ID: Developing an Efficient and Cost Effective Ground-Penetrating Radar Field Methodology for Subsurface Exploration and Mapping of Cultural Resources on Public Lands; CS-1261

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Lawrence Conyers; University of Denver – Denver, CO

FY 2003 FUNDS: $98K

DESCRIPTION: Military installations are in need of an efficient, accurate and readily useable method for discovery, mapping and possible avoidance of cultural resources in order to sustain military readiness. To date, no near-surface geophysical method has been shown to be fully effective in the discovery of buried cultural remains. Ground-penetrating radar (GPR) has recently proven to be very efficient at collecting data of buried objects in grids ranging up to 50x50 meters. This project will quantify and calibrate GPR for known archaeological features that are commonly found in many areas of the U.S. in order to make GPR a more exact and easy to use tool for the discovery and mapping of buried and invisible sites. GPR data will be collected at two facilities (the controlled archaeological test site (CATS) in Illinois, and the Hammer GPR site at the Hanford Reservation in Washington) using many different radar configurations. The data from the various radar configurations and environmental conditions will be used to discover optimum GPR collection and processing methods. These data will be compared to what is known about local conditions and the depth and composition of buried features. The final product will be a field and laboratory protocol that can be modified depending on the ground conditions encountered, and the depth and aerial extent of the target features. More accurate and efficient detection and mapping of buried cultural remains on DoD and DOE land decreases the reliance on traditional, arbitrary excavations that are both costly and destructive.

BENEFIT: This project will develop and refine the use of GPR technology in archeology that will be central to the design and implementation of future GPR studies in cultural resource assessment. The results will include a pre-data acquisition protocol for site analysis, which will allow researchers to predict conditions expected in the field and to adjust hardware and software configurations accordingly. Site analysis of this sort will promote both an understanding of GPR energy radiation and reflection in the ground and save money and time as conditions can be predicted and adjusted for in advance.

ACCOMPLISHMENTS: Twenty-three GPR data bases have been collected at the two tests sites using three GPR systems: Geophysical Survey Systems SIR-10 and the SIR-2000, and the Sensors and Software Pulse Ekko II. Antennas ranging from 250 to 900 MHz were used for data collection, under conditions that ranged from very dry to totally saturated. Data was processed using frequency filtering, migration and background removal programs. The known features at each site have been modeled in a Geographic Information System and coil and feature chemistry and physics have been used to calculate coefficients of radar reflectivity at each known interface, within horizontal depth slices. These two-dimensional models of the three-dimensional features will be used to compare directly to horizontal time-slices produced from each GPR reflection database. Visual displays have been made at each test site, to qualitatively show which methods are best, however, more quantitative analyses will continue.

TRANSITION: A quantitative analysis of GPR reflections during differing conditions, allows for the production of a protocol for GPR data collection on DOE and DoD lands. The protocol can then be used by cultural resource managers for GPR mapping, producing accurate maps of buried cultural sites, quickly and accurately.

PROJECT SUMMARY

PROJECT TITLE & ID: Methods for Assessing the Impact of Fog Oil on Availability, Palatability, and Food Quality of Relevant Life Stages of Insect Food Sources for TES; CS-1262

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Dennis Strenge; Pacific Northwest National Laboratory – Richland, WA

FY 2002 COMPLETED PROJECT

DESCRIPTION: To comply with the Endangered Species Act, the impact of fog oil releases on avian TES (or surrogates) have been evaluated in both field and laboratory studies. Although no direct acute effects on avian species have been observed, concern has been raised regarding a possible indirect impact via reduction in insect populations used as a food source for these species. This concern arises from the fact that petroleum oils of similar composition to that of fog oil have long been used to kill insect pests. These oils particularly target soft-bodied insects, eggs and larvae, and flying adult forms that are important dietary components of several avian and bat TES inhabiting military lands. This project investigated the impact of wind speed and canopy structure (key factors identified in past fog oil deposition research) on fog oil deposition and insect toxicity and behavior through the use of wind tunnel tests providing reproducible exposures, which are difficult to obtain in field tests. The impact of fog oil on insects based both on quantity and quality of food source for endangered birds and bats was measured. The final product of this project is a set of response functions describing mortality, morbidity, food quality and food availability of insect prey of TES in terms of oil deposition rate, average air concentration, wind speed during generations, and canopy structure.

BENEFIT: This study will provide a cost-effective (compared to field assessments) method for quantifying the potential impact of fog oil on the food base of TES inhabiting DoD lands where training activities are conducted. This will allow testing of prey species under relevant climatic and canopy conditions of specific TES. Because information on the effects of fog oil on important prey species of the red-cockaded woodpecker, several neotropical birds and two endangered bat species are tested in this project. The exposure-response data from the study will directly benefit risk assessment/management efforts for these species. This study will provide information relating exposure-response data to transport and environmental conditions for fog-oil smoke generation. This information will provide DoD installation biologists and regulators with whom they interface with a method to estimate the relative size of the zone of impact of fog. If the study indicates the potential for significant impacts on insects consumed by T&E species, the exposure-response data will allow estimation of the potential for impacts on T&E species as a function of fog-oil concentration, wind speed, and canopy.

ACCOMPLISHMENTS: Insect colonies were established and experimental protocols were developed. Preliminary screening tests of insects to the impact of fog oil smoke showed three times as many moths died following fog oil exposure compared to the control. All 1^{st} instar moths died when exposed to airborne concentrations of fog oil of $400 mg/m^3$ or greater. These data indicate that most instars of moth larvae are susceptible to fog oil poisoning at field relevant concentrations. A toxicity profile of fog oil at the different life stages was developed and the threshold toxicity of fog oil for each of the five larval instars of the geometrid moth was determined.

TRANSITION: The information gained from this project will be used by installation managers to make decisions about the application of fog oil during training exercises. The set of response functions describing the mortality, morbidity, food quality, and food availability of insect prey of TES in terms of fog oil deposition rate, average air concentration, wind speed during generations, and canopy structure provide the means to establish appropriate protocols for using fog oil and protection of T&E species.

PROJECT SUMMARY

PROJECT TITLE & ID: New Approaches to the Use and Integration of Multi-Sensor Remote Sensing for Historic Resources Identification and Evaluation; CS-1263

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Frederick Limp; University of Arkansas, AR

FY 2003 FUNDS: $102K

DESCRIPTION: This project will focus on the development of powerful new analytical approaches that demonstrate the effectiveness of non-invasive archaeological methods and the deployment of tools that offer an opportunity to recover a great deal of information about site content while reducing costs associated with traditional archaeological survey and excavation. Exploration and assessment of the benefits of combining a large suite of ground, aerial and space-based sensor data for the detection of subsurface archaeological features is central to this research. State-of-the-art remotely sensed data will be acquired at DoD installations Fort Bliss, Fort Benning, and Fort Riley, and at the DoE Savannah River Site. New and existing data from these installations will be complemented with existing site data from two additional locations, Whistling Elk and Mt. Comfort. These properties, selected based on cultural resource inventory, physical conditions (soils, vegetation), and degree of recent disturbance, contain a wide variety of archaeological sites in various natural environments. Remotely sensed data will be analyzed individually and in combination via a variety of innovative data fusion approaches, to make predictions about the nature of buried historic resources. A program of archaeological field-testing will be undertaken to validate predictions made during the data analysis phase.

BENEFIT: The results of this research program will: (1) generate knowledge about the predictive effectiveness of sensors individually and together; (2) describe the nature of the similarities, differences, redundancies, and performance characteristics of the sensors; (3) provide a cost-benefit analysis; (4) identify the kinds of archaeological features that may be detected with each method or combination of methods under various environmental conditions; and (5) recommend enhancements to current GPR technologies for archaeological applications. The project will additionally develop a digital soils data model that will allow installation managers to predict the potential usability of sensors at various locations on their properties.

ACCOMPLISHMENTS: Site surveys at Fort Riley, Savannah River and Fort Benning were initiated and ground geophysical data were acquired. All geophysical surveys were completed at Fort Riley. This included collecting data from five geophysical methods, most of which respond to different dimensions of subsurface physical properties. These five principal geophysical data sets were subjected to a principal components analysis that revealed common underlying dimensions of relationship. The Ground Penetrating Radar (GPR) survey at Fort Riley provided some promising results. In particular, many details in the building and nonbuilding areas were indicated that did not appear to occur on the initial data sets from the other instruments.

TRANSITION: The transition will be designed to provide installation staff and technical specialists in the remote sensing community with information on the effectiveness of the systems and appropriate field implementation strategies. Two key vehicles for dissemination of the results will be through the North American Database of Archaeological Geophysics (NADAG, http://www.cast.uark.edu/nadag/) and through the project linkages to the private sector as provided by the participation of SRI and Geoscan Research. It is anticipated that instrument designers and software developers will respond and create products that can be used in future applications at installations and other locations. The aspects of the project that are expected to transition under this include data fusion software system based on SRI's model and rule bases for eCognition use.

PROJECT SUMMARY

PROJECT TITLE & ID: Metal Ion Sensor with Catalytic DNA in a Nanofluidic Intelligent Processor; CS-1265 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Donald Cropek; U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory – Champaign, IL

FY 2002 COMPLETED PROJECT

DESCRIPTION: Anthropogenic sources of lead (Pb) from military operations require active monitoring and sensing to ensure environmental compliance and protection. This project created a highly selective and sensitive miniature sensor for Pb^{2+} by combining two recent advances: (a) catalytic DNA that is reactive only to Pb^{2+} and which can be tagged to produce fluorescence only in the presence of the metal, and (b) nano-scale fluidic molecular gates that can manipulate fluid flows and perform molecular separations on tiny volumes of material. This work developed the chemistry needed to combine Pb-specific catalytic DNA with the molecular gates and the protocol for separating, sensing, and quantifying Pb^{2+} in a complex matrix. Success in the development of this prototype lead sensor lends itself to rapid development of other targeted chemical sensors based on catalytic DNA that are uniquely reactive to any other metal and organic compound.

BENEFIT: Successful results in this research will provide a sensor prototype that stands apart from current sensor technology for lead in water in terms of ruggedness, sensitivity, selectivity, reusability, and field operability. This minute device can be used in multiple environmental, industrial, and ecologically sensitive applications for real time, in-situ measurement of lead in water samples. The miniature dimensions and the predicted low cost of this sensor type allows for siting multiple sensors for complete characterization of complex systems. The resultant cost savings is nearly ten-fold over current snapshot methods of sample collection, transport, and laboratory analysis, in addition to the benefit of continuous unattended monitoring. Because identifying the Pb-selective catalytic DNA sequence is accomplished via a novel combinatorial search, success in the development of this prototype lead sensor lends itself to rapid development of other targeted chemical sensors based on catalytic DNA that are uniquely reactive to any other metal or organic compound. Thus, relevance of this research is magnified beyond Pb^{2+} to include field sensors for other chemicals of interest such as PCBs, PAHs, and other metals (e.g., Al, Hg, Cd, and depleted uranium).

ACCOMPLISHMENTS: A simple prototype microfluidic sensor was assembled employing a lower vertical channel and an upper horizontal channel with a molecular gate membrane at the intersection. The lower channel was filled with buffer solution and an injection of lead ion solution. The upper channel was filled with a solution of the catalytic/substrate DNA assembly. Lead ions were moved by electroosmotic flow through the lower channel, up through the molecular gate, into the upper channel. The movement was monitored by an increased fluorescence in the upper channel upon reaction with the DNA. These results indicate the ability to move lead through the channels and gate device and react with unsupported DNA. In separate experiments it was determined that the interior of the gate channels must be coated with gold to covalently bind the catalytic DNA via thiol bonding. TEM pictures have illustrated the successful coating of 250 nm diameter channels through an electrolesis plating method. This method is the next step toward supporting the DNA within the molecular gate membrane.

TRANSITION: The Pb^{2+} chemical sensor based on catalytic DNA will provide the prototype for further study and applications to rapidly detect other chemicals of interest such as: PCBs, PAHs, and other metals, such as aluminum, mercury, cadmium, and depleted uranium. The prototype sensor will be deployable to DoD managers for the purpose of monitoring anthropogenic sources of lead.

PROJECT SUMMARY

PROJECT TITLE & ID: Miniature, Multiple Sensor Systems for Continuous Detection of Metals, pH, and Other Parameters; CS-1266 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. David Kidwell; Naval Research Laboratory – Washington, DC

FY 2002 COMPLETED PROJECT

DESCRIPTION: Sources of copper (Cu) from Navy activities such as antifouling agents on ship bottoms and dredging operations require active monitoring and sensing of individual copper (I and II) to ensure environmental compliance and protection. Due to the toxicity of copper especially in estuary environments, all sources of copper must be monitored to account for the relative impacts of the various sources. Current methods (i.e., atomic absorption using Method 7210 and 7211) measure total copper (Cu I and Cu II) including soluble and particle bound and do not measure the true toxicity known to result from Cu I. This one-year effort developed a miniature sensor system based on ion selective electrodes and other electrochemical measurements that detects individually copper I, copper II, pH, temperature, conductivity, chloride (or sodium), and turbidity. Because the measurements are determined in seconds, this sensor package is suitable for rapid surveying of the marine environment.

BENEFIT: All sources of copper must be monitored to mitigate the impact to the environment and to account for the relative impacts of all the sources. This sensor system will provide a prototype for a miniature, inexpensive, water monitoring system that can continuously and simultaneously monitor a number of variables.

ACCOMPLISHMENTS: A miniature water sensor was developed to measure Cu(I) and Cu(II) ions with an ion selective electrode (ISE). This easily fabricated and rugged reference electrode showed a stability for >40 days in an aqueous environment, providing more stability than commercial reference electors many times larger. Conductivity, absorbance, pH, ORP, K+, and Cl sensors all performed adequately. The fluorescent sensor was tested for detection of chloropyll but is unlikely to have the required sensitivity to detect low numbers of algal cells.

TRANSITION: The miniature sensor system based on ion selective electrodes can be deployed to DoD managers interested in rapidly monitoring copper and other electrochemical parameters in the marine environment.

PROJECT SUMMARY

PROJECT TITLE & ID: Nano-Engineered Electrochemical Sensors for Monitoring of Toxic Metals in Groundwater; CS-1267 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Thomas Zemanian; Pacific Northwest National Laboratory – Richland, WA

FY 2002 COMPLETING PROJECT

DESCRIPTION: This proof-of-principle study developed a novel class of micro-scale electrochemical sensors for measurement of metal ion concentrations in aqueous streams. The sensors were based on highly porous functionally coated electrodes. These materials afford significant capacities for adsorption of metal ions to functional ligands embedded in the electrically conductive coating. Selective electrodes have been fashioned at PNNL from chemical ligands in carbon paste or conductive polymer matrices. These electrodes are efficient and specific, but degrade over time due to depletion of the ligand-bearing material. The proposed electrodes bear the active ligands covalently bonded to high surface area supports, and thus retain chemical functionality despite diffusion or abrasive wear. Specifically, this project: (1) developed the fabrication technology to combine the desired conductive matrices, meso-porous supports, and adsorptive coatings; (2) tested the materials for uptake of aqueous lead and mercury; and (3) demonstrated the sensitivity of the square wave adsorptive stripping voltammetry-technique using the novel electrodes to measure aqueous lead (Pb) and mercury (Hg) ion concentrations.

BENEFIT: The proposed sensors will: (1) increase frequency and precision in data acquisition, (2) provide a means to detect short-lived events, (3) allow for robust and inexpensive construction method, and (4) provide specificity for metal species of interest. In addition to its value for groundwater monitoring, a subminiature electrode, suitable for a microscale/microfluidic electrochemical sensor device for measuring metal ion concentrations would also be useful for many industrial applications. In particular, the sensor would have uses for monitoring of any aqueous waste stream likely to carry metal ion contaminants.

ACCOMPLISHMENTS: In the course of embedding the Self Assembled Monolayers on Mesoporous Supports (SAMMS) materials in the conductive paste, it was discovered that activated carbon could itself serve as the substrate for the SAMMS materials. Consequently, such materials were fabricated and full testing for uptake of Cd(II), Hg(II), Pb(II),and Ni(II) at varying pH have been completed.

TRANSITION: The nano-engineered electrochemical sensors will be transitioned to DoD managers that are interested in monitoring Pb and Hg in groundwater. Further development of the sensor will provide opportunities to monitor other metals of interest. Just as for groundwater monitoring, the availability of selective in-line sensors would be of tremendous benefit to a broad range of industries.

PROJECT SUMMARY

PROJECT TITLE & ID: Impacts of Military Training and Land Management on Threatened and Endangered Species in the Southeastern Fall Line/Sandhills Community; CS-1302

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Rebecca Sharitz; Savannah River Ecology Laboratory, SC

FY 2003 FUNDS: $246K

DESCRIPTION: The goal of this research is to develop methods to evaluate effects of military training and land management activities on the sustainability of fall line sandhills habitats and their threatened and endangered species (TES) on military lands in the southeastern US. This project will also provide recommendations for adaptive management to optimize land management decisions. Numerous military installations from all services share some or most of this sandhills species assemblage. Management for sustainable sandhills TES habitat would enable DoD and other land managers to address multiple TES simultaneously; however, military training activities and forest management for longleaf pine woodlands are potential threats to the sandhills ecosystem.

Geographic information systems (GIS) and spatially explicit models (SEM's) are used to develop a more comprehensive understanding of the potential impacts that military training and forest management practices may have on TES in sandhills habitats. Specifically, the project will determine if the combinations of frequency and timing of burning, and of military use, that best promotes the sustainability of the sandhills habitat also provides suitable conditions for individual TES, such as gopher tortoise.

BENEFITS: Results of this research will provide land managers at military installations along the Fall Line ecoregion with information needed to make decisions concerning training intensity and forest management that more effectively protect sandhills communities and their TES, and concomitantly allow for continued military training.

ACCOMPLISHMENTS: Field metrics for discriminating sandhills from surrounding longleaf pine woodlands have been developed, based on abundance of sandhills-dominant trees, and canopy and soil characteristics. Within known reference sandhill sites, canopy tree species were tallied using standard forest sampling procedures, hemispherical photographs were taken to estimate canopy openness and the amount of light entering through the canopy, and soil cores were collected for soil characterization and nutrient analyses. Similar analyses at non-sandhill sites provided comparisons with sandhill conditions. These metrics are proving effective at discriminating sandhill communities on the ground and in confirming initial identification from the GIS analysis. In addition, populations of selected sandhill plant TES have been located and preliminary habitat data have been collected. Experimental release of an animal TES, the gopher tortoise, into sandhills sites on the SRS has been completed and initial surveys of burrow density in these populations have been completed.

TRANSITION: Information and recommendations from this research will guide resource managers at Fort Benning and Fort Gordon in developing management plans for sandhills areas. The protocols and techniques are applicable to all federal lands in the Fall Line sandhills region.

PROJECT SUMMARY

PROJECT TITLE & ID: Regenerating Longleaf Pine on Hydric Soils: Short and Long Term Effects on Native Ground-Layer Vegetation; CS-1303

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Joan Walker; U.S. Department of Agriculture – Forest Service, SC

FY 2003 FUNDS: $93K

DESCRIPTION: The longleaf pine ecosystem on DoD and other public lands provides habitat for many rare plants and animals, including federally protected species. Restoring and rehabilitating longleaf pine communities is essential for maintaining the health of protected species. This project evaluates a range of site preparation methods that could be used to restore longleaf pine stands on sites that no longer have a natural seed source, and determine the effects of these methods on the extraordinarily diverse ground layers that occur on moist, poorly drained sites. The study will also describe the persistent and long-term effects of plantation establishment. Immediate and short-term effects of management treatments on ground layer vegetation, and on longleaf pine establishment and early growth will be evaluated with a controlled field experiment. Long-term effects will be investigated by quantifying vegetation composition and structure in mature plantations, and relating current conditions to know treatment histories and to the vegetation in high quality natural areas.

BENEFITS: The results of this work will provide a scientific foundation to evaluate methods for managing longleaf pine and associated species on the landscape. The successful establishment of longleaf pine stands that provide habitat for threatened and endangered species on wet, poorly drained sites will provide managers with flexibility in simultaneously maintaining defense-oriented training and fulfilling Department of Defense obligations to preserve endangered species.

ACCOMPLISHMENTS: Research efforts to date have been directed toward locating and characterizing sites for installing the field experiment. The proposed sites were examined with a soil taxonomist and local botanical expert. An important feature of the Leon Soil, in which our experiment will be conducted, is an impermeable spodic horizon that can strongly affect tree seedling development. Preliminary soil characterizations revealed considerable heterogeneity in depth to the spodic horizon. Detailed maps have been prepared for half of the experimental blocks. The research team, including Camp Lejeune personnel, toured selected plantations in the region to see the effects of the mounding method, one of our experimental treatments not widely used in the NC coastal plain.

TRANSITION: Camp Lejeune managers and Forest Service researchers are full partners in this research. Information transfer will occur throughout the project with frequent site visits to discuss progress and observe results as they develop. Formal field tours will be conducted for Federal, State, and private land managers with similar management challenges. Upon completion, or if interim results warrant, site preparation methods will be modified through the annual silvicultural prescription process and the Integrated Natural Resources Management Plan revision (specifically Section 11.1).

PROJECT SUMMARY

PROJECT TITLE & ID: Toxicological Effects of Smokes and Obscurants on Aquatic Threatened and Endangered Species; CS-1332

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Donald Cropek; U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory – Champaign, IL

FY 2003 FUNDS: $300K

DESCRIPTION: The need for military readiness and maintenance of training lands carries with it the need and obligation to maintain various natural resources. Preparation for possible battlefield conditions requires military training activities to use smokes and obscurants (S&O). Many threatened and endangered species (TES) cohabit training areas where S&O are released; therefore, the impact of S&O on the vitality and survivability of TES and their habitats, including aquatic ecosystems must be ascertained.

This work will study the direct and indirect effects of actual field deposition of fog oil, graphite, CS (o-chlorobenzylidene malononitrile), and two colored smoke S&O on three phylogenetic classes of aquatic organisms including TE fish, their insect prey, and TE mussels. This will be done through field collection of S&O chemical deposition, field exposure of selected organisms, laboratory tests of S&O chemical deposition, and laboratory exposure of selected organisms. Data will be developed and obtained that will predict the impacts, effects, and mortality on relevant aquatic species from exposure to varying concentrations of S&O. In addition, the insect-fish-mussel, food-predator-life cycle-host interrelationships will be examined and interpreted in the context of observed results.

BENEFITS: This work will develop and refine the approach and information to be used by the military and other organizations to contribute to the overall management of aquatic TES and their habitats. These data will influence S&O usage and TES management to ensure environmental security and protection of valued aquatic resources preventing impairment of critical military training activities. Research will be published to provide guidance for selection and use of S&O in the field for optimal environmental protection with minimal impact on troop readiness.

ACCOMPLISHMENTS: This is an FY03 New Start.

TRANSITION: Information, data, and results of this effort will be made available to installation, major command, and headquarters biologists, natural resources managers, land managers, and decision makers, as well as to other federal and state agencies, including those regulatory entities which have jurisdiction or interest in the biological, chemical, and environmental parameters involved (e.g., TES, toxicity, air quality, water quality, pollution, health, etc). These results will show the degree of impacts and effects on actual insect prey of TES, relevant surrogate and actual threatened fish, and environmentally sensitive endangered benthic mollusks that may arise from using military S&O during field training.

PROJECT SUMMARY

PROJECT TITLE & ID: Application of ROV-Based Video Technology to Complement Coral Reef Resource Mapping and Monitoring; CS-1333

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Pamela Reid; University of Miami, Marine Geology and Geophysics – Miami, FL

FY 2003 FUNDS: $394K

DESCRIPTION: Recent declines in coral reefs across the globe underscore the need for new scientific tools to better understand ecological patterns and rates of change. Given that multiple factors are typically responsible for changes within reef ecosystems, the monitoring of reef health must be carried out at multiple spatial and temporal scales, rather than relying on only a few parameters. Comprehensive assessment of the coral reef resources demands a hierarchical mapping strategy involving micro-scale to macroscale measurements. Of immediate interest to the Department of Defense are types of changes within reef systems that can be monitored at the mesoscale scale.

The objective of this research is to develop technology based on usage of a remotely operated vehicle (ROV) to increase the speed and repeatability with which reef plots can be mapped and inventoried. Specific objectives are to: (1) apply advanced two dimensional (2-D) digital video mosaicing techniques to construct georeferenced images of plots on a coral reef; (2) extract and validate ecological indices of reef condition from the video mosaics; and (3) determine the range of environmental conditions (e.g., turbidity) for effective operation. As a secondary objective, the research program will explore development of tools to automate and/or assist image classification. This will involve 3-D reconstruction of specific reef features from stereo video data, and high-resolution multi-spectral imaging.

BENEFITS: This research will lead to the development of efficient methods for coral reef mapping and monitoring. The ROV-based mosaic technology offers numerous advantages over traditional, diver-based video transects, producing single, plot-scale, high-resolution images that are georeferenced and undistorted. These georeferenced images can be easily integrated with other data sets using Geographic Information Systems (GIS) to inventory reefs under DoD purview. This is an essential component of the legally mandated environmental documentation necessary for conducting military operations and will provide decision-makers with critical information necessary to maintain compliance with relevant statutes, regulations, and executive orders.

ACCOMPLISHMENTS: This is an FY03 New Start.

TRANSITION: The transition plan is designed to be flexible and economically feasible. The capability to produce georeferenced 2-D mosaics and extract relevant ecological parameters from these mosaics will be demonstrated. In addition, specifications for a prototype modular monitoring system will be produced. The modular nature of the package will enable flexible implementation of the technology and increase the economic feasibility of reproduction. Reproduction of the prototype system is expected to cost less than $100,000.

PROJECT SUMMARY

PROJECT TITLE & ID: Analysis of Biophysical, Optical, and Genetic Diversity of DoD Coral Reef Communities Using Advanced Fluorescence and Molecular Biology Techniques; CS-1334

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Paul Falkowski and Dr. Maxim Gorbunov; Rutgers University – New Brunswick, NJ

FY 2003 FUNDS: $331K

DESCRIPTION: The DoD maintains numerous facilities in tropical and subtropical environments that are adjacent to coral reefs. DoD is required to assess the impact of military activity on these surrounding benthic communities. Documenting the environmental state of reef communities is critical to developing remediation strategies that can both reduce anthropogenic impact and distinguish between natural and anthropogenic stress. The development of advanced technologies for environmental monitoring of benthic communities under DoD jurisdiction requires an understanding of how different environmental factors affect the key elements of the ecosystems and the selection of specific monitoring protocols that are most appropriate for the identification and quantification of particular stresses.

Specific objectives of this study are: (1) to develop advanced techniques for rapid and non-destructive assessment of the viability and health of coral reef communities with the capabilities of identification and quantification of natural and anthropogenic stresses, (2) to develop prototypes of Fast Repetition Rate (FRR) Fluorosensors for permanent underwater monitoring stations and Remote Operated Vehicles, and (3) to collect a library of baseline data on physiological, biophysical, bio-optical and genetic diversity of coral reef ecosystems near DoD installations in three geographic areas.

BENEFITS: This research will provide a set of quantitative baseline data, as well as advanced methods and technology for the assessment of benthic ecosystems near DoD installations. The FRR fluorometry is based on the same biophysical principles, as several other active fluorescence techniques, but it provides significantly greater quantity of parameters. This information is extremely valuable in the identification and quantitative assessment of specific environmental stresses (e.g., elevated temperature, excess irradiance, nutrient limitation, etc.). It is anticipated that the application of SCUBA-based FRR technology will help identify and distinguish between natural and anthropogenic stresses to benthic organisms.

ACCOMPLISHMENTS: This is an FY03 New Start.

TRANSITION: The goal is to commercialize the imaging FRR Fluoroscnsors by transitioning the technology to a small environmental science business. Transfer of the technology will also be through scientific meetings and journals as well as through a website of the Institute of Marine and Coastal Sciences (http://marine.rutgers.edu/ebme).

PROJECT SUMMARY

PROJECT TITLE & ID: An Integrated Approach to Assess the Impacts of Military Activities on Shallow Water Benthic Community Structure and Function in the Chesapeake Bay Ecosystem; CS-1335

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Linda Schaffner and Dr. Iris Anderson; Virginia Institute of Marine Science – Gloucester Point, VA

FY 2003 FUNDS: $245K

DESCRIPTION: Several military bases in Virginia and Maryland have been placed on the National Priorities List of most hazardous sites in the country due to non-point source pollution of adjacent aquatic ecosystems. Biocriteria-based methods, such as the multimetric Benthic Index of Biotic Integrity (B-IBI), have been applied in the Chesapeake Bay area to successfully elucidate water and sediment quality impairments and physical habitat disturbance. Although this method serves as a good indicator of anthropogenic disturbance, its relationship to key functional attributes of aquatic ecosystems, such as primary production and respiration, nutrient cycling, and food web structure, is not known.

This project will couple the B-IBI approach with more detailed investigations of benthic community structure and function as a means of assessing the impacts of military installations on the health of adjacent estuarine ecosystems. The specific objectives are to: (1) use the B-IBI to assess the average health of shallow water benthic communities in areas immediately adjacent to military installations; and (2) characterize other key aspects of benthic community structure and functional processes (meiofauna community composition and abundance, primary production, respiration, nitrogen mineralization, nitrification and denitrification) along gradients of impairment associated with military activities.

BENEFITS: This research will improve and expand existing tools that will help scientists and environmental managers better understand how military installations influence the Chesapeake Bay ecosystem. Biocriteria-based approaches will play a central role in water quality management in the future.

ACCOMPLISHMENTS: This is an FY03 New Start.

TRANSITION: To help the military utilize the results of this project, a technical guidance document based on the findings of this study will be produced. This document will consist of an interactive DVD based presentation that will make use of multimedia presentation formats (e.g. text and figure-based description of B-IBI methodology with digital video clips demonstrating appropriate sampling methods).

APPENDIX D
Pollution Prevention Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Next Generation Fire Suppression Technology Program; PP-1059

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Richard Gann; National Institute of Standards and Technology, Building and Fire Research Laboratory – Gaithersburg, MD

FY 2003 FUNDS: $1000K

DESCRIPTION: Halon 1301, the predominant and critical total flooding fire suppressant installed in weapons systems, is no longer in production due to its deleterious effect on stratospheric ozone. The objective of this program is to develop and demonstrate, by 2005, environmentally acceptable and user-safe processes, techniques, and fluids that meet the operational requirements currently satisfied by Halon 1301 systems in aircraft, ships, land combat vehicles, and critical mission support facilities. The results will be specifically applicable to fielded weapons systems and will provide dual use fire suppression technologies for preserving both life and operational assets. This effort leverages prior SERDP-funded research and the Research, Development, Test, and Evaluation (RDT&E) infrastructure created under the ongoing Department of Defense's (DoD's) near-term research program.

The research approach consists of six parallel Technical Thrusts, closely integrated to achieve specific milestones within an 8-year time frame. This approach was developed collaboratively by government, industry, and academic experts in fire science, the contributing technical disciplines, instrumentation, testing, and Halon 1301-protected weapon systems. Following are the six Technical Thrusts which embody 24 separate research elements.

1. Risk Assessment and Selection Methodology develops a process for choosing among alternative technologies by applying modern decision-making concepts.

2. Fire Suppression Principles establish the mechanisms of flame extinguishment using detailed experimental studies and computational models leading to new approaches for fire control.

3. Technology Testing Methodologies select, adapt, and develop test methods and instrumentation to obtain data on the effectiveness and properties of new suppression approaches.

4. New Suppression Concepts define new ideas for fire suppression based on chemical and physical principles.

5. Emerging Technology Advancement accelerates a variety of processes, techniques, and fluids that are currently under development.

6. Suppression Optimization develops the knowledge to obtain the highest efficiency of each candidate technology.

This is a "living" program representing the best current thinking for achievement of the objective, yet adaptable as the knowledge base grows. There are always risks in such an undertaking. For instance, there might be no chemicals that perform well for all the desired properties; no new fire suppression technologies might emerge; optimization principles might not improve mediocre approaches sufficiently; and lab-scale measures might not adequately predict real-scale performance. This research is designed to provide the scientific understanding to maximize the likelihood of overcoming risk factors.

BENEFIT: The outcome of this program will be demonstrated alternatives to Halon 1301. This will enable DoD weapon system managers to remove their dependence on a key ozone-depleting substance while minimizing fiscal and operation barriers to implementation.

ACCOMPLISHMENTS: The NGP is developing both improved understanding to guide the search for and identification of candidates worthy of further consideration. The following is a list of highlights achieved in FY02:

- Up to three of the priority suppressant compound families were selected for further testing. Laboratory measurements were performed on flame suppression efficiency for representative chemicals and estimates of toxic potency were obtained from literature studies or structure-activity relationships.

- Investigated the atomization and dispersion of different liquid agents in engine nacelle-like conditions throughout enclosures with and without obstructions, and evaluated the effectiveness of the agent to reach the location of a fire.

- Investigated the effect on agent atomization and dispersion under non-burning conditions of agent composition and physical properties; spray characteristics; agent atomizer design; and obstacle shape, size, temperature, and position relative to the agent deployment device.

- Defined what additional experimental configuration, operating conditions, and experimental data, not provided in FY2000 and FY2001, will be required to assist the computational sub-model development effort. Efforts were then directed toward modifying the NIST/SCT, and obtaining a full parametric data set under the agreed upon conditions.

- A CFD model was adapted to predict the transport of gaseous and liquid agents throughout regions with geometries not resolvable on a computational mesh.

- Applied powder panels to the lining of aircraft dry bays to provide passive, lightweight, and effective fire protection against ballistic impact. Projectile penetration of the dry bay and adjacent fuel tank releases agent from the powder panel into the fire zone to inert the space before the adjoining fuel spills into the space and is ignited by incendiaries. An NGP survey indicated that U.S. fixed wing aircraft do not employ powder panels, but there is growing interest. NGP's success with enhanced powder panel designs has sparked interest by several aircraft programs.

- At the suggestion of SERDP management, the NGP Technical Program Manager commissioned an Independent Review Panel (IRP) to assess progress to date and to recommend actions that could enhance the prospects for the NGP program to result in viable and practical alternative fire suppression technologies with NGP resources remaining at or near currently projected levels.

TRANSITION: This is an eight-year, comprehensive research and development (science and technology) effort with leveraged funding from all DoD Services, industry, and academia. Successful sub-projects will be further developed within this program. Successful projects will be transitioned into DoD engineering programs to further develop the technologies for implementation.

PROJECT SUMMARY

PROJECT TITLE & ID: Tri-Service "Green" Gun Barrel – A Physical Vapor Deposition for the Application of Environmentally Safe Coatings for Gun Barrel Bore Protection; PP-1074

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Larry Rush; U.S. Army, Benet Laboratories – Picatinny Arsenal, NJ

FY 2002 COMPLETED PROJECT

DESCRIPTION: This project developed an environmentally friendly, non-aqueous process for the deposition of tantalum onto gun pores, replacing the current hazardous aqueous electro-deposition process of chrome plating. This novel process used for the deposition of tantalum is called the cylindrical magnetron sputtering (CMS) process. The project resulted in an advanced technology demonstration addressing specific Army, Navy, and Air Force requirements in the plating of medium-caliber barrels. Moreover, it showed that the process can be spun off to large-caliber gun barrels and other applications, including cylinders for recoiling mechanisms, aircraft landing gear, the oil processing industry, the power generation industry, and the mining and exploration industry.

CMS is a dry, environmentally benign technology capable of depositing tantalum on gun tubes. It also has the flexibility to deposit other refractory metals and their alloys as well as being able to tailor the coating properties through the deposition thickness. The CMS process will protect the autofrettage residual stresses on the gun bore surface. Unlike the chromium process, CMS produces a smooth, continuous coating and eliminates the need for surface finishing. In addition, CMS offers a coating process with acceptable: deposition rates, dimensional integrity around the bore circumference and along the bore length, material density, and adhesion to substrate. Finally, the CMS process can be reversed to remove coating.

BENEFIT: Current weapon systems and those currently being developed or planned will have gun tubes with chromium deposited on their interior/bore surface to protect the bore surface from the hot propellant gases and the mechanical effects of the projectile. Current technology relies on an wet process known as aqueous electrodeposition. The chromic acid used in the deposition process contains hexavalent chrome, a known carcinogen that is extremely expensive to manage and dispose. For example, in FY95 for large caliber barrels, the cost of wastewater treatment and sludge removal was $2.3M.

ACCOMPLISHMENTS: Efforts continue to investigate the deposition of tantalum on gun barrels. The project developed the parameters required for depositing a uniform coating having the desired coating properties in the tower demonstrator developed for the M242 Bushmaster and the GAU-12 gun tubes. The 6" laboratory demonstrator was transitioned to the large caliber (120mm and 155mm) program and is looking at development in larger sizes using a new configuration for the target. The medium caliber tower for 25mm and 45mm activities is complete and has been commissioned and has been used for 45mm full-length coating.

TRANSITION: There is Tri-Service support for the program and typical medium caliber barrels from each of the Services will be coated with the new process and test fired at each of their respective facilities. The program is also heavily leveraged with others from not only the environmental area, but also from gun barrel wear and erosion areas. Industry has provided information to the program regarding environmental costs and has indicated interest in applying the technology after development.

PROJECT SUMMARY

PROJECT TITLE & ID: Replacement of Non-Toxic Sealants for Standard Chromated Sealants; PP-1075

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Alan J. Fletcher; U.S. Air Force Research Laboratory – Wright Patterson Air Force Base, OH

FY 2002 COMPLETED PROJECT

DESCRIPTION: The objective of this work was to formulate and test candidate non-chromated sealants that will provide equivalent or improved properties as compared to the existing chromated sealants while meeting the requirements of MIL-S-81733C. An additional goal was to reduce the volatile organic compound (VOC) content of the materials by 65 percent.

Sealants are required in aircraft systems and on weapons to provide protection against corrosion, prevent moisture entry, provide a fuel barrier, and provide electrical insulation. Traditionally, sealants use chromium as the primary corrosion inhibiting substance. Chromium has been designated as hazardous and is targeted for elimination in order to comply with either current or pending Occupational Safety and Health Administration (OSHA) requirements. Most sealants also contain VOCs such as methyl ethyl ketone (MEK) and toluene. Under this project team's guidance, a chromate-free corrosion inhibiting sealant was developed, tested, and transitioned to the field. A new polymer was developed that is characterized by properties beneficial to corrosion-inhibiting sealants: (1) rapid cure times without a reduction in work life; (2) pleasant odor; (3) excellent rheological properties; (4) excellent cure at low temperatures; and (5) high solvent resistance. The proposed work was directed towards use of this new polymer to formulate corrosion inhibiting sealants for all the types and classes of MIL-S-81733.

BENEFIT: The benefits of this successfully completed project include: (1) reduced use of hexavalent chromium and VOCs; (2) development of longer shelf-life sealant formulations; (3) development of primerless sealant formulations; and (4) expansion of technology enabling the replacement of other chromated sealants.

ACCOMPLISHMENTS: Testing of a PRC-DeSoto prototype formulation showed that the material had excellent corrosion-inhibiting properties. PRC-DeSoto optimized the material and resubmitted it to UDRI, NAWC and ARL for testing. A complete qualification for the material to AMS 3265 was performed. Once the qualification tests were complete, the new sealant was given a commercial product number and placed on the qualified products list (QPL) for AMS 3265. This was the first step to transitioning this new sealant as a drop-in replacement for some of the current chromated, corrosion-inhibiting sealants. In addition to this work, PRC-DeSoto began the development of another class of non-chromated, corrosion inhibiting sealants. The prototype formulation was submitted to UDRI for testing. Other classes of sealant were developed, tested, and qualified until a complete line of products was available to replace all the existing chromated sealants. It is possible that enough classes were developed to effectively replace 90 percent of the current chromated sealants.

TRANSITION: MIL-S-81733 will be revised and implemented throughout DoD to incorporate the new non-chromated sealant compound while meeting all the other specification requirements.

PROJECT SUMMARY

PROJECT TITLE & ID: Supercritical Fluid Spray Application Process for Adhesives and Primers; PP-1118

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Marc Donohue; Johns Hopkins University – Baltimore, MD

FY 2002 COMPLETED PROJECT

DESCRIPTION: It is estimated that 8.5 billion pounds of synthetic polymer adhesives are used annually, of which approximately 55 percent are volatile organic chemicals (VOCs). VOCs commonly used in applying adhesives include aromatics (e.g., toluene), ketones (e.g., acetone, methyl ethyl ketone), and others (e.g.,methanol, chloroform). They are ozone depleting substances which negatively impact worker health, safety, and environment. Environmental standards for these substances require hazardous material management including cost of permits and emission control equipment. The project objective was to investigate and develop low/non-VOC, non-structural adhesives to substitute for the current high-VOC, non-structural adhesives used in military applications. This project adapted the UNICARB spray application process to adhesives in two ways: (1) continuous process for use in a manufacturing setting; and (2) portable hand held batch process for use in small jobs or repair scenarios.

BENEFIT: The principle cost benefits of this project will be from reformulation of existing adhesives now used by the military, and reduction in environmental impacts associated with the VOCs. By re-engineering the UNICARB process to one that can be applied with a hand-held device, the military will be able to increase the number of applications and venues where environmental compliance can be achieved. The advantages of adopting this process include: (1) reduction in VOC emissions; (2) reduction in solvent costs; (3) use of existing and proven adhesives and primers; (4) more evenly distributed coatings; (5) reduction in labor costs; (6) reduction of worker health and safety costs; and, (7) reduction of costs associated with hazardous material management respective to permits and emission control equipment.

ACCOMPLISHMENTS: Six systems were characterized: acrylic, neoprene, styrene-isoprene-styrene copolymer, and styrene-butadiene-styrene copolymer, polyurethane, and polyalkylene glycol. The results show that 20-to-40 percent reductions in VOC content are possible without loss of performance using the UNICARB system. Additionally, reductions in drying and processing times are possible due to the elimination of viscosity reducers in the composition.

TRANSITION: The Department of Defense's participants in the project were the Tank Automotive & Armaments Command and the Aviation & Missile Command. The investigator is coordinating with adhesive manufacturers and equipment companies to manufacture this technology.

PROJECT SUMMARY

PROJECT TITLE & ID: Critical Factors for the Transition from Chromate to Chromate Free Corrosion Protection; PP-1119

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Rudolph Buchheit; Ohio State University – Columbus, OH

FY 2003 FUNDS: $168K

DESCRIPTION: The overall goal is to acquire a fundamental understanding of the chemical and physical processes and mechanisms of corrosion protection by chromate-based coatings applied to metal surfaces with a specific focus on corrosion protection of aluminum alloys. This project comprises a four year fundamental research effort. Specific objectives are to: (1) define a set of phenomenological and fundamental rules that describe the role of microstructural heterogeneity in chromate conversion coating formation and breakdown; (2) define the relationship between chromate conversion coating structure and chemistry, and coating properties for coatings applied under non-ideal conditions such as those that exist during coating applications in manufacturing and military maintenance depot environments; (3) determine the extent to which application method, coating age, and alloy substrate chemistry affect the self-healing nature of chromate coatings; and (4) develop rapid, quantitative, and predictive tests to assess properties and performance of chromate conversion coatings.

BENEFIT: Chromate corrosion protection technologies are expensive to operate and generate much hazardous waste. The expected benefit of this research is an increased fundamental understanding of the mechanisms of corrosion protection by chromate-based coatings. Ultimately, this information will support the development of effective chromate-free alternatives.

ACCOMPLISHMENTS: This effort has found that much of the distinctive phenomenology of chromate coating formation and breakdown is associated with inorganic polymerization of hydrated chromium species. From this central idea, consistent explanations for a variety of chromium conversion coating behaviors ranging from coating formation to coating aging, and self-healing have been constructed. Additionally, the notion of inorganic polymerization has been used as the basis for developing a related conversion coating process based on vanadium chemistry.

TRANSITION: All Services and Department of Defense partners are continually appraised of the results from this fundamental research, and this information will be used to aid in modifying procedures and specifications for corrosion protection by coatings.

PROJECT SUMMARY

PROJECT TITLE & ID: Mechanisms of Military Coatings Degradation; PP-1133

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Steven McKnight; U.S. Army Research Laboratory – Aberdeen Proving Ground, MD

FY 2002 COMPLETED PROJECT

DESCRIPTION: Military coating systems are usually repainted for the following reasons: loss of appearance; chipping, peeling, and debonding of the coating; and corrosion of the substrate. The primary technical objective of this project was to identify, model, and predict degradation mechanisms that lead to military coating system failures, which require depaint and paint operations over the life of the weapon system. The project developed models of coating degradation and provided a scientific basis to develop new durable coating formulations that will help to achieve this goal. The complexity of the problem demands complementary studies to fully understand the degradation mechanisms. This project investigated mechanisms of military coatings degradation used on aircraft, combat ground vehicles, and support equipment. The primary focus was on the primer/topcoat systems that are being fielded to comply with environmental legislation and regulations. Both accelerated tests as well as static and dynamic field conditioning to assess coatings degradation in military systems and environments were investigated. Most prior coatings degradation work has focused on commercial systems and has attempted to relate accelerated lab tests to actual service conditions. The response of any coating system to the environment is complicated and depends on resin type, pigment-resin, primer-topcoat, and primer-substrate interactions. Each element must be addressed to fully understand the degradation mechanisms of the coating system as a whole.

BENEFIT: The end result of this project was an understanding of the mechanisms that explain the degradation of organic coating systems when exposed to military type environments. These mechanisms were modeled and included in a statistical method for accurately predicting the performance of coating systems. Furthermore, an extensive database was being produced and shared with Department of Defense (DoD), industry, and academia that documents results from accelerated aging, static weathering, and dynamic weathering of the new water-reducible coatings systems that are targeted for insertion in the near future. A thorough and quantified understanding of the mechanisms of coatings degradation will promote further confidence in environmentally friendly coatings and thereby increase acceptance of these new systems. Improved confidence will result in faster implementation of the low volatile organic chemical coatings on military platforms.

ACCOMPLISHMENTS: This project achieved several notable results: (1) identification and quantification of appearance changes resulting from accelerated and static aging; (2) verification of photodegradation mechanism of urethane topcoat; (3) development and validation of moisture transport model for coating system; and (4) creation of Electrical Impedance Spectroscopy (EIS) equivalent circuit models. The overall achievement of this SERDP-funded effort was to identify, model, and predict coatings' degradation mechanisms that frequently lead to military coating failures, with the fortuitous result of establishing confidence in current environmentally friendly military coating systems that positively impact both pollution prevention and DoD cost avoidance.

TRANSITION: The results and models will be transitioned by promoting their use as bases for defining performance criteria and in the contracts issued during the acquisition (or rebuild) process. Additionally, the models will be incorporated into materials specifications and/or manuals as criteria for qualification or use. Finally, standardization and industry acceptance of such models will be pursued through existing work groups and existing relationships with materials' suppliers.

PROJECT SUMMARY

PROJECT TITLE & ID: Primerless RTV Silicone Sealants/Adhesives; PP-1135

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Dean Martinelli; U.S. Army Armament, Research, Development and Engineering Center – Picatinny Arsenal, NJ

FY 2002 COMPLETED PROJECT

DESCRIPTION: Room temperature vulcanizing (RTV) silicones, developed in the late 1940's, have played an important role in the design and superior performance of weapon systems (airplanes, missiles, electronics, ammunition, vehicles and nuclear weapons) developed by the Department of Defense (DoD) and Department of Energy (DOE). A unique combination of properties has made them the material-of-choice for designers wanting to improve and increase weapon performance. RTV silicones are used as adhesives, sealants, coatings, heat insulators and encapsulating materials. For RTV silicones to achieve a high level of consistent adhesion to various substrates, a saline primer is applied prior to silicone application. These primers contain 90-98% volatile organic compound (VOC) solvents, which evaporate into the air. The objective of this project was to develop, evaluate, and transition a primerless self-bonding low temperature curable addition cured silicone, which eliminates the use of high VOC primers without compromising durability, compatibility, thermal resistance and long term stability. The technical approach included four phases. In phase I, current addition cured silicones available off the shelf were modified with a bifunctional adhesion promoter compound. In phase II, a less inhibiting adhesion promoter, based on structures defined by molecular modeling was utilized in an attempt to develop room temperature curing systems. Laboratory adhesion evaluations were used to establish "go/no go" criteria for technology development in phase II. To expand adhesion capability to a variety of substrate materials, including plastics, novel adhesion promoting concepts were evaluated in phase III using guidance from molecular modeling predictions. Phase IV demonstrated the use of a new primerless silicone formulation.

BENEFIT: This technology will eliminate traditional primers leading to: (1) reduction of over 500,000 lb/yr of VOCs; (2) avoidance of costs from waivers, deviations and fines associated with the use of non-compliant materials; (3) savings derived from reduced hazardous waste disposal costs; (4) improvement of throughput; (5) reduction in inventory management costs; and (6) cost savings from reduced purchasing, material handling, and specification consolidation.

ACCOMPLISHMENTS: In the final phase of this effort, government laboratories were tasked to evaluate/validate the degree of adhesion of the best candidate, optimized 3rd generation formulations to thermoset and thermoplastic substrates. Evaluations were conducted under both shear and tensile modes. The Polymer Production Facility (PPF) at the DOE/Kansas City Plant (KCP) developed the capability of synthesizing/packaging/distributing primerless silicone "kits." The PPF at the DOE KCP, received all safety approvals and authorization to procure chemicals for all four Primerless Silicone formulations. The PPF facility received authorization to ship the Primerless Silicone kits. The first set of kits were delivered to the appropriate DoD labs in late September 2002.

TRANSITION: The transition of this technology will occur through revision of military specifications (MIL-A-46106, etc.) and by modification of current data packages with engineering change proposals.

PROJECT SUMMARY

PROJECT TITLE & ID: Nondestructive Testing of Corrosion Under Coatings; PP-1137

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. John Weir; Northrup Grumman Corporation – Bethpage, NY

FY 2002 COMPLETED PROJECT

DESCRIPTION: Aircraft painting and repainting operations result in significant emissions of volatile organics, organic and inorganic hazardous air pollutants, and hazardous waste. Aircraft paints are routinely removed to reveal the presence of corrosion on the surface of metal structures and the aircraft is subsequently repainted. Surface corrosion on aluminum aircraft skins and around joints and fasteners is often the precursor to buried corrosion. The objective of this project was to develop nondestructive inspection (NDI) techniques to detect the presence of corrosion under an organic film in order to reduce the amount of painting and depainting that is performed. This project developed: (1) A spectral NDI technique employing an optical reflectance probe in the near/mid intra-red (IR) region combined with Directional Hemispherical Reflectance (DHR) and Fourier transform infrared reflectance (FTIR) integrated detector; (2) Wide-area spectral imaging (WASI) using spectral filters and high-resolution focal plane cameras to allow rapid initial assessment of sub-paint corrosion; and (3) a Scanning Kelvin Probe (SKP) electrochemical method employing a calibrated capacitance probe to indirectly measure corrosion potential across a surface. These inspection and measurement techniques were used to target and map specific areas that require maintenance due to corrosion, thus eliminating the need to completely strip and reapply the exterior coatings. The technical approach included five major tasks: (1) baseline measurements of unexposed coatings and typical corrosion products to build up a database of standards; (2) evaluation of aged aircraft components; (3) optimization of measuring systems at varying levels of corrosion and their modification for field use; (4) prototype verification (in conjunction with the Naval Air Warfare Center Aircraft Division; and (5) preparation of a transition plan for cost-effective applications.

BENEFIT: A successful project would minimize the number of times the aircraft exterior coatings are stripped and reapplied provides substantial pollution prevention and cost saving opportunities. The inspection and measurement techniques would provide a means to verify the condition of coating, thus allowing for a switch to a condition-based rather than schedule-based maintenance and verify the condition of the primer and surface preparation once the topcoat has been removed, eliminating a portion of the rework that now routinely occurs.

ACCOMPLISHMENTS: The final year of the project included the continued evaluation of surface morphology imaging. An optimized IR illumination system was created and moved into the field for testing. Spectral filters were employed, as well as customized software to allow for rapid, wide area assessment of corrosion and metal surface morphology of painted aircraft structures. The success of wide area IR spectral imaging in detecting not only corrosion through paint but also metal surface morphology provides this technology the potential to see cracks. Little or no light scattering is seen in the mid IR images of the metal underneath the paint, so IR wide area imaging has the potential be a complete visual inspection technique.

TRANSITION: Weapon systems will be identified that can use the spectral imaging and electrochemical measurement technologies to assess the condition of underlying substrates relative to corrosion without coatings removal. This technology will then be transitioned to the DoD user community to minimize environmental wastes and emissions associated with coating materials.

PROJECT SUMMARY

PROJECT TITLE & ID: Cleaning Verification Techniques Based on Infrared Optical Methods; PP-1138

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Shane Sickafoose; U.S. Department of Energy, Sandia National Laboratory – Albuquerque, NM

FY 2002 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to develop a real-time method to provide both qualitative and quantitative assessments of surface cleanliness for a wide variety of military cleaning applications. The introduction of new environmentally acceptable solvents for traditional chlorinated hydrocarbon materials has produced major uncertainties in standard cleaning procedures. As a result, many applications overutilize solvents that, in turn, leads to the additional usage, handling, and disposal of hazardous materials, while also wasting personnel operating time. Currently, the detection of surface contamination on reflective surfaces is most convenient and rapidly done by the Fourier transform infrared reflectance (FTIR) method which provides both quantitative and qualitative information on surface coatings. Specifically, the project: (1) developed a prototype, on-line widely tunable infrared laser based instrument with high speed surface-imaging capability but with limitations on the number of detectable organic contaminants; and (2) optimized an FTIR based instrument with high sensitivity for organic species on a variety of surfaces, but with limitations on speed and surface coverage for real-time analysis of surface contaminants at very low level of concentrations. The proposed instruments differ in the nature of the information they provide. The first produces images that directly indicate the spatial extent and location of contamination. The second provides a spectrally-resolved measurement of the surface reflectance at a single point.

BENEFIT: This project developed two IR optical methods that address the need for new surface cleanliness analysis technologies. The methods will be able to: (1) operate in real-time and will be useful in process monitoring and control; (2) provide qualitative and quantitative output for comparative assessment of cleanliness levels (both quantitative amounts and species present); (3) handle a wide variety of military specific applications, such as repair and remanufacturing processes at repair depots; and (4) measure cleanliness levels that can be related to required materials property requirements for various surface preparation processes (e.g., repair or application of protective coatings).

ACCOMPLISHMENTS: The laboratory infrared-laser imaging instrument demonstrated the successful detection of a variety of contaminants common to defense depot repair and refurbishment operations. The design and fabrication of an improved, portable FTIR instrument has been successfully completed in cooperation with Surface Optics Corporation (SOC). This instrument incorporates grazing-angle reflectance for maximum sensitivity to surface contamination, and was thoroughly tested in comparison with laboratory research instruments. Three successful field demonstrations were conducted showing instrumental detection of residual contamination on aircraft surfaces prior to, and in some cases, following standard cleaning procedures. The device is now commercially available from Surface Optics Corporation (SOC) and units have been purchased by the Boeing Corporation and National Aeronautics and Space Administration (NASA) for cleaning verification applications on aircraft and aerospace components. An additional spectrometer has been purchased by Oak Ridge National Laboratory. Based on feedback from personnel at Hill AFB and at Naval Depot North Island, SOC upgraded the prototype with more user-friendly features.

TRANSITION: Transition to both research and development organizations, and Department of Defense (DoD) end users will be done through field testing at DoD facilities, communicating the results to DoD and Department of Energy (DOE) users, and aggressive pursuit of commercialization.

PROJECT SUMMARY

PROJECT TITLE & ID: Non-Structural Adhesives Requiring No VOCs; PP-1139

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Claude Selitrennikoff; MycoLogics – Denver, CO

FY 2002 COMPLETED PROJECT

DESCRIPTION: Currently available adhesives include epoxy-polyamides, polyurethanes, organo-silanes, cyanoacrylates, and polyvinyl acetates. These often require toxic volatile organic compounds (VOCs). Commonly used VOCs include toluene, methylethylketone, acetone and xylene. In sunlight, VOCs and nitrogen oxides produce ozone. Other VOC interactions contribute to the formation of photochemical smog. Non-VOC adhesives would substantially reduce this form of air pollution. The search for strong, environmentally compatible adhesives has turned to such examples in nature as the tenacious adherence of barnacles and mussels to rocks. Although the properties have indeed been spectacular, production of these adhesives on a commercial scale is problematic. The objective of this project was to use microorganisms as a source of novel adhesives that do not include any toxic VOCs. These natural compounds are environmentally safe yet still meet physical property performance requirements for numerous Department of Defense (DoD) applications.

BENEFIT: The Army, Navy, and Air Force use non-structural adhesives for gaskets, instrument panels, textiles, packaging, and labeling. Medical applications include biocompatible tissue augmentation, wound closure and drug delivery systems. DoD will realize significant cost savings from compliance with environmental regulations and the decrease in medical costs associated with the use of VOCs.

ACCOMPLISHMENTS: Three hundred and fifty microorganisms were screened for production of adhesives. Five were found that produce adhesives with tensile strength greater than 500 psi on bare aluminum. One adhesive was selected for the focus of work during the final section of the project. With identification of the polymer backbone and completion of associated tasks, attention shifted to acquiring data critical to scaled-up production. Several runs were made to determine parameters associated with production of high levels of adhesive. Absorbance at 600 nm, pH, and product amount were recorded at intervals. The adhesive strength of the product was determined on samples taken at 24, 36, and 48 hours. Water resistant derivatives were prepared and tested for adhesive strength and water resistance. Derivatives were able to retain good adhesive strength at 75-98% humidity for 1 week. Scale up work has been completed with the successful running of two 3500 liter batches. Samples are now available for field tests.

TRANSITION: A transition team meeting provided valuable input to help ensure that the adhesives will be useful to DoD. The adhesives will be tested to qualify them for Army, Navy, Air Force, and Department of Energy (DOE) applications, as well as for use in the private sector.

PROJECT SUMMARY

PROJECT TITLE & ID: Electro-Spark Deposited Coatings for Replacement of Chrome Electroplating; PP-1147

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Andy Goetz; U.S. Army Armament Research, Development, and Engineering Center – Picatinny Arsenal, NJ

FY 2002 COMPLETED PROJECT

DESCRIPTION: Chrome electroplating is one of the most widely used surface treatment processes throughout the military services. The current alternative technologies, such as high velocity oxygen fuel (HVOF) process, are gradually replacing chrome electroplating for some applications. However, there currently exists a need for alternate technologies where alternate technologies such as HVOF coatings cannot be applied. Electro-spark deposition (ESD), a novel coating technology, is a pulsed-arc, micro-welding process that uses short-duration, high-current electrical pulses to deposit, with very low heat-input, a consumable electrode material on a metallic substrate. The short duration of the electrical pulse produces very rapid solidification of the deposited material resulting in a true metallurgical bond while maintaining the substrate at ambient temperatures. The process releases no hazardous wastes, fumes or effluents, is cost-effective, requires no special chambers, spray booths or operator protection, and eliminates the hydrogen embrittlement problems that can occur with some substrates. The objective of this project was to develop process control sensors, process parameters, equipment, and techniques using ESD to coat inside diameters and other difficult geometries with robust wear and corrosion-resistant coatings that will replace current chromium electroplating applications. The technical approach consisted of developing the process parameters for selected material coatings required for specific military applications, and the process control sensors and algorithms necessary to achieve those parameters in non-line-of-sight applications. The components were tested as part of the process optimization efforts, using specific test conditions defined by the military services.

BENEFIT: This technology will complement current replacement technologies, such as HVOF, by allowing coating of non-line-of-sight geometries that HVOF and other thermal-spray processes cannot coat. Cost benefits include: (1) low capital expense (approximately $30K) compared to new chromium (Cr)-plating lines (greater than $1 million) or HVOF (greater than $400K); (2) elimination of waste disposal costs, (3) $0 for ESD compared to greater than $10 million per year reported for Cr-plating for the Army alone; (4) reduced or eliminated surface preparation costs relative to either Cr-plating or HVOF processes; and (5) savings from portability of process to allow use in field or shipboard to coat or repair components in-place, with minimum set-up.

ACCOMPLISHMENTS: Identification and characterization of the key process parameters necessary for process control in non-line-of-sight applications was completed. Control algorithms, software, and hardware for automated 3-axis control of parameters for non-line-of-sight geometries was successfully developed and is the subject of an Invention Disclosure. A hard surfacing material, Stellite 21, was identified that is capable of crack-free deposits to at least 250mm thick, is fully corrosion-resistant in American Society for Testing and Materials (ASTM) B117 salt fog tests, and has as-deposited hardness equal to the lower range of chrome plate. The first round of fatigue tests were completed and results of the test were ambiguous. Additional tests are planned. Development of process controls and the sensors necessary for manual ESD coating of non-line-of sight geometries is in progress and on schedule. This project is in the process of completing their testing and writing their final report.

TRANSITION: This project generated a working prototype of ESD system for non-line-of-sight (NLOS) surface coatings, and protocols for process testing. Results of the process tests for the military Services were reported to team members and to the technical community at the Hard Chrome Alternatives Team (HCAT).

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Conductive Polymers as Environmentally Compliant Coatings for Corrosion Protection; PP-1148

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Peter Zarras; Naval Air Warfare Center – China Lake, CA

FY 2003 FUNDS: $500K

DESCRIPTION: Corrosion prevention using new conductive polymer (CP) coating materials will be the focus of this project. Environmentally compliant formulations combined with a benign process for the application of these coatings will provide the Department of Defense (DoD) community with an attractive alternative to current chromate-containing coatings. For years the chromate-containing coatings have been used to treat aluminum alloys such as 7075-T6, 7075-T3 and 2024-T3. Many DoD platforms such as the F-18, F-16, F-22, Joint Strike Fighter, MV-22, CV-22, H-60, C-141, C-130, C-5, and P-3 Orion aircraft use these chromium treated alloys. Hexavalent chromium (Cr^{+6}) has been identified as a health threat, and because of its toxicity, is currently highly regulated. New EPA regulations governing air emissions and lower OSHA permissible exposure limits (PEL) have greatly reduce the levels of Cr^{+6} allowed to be discharged into the industrial environment where workers will risk exposure to this known carcinogen. Therefore, chromate-free coatings are needed that also exhibit equal or superior corrosion protection. Conductive polymer coatings provide such an opportunity to reduce these hazardous materials, eliminate Cr^{+6} from coating formulations, allow compliance with new environmental regulations, and reduce hazardous disposal costs while ensuring mission readiness and worker safety. Several key steps to demonstrate the concept are:

Preparation of CP Powders: The first phase of this study is to prepare kilogram quantities of demonstrated poly(bis-(N-methyl-N-hexylamino)phenylene vinylene) (BAM-PPV) materials at the Naval Air Warfare Center Weapons Division (NAWCWD), China Lake, CA. Concurrent with this effort will be the preparation of 10-gram quantities of oligoaniline acrylate polymer (OAP) by Rensselaer Polytechnic Institute (RPI) at Troy, NY. The NAWCWD-prepared BAM-PPV has been well characterized and has shown conclusive evidence of corrosion inhibition from constant current (galvanostatic) and constant potential (potentiostatic) measurements. These electro-chemical studies were conducted in concentrated salt-water solutions and provided quantitative evidence in reducing the pitting corrosion of aluminum alloys. The procedure for scaling up these CP materials has been successfully demonstrated at the 200-gram scale in moderate yield and high purity. Scale-up to kilogram quantities will proceed using the same procedure. Purity will be demonstrated by the same characterization techniques as previously used for the multi-gram batches (NMR and DSC). One small batch of the water-borne polymer, WAM-PPV, has been prepared, hence there is risk in scale-up, however, no difficulties are anticipated. RPI will prepare multi-gram quantities of OAP. Copolymers will be prepared with monomers used in the paint industry such as butyl acrylate, methyl methacrylate, and ethyl hexyl acrylate. This synthetic effort will focus on control of the Mw of polymer to allow easy processability during coating applications.

Paint Formulations with BAM-PPV and Benign Applications of these Materials: CP will be prepared for use in three different chromate-free formulations/processes. Water-borne paint/primer formulations (using water-soluble polymers or water-emulsified polymers) will be coated onto aluminum alloy substrates 7075-T6, 7075-T3, and 2024-T3. BAM-PPV materials will be dissolved/dispersed in liquid CO_2 formulations and coated on the same coupons at NAWCWD. (OAP will not be formulated pending corrosion testing of the neat material.) BAM-PPV materials will be used in powder-coating formulations developed at NAWCWD and coated onto these coupons by the Naval Aviation Depot, (NADEP) Jacksonville, FL using their spray booths. These three processes eliminate all solvent VOC content. Some CP coatings will also have a topcoat, such as MIL-C-27725 (translucent polyurethane topcoat), to compare with current coatings.

BENEFIT: The expected payoff is fourfold: (1) increased environmental safety by reducing toxic metals; (2) increased endurance of military equipment subject to corrosion conditions (humidity, seawater, and salt spray); (3) increased mission readiness; and (4) significant cost savings by reducing painting/depainting waste treatment.

ACCOMPLISHMENTS: China Lake has successfully scaled-up the BAM-PPV to hundreds of grams. Rensselaer Polytechnic Institute has successfully demonstrated at the multi-gram level oligoaniline acrylate polymer. A flame deposition technique performed by MicoCoatings Technologies, Inc. (MCT) has been successfully applied using pure BAM PPV onto aluminum substrates. The performance of the pure BAM PPV coating onto aluminum alloy is comparable to chromate conversion coating (CCC) under neutral salt fog testing (ASTM B117) for 3000 hours. Additional coating formulations are under development and will be applied to metal coupons.

TRANSITION: This approach is based on a tight feedback loop between industry and end-users to provide a fast-track approach to product development for fleet-wide use.

PROJECT SUMMARY

PROJECT TITLE & ID: Clean Dry-Coating Technology for ID Chrome Replacement; PP-1151

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Irwin Singer; U.S. Naval Research Laboratory – Washington, DC

FY 2003 FUNDS: $0K (2004 Funding 150K)

DESCRIPTION: Chrome plating is heavily used throughout the DoD on almost any system subject to wear - aircraft, ships, tanks, guns, hydraulics, etc. In order to avoid the high volume waste streams inherent in wet plating technologies, the research team proposed a dry-coating method - plasma sprayed Tungsten Carbide-Cobalt (WC-Co) for internal diameter (ID) as small as 1.5 inches. Recent work funded by Defense Advanced Research Project Agency (DARPA), Office of Naval Research (ONR), and the commercial sector has shown that plasma spray with small (1-10um) or nanoscale powders (20um agglomerates or 20nm particles) produces very smooth coatings with the porosity and adhesion of high-velocity oxygen fuel (HVOF). Development of a suitable spray method for miniature ID guns will extend the plasma spray process to 1.5" ID to reach most of the actuator components, and modification of these guns may permit us to reach 1" ID for the smallest pins, hydraulic actuators, and other components. For some applications, such as sidewalls of grooves in IDs, or very thin-walled, heat-sensitive components, the ESD process is likely to be more cost-effective. ESD is a consumable electrode micro-welding technology with heat input that is extremely small and limited to the surface layer, and it is ideal for small areas and difficult geometries.

The objective of this project is to develop an ID coating technology that is clean, can be used for rebuilds, and is environmentally acceptable. This will be accomplished in three tasks: (1) conducting research on the deposition of smooth, high quality plasma spray WC-Co coatings on IDs greater than 2.5", using existing guns with small particles and with agglomerated nanoparticles, (2) developing and testing new miniature ID plasma spray gun for use with small particles and nano-agglomerates which could drive the minimum coatable ID down to 1", and (3) ensuring that the technologies not only provide good performance at an acceptable cost, but also fit the diverse needs of maintenance operations.

BENEFIT: The immediate environmental benefit of the thermal spray approach is the complete elimination of hexavalent chromium mist and the chromium-contaminated toxic wastes associated with chrome plating, stripping, and masking operations. This coating method has the potential for significant cost reduction in both production and sustainment. In general, WC-Co coatings at least 2 - 3 times longer than hard chrome. This leads to lower frequency-of-repair, better mission-readiness, and the ability to keep a lower spare parts inventory. The much reduced production time over chrome plating gives faster turn-around in overhaul operations, also enhancing mission readiness and reducing inventory requirements.

ACCOMPLISHMENTS: Coatings of WC-Co and tribaloy have been demonstrated inside 3" ID tubes using three different plasma guns designed for ID deposition. These coatings have properties (hardness, porosity, stress, etc.) that appear to be acceptable. The various plasma spray coatings are now being applied to all of the different types of test specimens. The baseline hard chrome-plated specimens have been largely completed at Naval Aviation Depot, Jacksonville and provided to Navy Reserve Center for testing.

TRANSITION: The project is designed to feed directly into an equipment and process development and demonstration/validation program that will be able to follow rapidly upon the completion of the SERDP program. The final deliverable will be a technical report detailing the plasma spray methods that are ready for demonstration and validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Electroformed Nanocrystalline Coatings: An Advanced Alternative to Hard Chrome Electroplating; PP-1152

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Doug Lee; Babcock & Wilcox - Ontario, Canada.

FY 2002 COMPLETED PROJECT

DESCRIPTION: Hard chromium (Cr) coatings (0.25 to 10 mil thick) are used extensively for imparting wear and erosion resistance to components in both industrial and military applications. This is because of their intrinsic high hardness (600-1000 VHN) and low friction coefficient (<0.2). The most common means of depositing such hard chromium deposits has been through the use of chromic acid baths. Health risks associated with the use of hexavalent chromium baths have been recognized since the early 1930's. More recently, such hexavalent Cr baths have been shown to enhance the risk of cancer of the lung and nose.

The technical approach consisted of a three-phase project. Phase I provided identification and preliminary experimental assessment of suitable nanoscale electrodeposition systems that satisfy the environmental objective and provide the mechanical performance requirements. This phase focused upon identifying the most promising systems from an environmental performance and cost perspective. Phase II dealt with developing and optimizing the most promising systems identified in Phase I and incorporated additional performance evaluation including wear, thermal stability, and corrosion testing. Phase III efforts focused upon the optimization of nanoscale 'bore-plating' techniques which represent key applications for the Department of Defense (DoD).

BENEFIT: This project will allow the complete elimination of hexavalent Cr at rework, maintenance, and manufacturing facilities within the DoD. DoD currently spends over $10 million dollars per year in hazardous material disposal costs associated with hard chrome electroplating. The proposed nano-scale coating approach would allow for the retention of numerous benefits associated with hard chrome plating technology (i.e., non-line-of-sight application, excellent coating adhesion, dimensional consistency, and superior surface finish). In addition, this approach will allow for the use of existing hard chrome plating infrastructure within the defense sector. This will significantly reduce the time and cost to practical implementation. Moreover, the proposed nano-technology is expected to provide significant performance and life cycle cost benefits over current hard chrome plating technology.

ACCOMPLISHMENTS: A nanocrystalline cobalt-phosphorus alloy and associated process was established, studied, and optimized. Performance tests were conducted on uncoated and coated samples (as well as reference materials) to establish properties and performance. Efforts are underway to apply the nanocrystalline cobalt-phosphorus alloy coating to internal diameter surfaces. Anode selection and plating parameters have been selected and are currently being tested on mockups designed to simulate the typical internal diameter surfaces encountered in DoD applications. Activities remaining to complete the development project include completing the remaining material tests, completing the internal diameter geometry study, demonstrating the costing process on a DoD component, and preparing a final report.

TRANSITION: It is anticipated that the proposed nano-scale coating technology will fully utilize the existing hard chrome plating infrastructure (i.e., contractors, equipment, specifications, etc.) with minimum capital expenditure, thus significantly reducing the time and cost to practical implementation within the DoD. The specific deliverables from this project include an environmentally compatible electrodeposition process to replace hard-chrome electroplating, suitable electrodes and fluid delivery system for a DoD non-line-of-sight application, annual reports, peer reviewed articles, and design guidance on further applications.

PROJECT SUMMARY

PROJECT TITLE & ID: Reduced Particulate Matter Emissions for Military Gas Turbine Engines Using Fuel Additives; PP-1179

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mel Roquemore; Air Force Research Laboratory – Wright-Patterson Air Force Base, OH

FY 2003 FUNDS: $759K

DESCRIPTION: It is estimated that U.S. military aircraft emit about 600,000 kg of particulate matter into the atmosphere each year. Most of this particulate matter is in the form of soot particles with diameters less than 2.5 microns ($PM_{2.5}$). There is a growing body of evidence that these small particles cause both health and environmental problems. The technical objective of the project is to develop one or more fuel additives for JP-8, JP-5, and diesel fuels that will reduce both the mass Emissions Index (EI (M)), (grams of $PM_{2.5}$ emissions/kilogram of fuel) and the number density Emissions Index (EI (ND)), (particle number density/ kilogram of fuel) of $PM_{2.5}$ at the exhaust exit of military gas turbine engines by 70 percent. The additive should be benign to the environment and the fuel system, cost no more than $0.01 per gallon of fuel, and not reduce engine performance and life. Three complementary technical approaches will be followed: (1) fundamental approach, (2) quantitative Structure Activity Relationships (QSAR) approach, and (3) select and test approach. The fundamental approach is to conduct basic experiments with additives that have shown a tendency to reduce $PM_{2.5}$ emissions and give insight into the additive mechanisms so that improved additive formulations can be developed. The QSAR approach will provide a mathematical formula that correlates $PM_{2.5}$ reductions to molecular, chemical, and physical properties. The formula will be used to select the next generation of additives to be tested. The select and test approach involves obtaining additives from additive companies and testing them. The companies will be given the results of the additive tests so they can reformulate their additive package and submit it for the next round of testing.

BENEFIT: The insights gained from these studies will be valuable to the understanding of PM formation processes and provide other researchers with a valuable resource for the design of next generation PM mitigating additives. The fundamental experiments involve simple experimental geometries that can be easily modeled. That information will be useful in developing and designing low PM emissions combustors. Finally, an additive or additives will be identified which reduces PM emissions from gas turbine engines by 70%. In the long term, Base Commanders and managers will be able to meet military readiness and local air quality standards of the Clean Air Act Amendments (1990) and upcoming amendments to this Act.

ACCOMPLISHMENTS: The research efforts in the first two project years have provided a fundamental understanding of the effects of oxygenated compounds on soot formation across a range of combustion environments an accomplishment that has never before been achieved in the field of combustion. Appropriate methodologies for systematically conducting experiments and interpreting the results with the aid of detailed computational models were established to identify the intricacies of the soot formation and oxidation processes in the laboratory flames and reactors. The fundamental insights into the effects of oxygenated compounds on soot formation and the research methodologies that led to them form the foundation for the research that will be conducted in the final two years of the project. Another key element that shaped the research plans for the final two years of the project was the discovery of a commercial additive that is effective in reducing soot in gas turbine engines and combustor simulators at the Air Force Research Laboratory. The challenge now is to understand how it functions and extend this toward the development of more effective additives.

TRANSITION: The project will provide a new methodology for evaluating additives to reduce PM emissions from turbine and diesel engines and provide a fundamental understanding of PM emissions from turbine and diesel engines for military and commercial applications.

PROJECT SUMMARY

PROJECT TITLE & ID: Castable, Solvent-Free Red Phosphorus Smokes for Target Markers; PP-1180

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Daniel Nielson; Thiokol Propulsion – Corinne, UT

FY 2002 COMPLETED PROJECT

DESCRIPTION: Red Phosphorus (RP) is a material used historically for the production of certain types of target markers. Although mature and reliable, the current process involves the use of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs), which are usually quite flammable, electrostatic discharge (ESD) sensitive, and harmful and/or toxic if inhaled or ingested. The technical objective of this project was to develop castable or pourable, chemically-cured RP formulations with sufficiently high binder content to totally eliminate the need for solvent processing aids, while concurrently mitigating ESD sensitivity. This must be achieved while still maintaining the burn characteristics and white smoke-cloud formation produced by existing RP formulations.

The project initially evaluated three types of chemically cross-linked energetic binders in RP smoke formulations. Energetic polymers that were evaluated are poly-azide polymers (e.g., glycidyl azide polymer), nitrate ester polymers (e.g., plasticized nitrocellulose), and inert polyether polymers with energetic plasticizers. The same core set of tests used to establish the rheology/processing characteristics, hazard sensitivity, structural (mechanical) integrity, and ignition and combustion characteristics were used to determine the binder system. The best performing RP smoke formulations were evaluated as potential prototype target markers.

BENEFIT: Advancements in terms of cost savings, increased safety, and environmental concerns are expected for the solvent process, cast process, solvent waste, and VOC usage. The proposed formulations and processes should also provide extended storage life, required smoke, and higher production efficiency. Castable RP smokes offer very low risk for transitioning to large-scale production. Extensive manufacturing infrastructure and capability exists in the private industry and government facilities to batch-mix and cast solvent-free compositions like those proposed for this program.

ACCOMPLISHMENTS: The baseline castable RP composition has been loaded and demonstrated in MK25 tubes. The MK25 is a Marine Location Marker, which is an end-burning grain (vs. the explosively disseminated MK67 grain), has burn time, smoke visibility, and flame visibility (night-time operation) requirements. The first tests of the device met the required burn time and exhibited excellent night-time visibility. Additional work in bondline improvement and composition optimization would be beneficial, and is being pursued. This project is in the process of completing their testing and writing their final report.

TRANSITION: The developed formulation and process will be transitioned to the demonstration and validation phase based on successful test and evaluation of fully configured Army, Navy, and Air Force red phosphorous target marking and obscuring rounds. The proposed technology could be transitioned to any industry with similar facilities, equipment, and technical capability.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmentally Compliant Sprayable Low Observable Coatings that Facilitate Rapid Removal and Repair; PP-1181

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Kovar; Foster-Miller, Inc. – Waltham, MA

FY 2003 FUNDS: $832K

DESCRIPTION: Since the enactment of the 1990 Clean Air Act Amendment, the U.S. military and aerospace industry has achieved large reductions in emissions of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) from aircraft coating application and removal processes. The National Emissions Standards for Hazardous Air Pollutants (NESHAP) sets limits averaging approximately 400 g/L of VOCs for general aircraft coatings; however, specialty coatings, including radar absorbing material (RAM) coatings for low observable (LO) aircraft were exempt from the 1998 NESHAP implementation. Although many RAM coatings contain a very high level of VOCs (greater than 600 g/L), the Environmental Protection Agency (EPA) agreed to exempt LO coatings due to a lack of suitable low VOC RAM substitutes and the comparatively low volume of usage at that time. Over the next decade, the U.S. military plans to deploy several new weapons systems that utilize LO technology and to retrofit several existing systems to render them more "stealthy." As a result, the emission of VOCs from RAM coatings is expected to increase up to 2 million pounds per year.

This project will develop an innovative No-VOC Low Observable Coatings (NVLOC) system that will meet or exceed all current and projected DoD mission requirements for RAM coatings, and will effectively eliminate the generation of VOCs and HAPs in the initial application. It may be possible in subsequent work to render these No-VOC RAM coatings to be easily removed and reapplied in an environmentally benign manner. In addition this coating will permit improved, low-cost methods for spot removal and repair of these environmentally compliant LO coatings.

BENEFIT: The immediate environmental benefit will be the elimination of the disproportionate amount of VOCs and hazardous air pollutants (HAPs) generated by the application of LO coatings. Successful implementation will result in a nearly 100 percent reduction in VOC emissions generated during the spray application of RAM coatings. Potential cost savings related to the elimination of VOCs is estimated to be between $9 to $30 million annually. These No-VOC coatings may also lead to a rapid, effective HAPs-free coating removal process. Radical reductions in labor hours are expected. More environmentally friendly coating removal processes may also be feasible in the future.

ACCOMPLISHMENTS: The key enabling technology for this effort is a No-VOC, one-part polyvinyldioxolane based polyurethane (PUVD) resin. The resin contains no free diisocyanates. Foster-Miller, Inc. (FMI) evaluated and selected each of the coating system components for sprayable No-VOC RAM coatings materials. These components were then integrated, evaluated, and down selected into a functional system. Initial screening tests were completed by measuring the physical properties of the coatings and determining cure protocol. Effort was also concentrated to apply the coating layer-by-layer to build up the required thickness in the intended application. The first level of environmental testing was carried out to ascertain that the resin does not decompose into toxic materials and is stable upon storage using head space analysis. No decomposition was detected after 24 weeks of storage at ambient conditions.

TRANSITION: This environmental benign coating technology will provide a tremendous reduction in the life cycle cost as well as improved availability/mission readiness of LO aircraft with potential applications for other weapons systems.

PROJECT SUMMARY

PROJECT TITLE & ID: Electrostatic Fuel Atomization for Gas Turbines to Achieve Reductions in Particulate Emissions; PP-1184

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. David Guimond; Naval Surface Warfare Center – Philadelphia, PA

FY 2003 FUNDS: $447K

DESCRIPTION: Reducing particulate matter (PM) emissions in today's gas turbine engines is possible with implementation of electrostatic atomization technology. Benefits of implementing this technology include improved fuel consumption at low power, reduced gaseous emissions, reduced carbon fouling, and quantum reduction in fuel pump parasitic loss and cost. Fuel atomization has a first order effect on the formation of PM in virtually all combustion processes. The objective of this project is to develop and evaluate the capability of electrostatic atomization fuel injection technology to achieve reductions in particulate and gaseous emissions produced during the combustion process in gas turbine engines. The current technology consists of a dual-orifice nozzle with electrostatic injectors. CFD Research, Allison, and the Naval Surface Warfare Center Carderock Division (NSWCCD) will perform a proof-of-concept test with an Allison 501-K gas turbine engine. Charged Injection Corporation will adapt the recently patented electrostatic atomization breakthroughs to the 501-K fuel injector primary nozzle.

BENEFIT: The goal of the project is to demonstrate an 80 percent reduction in $PM_{2.5}$ with electrostatic fuel atomization technology. The baseline emissions of the engine will be compared with the emissions from the same engine after the electrostatic fuel atomization technology has been installed. In addition to emission reduction, the proposed electrostatic atomization fuel injection technology would provide a payback from improved combustion efficiency at part power operation at which ships typically operate. Navy ship propulsion gas turbine engines operate at 33 percent of full load power capacity, on average; similarly, ship service gas turbine engines operate at 50 percent of full load power capacity, on average. During typical part power operation at low to mid-range power levels, combustion efficiency is approximately 93 percent. With the electrically atomized fuel nozzle system, analysis indicates efficiencies of 98 percent. Annual savings per ship would be $120,000 (3 engines x $40,000). Thus the average savings over the fleet of 50 DDG51 ships would be $6,000,000 per year.

ACCOMPLISHMENTS: An induction technique is being used to achieve the electrostatic charging. Induction charging allows higher fuel flow rates than other charging approaches. Design and specification of the prototype electrostatic atomizer has been completed. Measurements of the limiting charging capacity for the atomizer have been made. Ambient spray testing of the electrostatic atomizer and the baseline fuel injector has been performed. Measurements of droplet size, distribution, and patternation have been made. Understanding of the electrostatic gas turbine spray combustion parameters in the 501-K gas turbine engine will be required for selection of the optimum spray patterns.

TRANSITION: At the conclusion of the project, NSWCCD will coordinate the transition of this technology to a demonstration program on a fleet ship service gas turbine generator set.

PROJECT SUMMARY

PROJECT TITLE & ID: A NIST Kinetic Data Base for PAH Reactions and Soot Particle Inception during Combustion; PP-1198

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. George Mulholland; National Institute of Standards & Technology – Gaithersburg, MD

FY 2003 FUNDS: $325K

DESCRIPTION: Polycyclic aromatic hydrocarbons (PAH) are key molecular precursors to soot formation, but there is little known about their rates of formation and evolution in a flame environment or the dynamics and structure of the transition from a large PAH molecule to an incipient soot particle. The overall objective is to develop a National Institute of Standards and Technology (NIST) chemical kinetic database and an accompanying particle formation model that will describe the transformation of fuel molecules to their desired end products of carbon dioxide and water and the undesired end products of PAH and soot. The specific processes to be considered are fuel breakdown to precursors and subsequent growth to PAH, key gas-phase PAH formation/destruction chemical reactions, and key PAH-to-particle transition steps. The database and model will contain experimental data collected in a shock tube and in a novel well-stirred reactor with flow "chopped" PAH injection. Both atmospheric and high-pressure experiments will be performed. The database will be rigorously evaluated and extended with the recently developed NIST CHEMRATE computer program. The deliverable will consist of chemistry and particle-inception models that can be used in computational fluid dynamic models of diesel and gas turbine engines.

BENEFIT: Manufacturers of military aircraft engines have a strong interest in understanding soot formation in gas turbines. The deliverable will be a publicly available NIST database and soot inception model adaptable for use in computational fluid dynamic (CFD) models of diesel and gas turbine engines.

ACCOMPLISHMENTS: Significant progress has been made on modeling heptane combustion including the production of PAHs, which are soot precursors. Heptane was chosen as a surrogate for JP-8. Heptane is representative of the alkanes that are the major chemical group making up JP-8 fuel. The oxidation reactions of heptane have been studied in the past; however, there has been little study of the cracking reactions which are important to the PAH kinetics and soot formation. Quantitative kinetic data for the product distribution for the decomposition reactions have been obtained from a combination of shock tube data and the use of the CHEMRATE software. A kinetic database for heptane combustion has been assembled and the burning velocity, ignition delay, and product concentration for radicals, acetylene, benzene, and PAHs have been computed. An important consequence of this work is the possibility of expanding the present procedures to cover larger alkanes found in JP-8. Two manuscripts have been completed regarding this topic.

Other major progress has been made is in the characterization of the chemical content and size distribution of "early" smoke. Several papers, including a 2002 Combustion Institute paper, have demonstrated the similarity of the inverse diffusion flame soot to that of the early soot of a laminar diffusion flame. The study included the first quantitative measurements of the PAH distribution in the early smoke.

TRANSITION: General Electric has agreed to monitor our progress, provide technical guidance when needed, and ensure that our efforts possess transition potential and remain relevant to the needs of aircraft engine designers.

PROJECT SUMMARY

PROJECT TITLE & ID: Computational Design of Corrosion Resistant Steels for Structural Applications in Aircraft; PP-1224

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Gregory Olson; QuesTek Innovations LLC – Evanston, IL

FY 2003 FUNDS: $159K

DESCRIPTION: In many structural applications for aerospace ultra-high strength steels are used because they can provide the lightest weight for highly loaded systems. These steels, however, lack adequate corrosion resistance and are commonly cadmium coated. The environmental problems with cadmium are intrinsic to the material itself, creating occupational safety and health (OSH) risks and raising maintenance costs throughout the life of all cadmium-plated parts. Many items that are cadmium plated, such as landing gear, are damage intolerant, and sensitive to hydrogen embrittlement and stress corrosion cracking. This sensitivity makes stress corrosion cracking the primary failure mechanism for landing gear. This often causes significant collateral damage to an aircraft, even though the failure usually takes place while it is parked. The development of an ultra-high strength stainless with corrosion resistance and strength to meet the requirements for landing gear has been the focus of traditional alloy development efforts for many years without success. The traditional empirical approach has been too costly and time consuming to be effective. A new technique, using advanced computational materials modeling and systems engineering methods, known as Materials by Design™, was used to design an innovative new prototype stainless alloy during a SERDP SEED project. This prototype, termed S53, proved to be more compelling than any previously developed stainless for this application, warranting a full SERDP project exploring this alloy.

The overall technical objectives of the project are to: (1) explore appropriate processing standards for alloy production processes, component manufacturing processes, and overhaul and repair processes to provide the information required for manufacture of components of the alloy, and (2) provide adequate test data for mechanical behavior, corrosion resistance, and embrittlement resistance and life-cycle cost to prove the ability of the alloy to replace current, cadmium-coated, aircraft structural steels using standard manufacturing techniques.

BENEFIT: The largest impact will be on the reduction of life-cycle cost and toxic waste in DoD squadrons and maintenance depots. Derivatives of the new steel will also be valuable replacements in actuators and for sustainment of legacy systems, which is the reason that the Aging Landing Gear Life Extension program (ALGLE) is assisting in the activities of this program. In addition, this program will provide a clear demonstration of the Materials by Design methodology itself, which holds the promise of much faster and less expensive development of alloys to meet the needs of higher performance, lower cost of ownership, and environmental cleanliness. Engineers will no longer have to compromise their designs to accommodate materials that are available but can determine the materials they need to meet the challenge before them.

ACCOMPLISHMENTS: The following is a list of highlights achieved in FY02: The final composition screening, designated S53-5, has been completed. The results indicate improved toughness at the Hardness Rockwell C scale 54-55 strength level over previous designs. Final selection of composition for 3,000 lb scale production was completed. Heat treatment process has been validated on 30 lb prototypes. The results have been validated against master curve models. A test protocol has been developed and will be finalized.

TRANSITION: The technical approach of the project is designed to bring the alloy to the point of demonstration/validation testing for landing gear components. Based on its alloy development and chrome plating replacement experience, QuesTek will integrate the mechanistic modeling components used to design the alloy to streamline the process optimization and test program at significant reduced cost. In order to bring the technology to the demonstration/validation stage, it is necessary to produce a steel production specification and heat treatment specification to define the alloy, a steel properties performance database to support the technical case for the new steel, and detailed cost data to support the business case. The Air Force program manager for landing gear has committed to conduct a dem/val project to develop data required to make an implementation decision for the use of this material on Air Force landing gears.

PROJECT SUMMARY

PROJECT TITLE & ID: Green Medium Caliber Munitions; PP-1237

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Roman Fednya; U.S. Army Armament Research, Development, and Engineering Center – Picatinny Arsenal, NJ

FY 2003 FUNDS: $120K

DESCRIPTION: In an effort to address medium caliber ammunition environmental problems in a systematic manner, SERDP recommended that an umbrella program approach be utilized. In response, the US Army solicited the medium caliber ammunition technical community for membership on the Technical Advisory Committee (TAC) to better focus on the large number of diverse environmental issues. The TAC was formed in February 2001 and held a kickoff meeting on 28 March 2001 at TACOM-ARDEC, Picatinny Arsenal, NJ. Key agenda topics included SERDP program guidelines and identification of environmental problems by the using services and major contractors. Representatives from academia also presented research activities supporting DoD. A green priority matrix identifying specific contaminants and quantities was addressed. The quantification of specific pollutants in the area of lead and toxic materials led to the development of this priority matrix based on the projected future multi-service medium caliber ammunition production acquisitions. The matrix assigned a high, medium, or low priority for the various contaminants and calibers involved.

BENEFIT: The TAC's highest priority is the elimination or replacement of lead and toxic heavy metals. The TAC also provides specialized expertise that can more effectively prioritize environmental needs and timelines to develop Statements of Need (SONs). The nine focus areas include ignition systems, miniature detonators, miniature fuze electronics, propellants, tracers/incendiaries, detonators, paints, sealants/ adhesives, and metal parts.

ACCOMPLISHMENTS: FY02 and FY03 SONs were developed and issued for the purpose of soliciting research proposals for ignition systems, electric and stab detonators, chemical batteries, and propellants. An FY04 SON addressing heavy metals in incendiary materials was issued in November 2002. Four proposals were approved for funding in FY02. Funds have been issued, contracts awarded and activities initiated to support detonator and primer research. The FY03 program has also been approved. Funds are pending to support research efforts for stab detonators, propellants, and internal power supplies.

TRANSITION: The TAC is scheduled to prioritize environmental needs and develop SONs in nine medium caliber ammunition focus areas through FY08.

PROJECT SUMMARY

PROJECT TITLE & ID: Twin Screw Extruder Production of MTTP Decoy Flares - Pollution Prevention through Solvent Elimination; PP-1240

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Carol Campbell; Thiokol Propulsion – Brigham, Utah

FY 2003 FUNDS: $158K

DESCRIPTION: Magnesium, Teflon, and Viton or Hytemp (MTV or MTH) aircraft decoy flares continue to be important countermeasures to protect military helicopters and fixed-wing aircraft against heat-seeking missiles. Environmental and safety concerns are major drawbacks to the current processing technology for manufacturing these compositions. The current processes are batch processes that require transfers of large quantities of highly flammable solvents from one container to another. The solvents, acetone (VOC) and hexane (HAP), vaporize into the atmosphere where they pose both environmental and safety hazards. Numerous events involving personnel injury and death have occurred. Risks of accidental ignitions are high, but eliminating these risks has been shown to be both difficult and expensive. In addition, open burning of scrap and demilitarization of items also present an environmental pollution problem.

Decoy flares produced by a twin-screw extrusion process do not require the use of HAPs or VOCs during manufacture. A continuous twin-screw extruder (TSE) will be used to mix/extrude magnesium, Teflon, and polystyrene or ethylene-vinyl acetate thermoplastic binder (MTTP) into a decoy flare composition. The new material must meet or exceed current MTV or MTH countermeasure product performance specifications. Computer modeling, torque rheometry, and capillary rheometry will be used to establish the optimal extrusion formulation and process parameters. Strict process safety measures will be taken throughout the entire program to ensure the safe operation of this research and development effort.

BENEFIT: The proposed process will significantly reduce the air pollution, personnel health hazards, potential loss of life through solvent fires, and hazardous wastes associated with MTV or MTH countermeasure production. Cost savings would be realized by eliminating hexane and acetone from the manufacturing process. A preliminary cost analysis shows that 3.4 million dollars could be saved in countermeasure production over the next five years by eliminating these solvents. An additional cost savings would result from the improved process yield using the new technology.

ACCOMPLISHMENTS: Ingredients have been approved for evaluation. The rheological work in the torque and capillary rheometers has been closely linked to the work that has been progressing in the 19-mm twin-screw extruder. Both have been used as screening tools for processable materials in the extruder and have been proven to be effective. A pre-blend formulation has also shown great promise in the extruder and supporting equipment and will be evaluated for further processing.

TRANSITION PLAN: The developed decoy flare formulation and process will be transitioned to the demonstration and validation phase based on the fully configured Army, Navy, and Air Force decoy flares. A pilot lot will be manufactured for this effort in accordance with the Army, Navy, and Air Force military specifications. This program focuses on corporation and open technology transfer between government and industry. Objective of this effort is to develop an environmentally acceptable aircraft decoy flare formulation.

PROJECT SUMMARY

PROJECT TITLE & ID: Low Temperature Powder Coating; PP-1268

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Glen Merefeld; General Electric Corporate Research and Development – Schenectady, NY

FY 2003 FUNDS: $325K

DESCRIPTION: The Department of Defense (DoD) currently spends millions of dollars each year in procuring, using, and disposing of toxic and hazardous materials associated with solvent-bourne coatings for corrosion protection of fixed and mobile systems. The use of powder coatings eliminates more than 95 percent of the toxic and hazardous materials associated with the application of corrosion protection coatings. This SERDP project will provide a pollution-prevention-based solution to the continuing decline of the environment caused by solvent-based paint manufacturing processes as well as the elimination of chromate based primer systems.

In a 24-month project, a team comprised of DoD (NavAir and U.S. Air Force), DOE (Kansas City Plant), and large and small private industries (GE Corporate Research and Development and Crosslink Powder Coatings, Inc.) will identify and develop mission-critical powder coating resins that will eliminate volatile organic compounds, chromates and hazardous waste. Specifically, resins that are low-temperature curable (greater than 230F), durable, corrosion inhibiting, and weather resistant will be developed. The new materials and processes will significantly reduce volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) when applied to the temperature-sensitive weapons system components. A full system approach consisting of three tasks will be employed in this program, as follows: (1) formulate novel materials, (2) develop powder coating materials, and (3) develop field repair techniques.

BENEFIT: Development of a new low-cure-temperature powder coating technology will improve the manufacturability, use, and repair of temperature-sensitive, coating-protected weapons, aircraft, and auxiliary equipment. Additionally, the elimination of toxic chemicals, VOCs, and the reduction of hazardous wastes will minimize risks to human health and the environment, while also delivering considerable cost savings by avoiding fines for non-compliance to federal, state, and local mandates. In addition, a typical powder costing resin has the potential to reduce labor and material costs by a factor of 10 or more, while total wastes and VOCs can be reduced by a factor of 100 or more.

ACCOMPLISHMENTS: There are no accomplishments due to issues which forced the project to start late into 2002.

TRANSITION: At the end of this project, one or more powder systems will be ready for demonstration and validation on full-size weapon systems and aircraft support structures by military partners.

PROJECT SUMMARY

PROJECT TITLE & ID: Reduction of Solid Waste Associated with Military Rations and Packaging; PP-1270

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jo Ann Ratto; U.S. Army Natick Soldier Center – Natick, MA

FY 2003 FUNDS: $126K

DESCRIPTION: The nanocomposite packaging effort addresses the environmental need for solid waste reduction for military rations. The current packaging uses high barrier multi-layered materials containing a foil barrier to isolate the contents from oxygen and undesirable moisture. This barrier creates waste that is difficult to recycle or biodegrade. The objective of this project is to research and develop a cost effective, environmentally friendly, nanocomposite packaging material that will reduce the amount of solid waste associated with current and future military rations and packaging. The project will produce a novel nanocomposite packaging material that ultimately will eliminate military solid waste due to its recyclability and biodegradability. One promising class of nanoscale materials being investigated is that made from monmorillonite clays intercalated with organic polymers. Montmorillonites are silicate materials arranged in thin sheet-like layers. The ability to intercalate organic polymers in between the layers of the clay is what imparts the unique properties to the composites. Montmorillonite has been shown to reinforce plastics, increase barrier properties, improve dimensional stability, increase heat distortion temperature, and increase flame retardancy.

BENEFIT: If the nanocomposite packaging substitute is successful there will be a reduction in the plastic waste used for the current meal ready-to-eat (MRE). The current materials will be replaced with recyclable or biodegradable nanocomposites with improved properties and potential to reduce the cost of the military packaging.

ACCOMPLISHMENTS: Polylactic acid (PLA) and a variety montmorillonite clays (4 differently organically modified clays at 5 percent loading) were extruded by a miniextruder at a variety of temperatures and two screw speeds. The samples were analyzed by X-ray diffraction to determine the polymer/clay interaction and degree of exfoliation. Based on the X-ray results, there was one clay that showed more exfoliation than the others; therefore, this montmorillonite clay was chosen to use for the remainder of the PLA nano-composite study. The PLA and clay were compounded using a ThermPrism, twin-screw extruder. A plasticizer (biodegradable citrate ester) was also used in the formulation to reduce the brittleness of the pure PLA. Films were made using the blown film die on the same extruder. These films were analyzed by thermogravimetric analysis, differential scanning calorimetry, gel permeation chromatography (GPC), and mechanical and barrier properties. The results are promising and show a thermal stability increase of 20 degrees from the homopolymer, and a 70 percent increase in Young's modulus and 160 percent improvement for water barrier. Films are still being characterized for their ability.

TRANSITION PLAN: Material manufacturers will be consulted and involved in scaling up barrier film manufacturing from laboratory-size to industrial-size equipment. Natick technical teams, procurement agencies and industrial partners will participate in the down selection of materials, based on cost and producibility factors. New performance specifications for the incorporation of these advanced packaging materials into processed rations will be completed.

PROGRAM SUMMARY

PROJECT TITLE & ID: Low-Cost and High-Impact Environmental Solutions for Military Composite Structures; PP-1271

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Sands; U.S. Army Research Laboratory – Aberdeen Proving Grounds, MD

FY 2003 FUNDS: $570K

DESCRIPTION: Resin systems for liquid molding (LM) applications are being implemented with increasing frequency into designed structures for military composite platforms. The use of low-cost resins for LM, however, has a deleterious side effect. The viscosity reducing agent, typically styrene monomer, is a hazardous volatile organic compound that is freely emitted into the environment during mixing, processing, curing, and fielding of the composite structures. The key objective of this program is to formulate low-cost composite resin systems suitable for LM of composite components, including vinyl ester based composites. The project seeks to reformulate resin compositions used in LM fabrication to decrease volatile organic compound (VOC) concentrations, resulting in reduced emissions throughout the composite life-cycle.

The technology being developed includes three approaches to mitigating VOC emissions by modifying existing baseline vinyl ester resin formulations. First, we seek to minimize emissions by decreasing the overall VOC concentrations in the resin blend. Second, we attempt to bind the VOCs into the matrix by increasing the reactivity at the composite interfaces, both surface and fiber interfaces. This last approach will involve substantial changes in the chemistry of the vinyl ester (VE) resins, which will require investigations into the reactivity relationships between the functional monomers in a multifunctional resin blend. A final push to reduce VOCs may incorporate combinations of the above technology approaches.

BENEFIT: The benefit of this project is to reduce VOC emissions across a broad range of composite applications for military platforms. A key to this program will be keeping costs of new resin formulations at reasonable levels to make the new alternatives competitive with current market resins, such as vinyl ester and polyester-based composites.

ACCOMPLISHMENTS: A macro-thermogravometric analyzer (macro-TGA) was developed to measure the styrene emissions from vinyl ester resins because the results from more conventional techniques, such as micro-TGA, had low reproducibility due to the small masses involved. Characterization techniques, including fourier transform infrared spectroscopy and high-performance liquid chromatography, show that VE monomers with narrow molecular weight distributions and bimodal blends of these monomers have been successfully prepared. Emissions studies from these and commercial VE resins display a characteristic elbow where the initial emission rate of styrene suddenly drops to a much lower emission rate. Of the petroleum-based comonomers studied for styrene replacements, cyclohexyl methacrylate has shown to be the most successful because its VE resins have low vapor pressure, good thermo-mechanical properties, and acceptable viscosities. A number of synthetic procedures have been developed to produce fatty acid-based monomers. These monomers are inexpensive, have very low volatilities, and improve global sustainability. Results have shown that fatty acid monomers can be blended with styrene to reduce the styrene content in VE resins while maintaining good thermo-mechanical and rheological properties.

TRANSITION PLAN: The resin formulations can be transitioned using key market players in the composites resin industry. The small resin manufacturers currently interested in supplying these technologies include UCB Radcure and Applied Poleramic, Inc. Our close relationships with these companies allow us to successfully develop materials for direct transition into military platforms.

PROGRAM SUMMARY

PROJECT TITLE & ID: Enhanced Electromagnetic Tagging for Embedded Tracking of Munitions and Ordnance during Future Remediation Efforts; PP-1272

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Keith Shubert; Battelle Memorial Institute – Columbus, OH

FY 2003 FUNDS: $30K

DESCRIPTION: Significant advances in the detection of unexploded ordinances (UXO) must be pursued and implemented to enable the DoD to conduct safe and environmentally-benign training missions. Battelle Memorial Institute has proposed embedding radio frequency (RF) tags on ordnance items to aid in locating UXO in the ground. The tag must be secured to the candidate ordnance item and be capable of surviving the delivery system. The tag must also survive ground impact and terrain penetration, as is the case with nonfunctioning (i.e., unexploded) ordnance items. The buried tag will be required to respond to and then signal the tag interrogation module when the detection system is brought nearby. The overall objective of this project is to: (1) advance current RF tag capability to survive the operating conditions associated with munitions; (2) provide information on the munitions location; and (3) create technology compatible with operational and tactical deployment. The approach for this study is to determine reasonable operating objectives for current RF tag technology or other innovative tagging devises and evaluate tag technology against known constraints or newly established and prioritized operational criteria. Several candidate Tag/Interrogator systems will be systematically explored and tested and a recommendation will be made to the Government at the end of the contract.

BENEFIT: The immediate benefit of the successful execution of this project will be the demonstration of the proof-of-principle of successful detection and location of unexploded ordnance and munition items that have pre-embedded RF tags. The additional required materials and processes will be shown to be comparatively inexpensive. The resulting long-term benefit will significantly decreased costs of range remediation because of the much higher probability of detecting unexploded ordnance with many fewer false alarms.

ACCOMPLISHMENTS: There are no accomplishments due to contracting issues that forced the project to start late in 2002.

TRANSITION PLAN: From the beginning of the project, every effort will be made to ensure that the results and findings of this effort are evaluated in the constraints of eventual DoD implementation. The project team includes key individuals from Navy, Army, and Air Force with munitions and ordnance management responsibilities. The project will also be focused on the next step in the development process that will be the implementation of a demonstration system that will allow more realistic evaluation by the DoD munitions and ordnance community and the appropriate environmental agencies.

PROGRAM SUMMARY

PROJECT TITLE & ID: Multispectral Munitions Locating System; PP-1273 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Al Quintana; Naval Air Warfare Center Weapons Division – China Lake, CA

FY 2002 COMPLETED PROJECT

DESCRIPTION: The ability to accurately identify and locate munitions and impact areas has become a major concern on military land ranges due to the environmental and safety concerns. The optical augmentation concept used for the multispectral locating system comes directly from comments by Explosive Ordnance Disposal (EOD) personnel responsible for clearing test ranges after operations. The concept uses a simple retro reflective material applied to the munition which makes it easy to locate when properly illuminated and viewed with a matched detector. This will make the munition very conspicuous even when partially obscured.

The objective of this effort was to develop optical augmentation that can be used to reliably locate unexploded munitions on the surface of a land test range. The technology will also be able to (1) identify optimum sensors for the task, (2) demonstrate optical augmentation, and (3) evaluate whether the concepts can be effective in reducing the effort and cost of removing UXO.

BENEFIT: The system will facilitate the timely removal of hazardous UXO material so that range personnel can enter and reuse an area safely. Long term safety hazards are reduced by reducing the amount of UXO in a test range not accounted for. There is also the need to remove hazardous UXO to prevent the materials long term potential to enter the ecosystem. Pollution prevention is served by removing munitions that may over time leach out hazardous material.

ACCOMPLISHMENTS: Optical system analysis revealed that, even after augmenting BLU-97 munitions with microprismatic retroreflective material, the resulting camera contrast ratio was inadequate to reliably identify the target. Alternative approaches are currently being investigated with and without retroflective material.

TRANSITION PLAN: This effort is proposed as a concept demonstration effort. Field tests performed with the optical augmentation prototypes will demonstrate the observable contrast of BLU-97 facsimiles in a desert environment. If the field tests and evaluations by EOD personnel indicate that the scheme is desirable, further development of an optical augmentation scheme will be warranted. Based on favorable results and comments from these teams we will solicit a SERDP development task to refine the concepts and move them forward for further development and utilization on test ranges.

PROGRAM SUMMARY

PROJECT TITLE & ID: Non-Leaching, Benign, Fouling Control, Multilayer Polymer Coatings for Marine Applications; PP-1274 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Christopher Ober; Cornell University – Ithaca, NY

FY 2002 COMPLETED PROJECT

DESCRIPTION: Several commercial fouling release (FR) coating systems are on the market. All are based on silicone technology, yet none meet all of the desired performance characteristics. Many lack the toughness required to stand up to the rigorous physical demands of the marine environment, do not sufficiently and consistently self-clean, and due to polymer re-structuring or other degradation pathways, lose many of the desirable surface properties with time and exposure to the marine environment. The objective of the project was to develop non-toxic, copper-free, environmentally benign antifouling polymer coatings produced by blending styrene-ethylene/butylene-styrene (SEBS) thermoplastic elastomers with surface-active block copolymers (SABC). The project intended to demonstrate the proof-of-principle of these multilayer systems and, with understanding of the key problems involved, develop improved systems for fouling release that mitigate the use of toxic organocopper antifoulants. This was accomplished by determining whether polar or non-polar SABC offer the best materials for non-fouling coatings and optimizing these materials, and designing and synthesizing large enough quantities of optimized SABC to provide samples for long-term testing.

BENEFIT: The new copper free coating will be designed to exceed the current performance of fouling release silicone coatings and eliminate the use of toxic organocopper antifoulants.

ACCOMPLISHMENTS: This project successfully synthesized a semi-fluorinated material with the optimal semi-fluorinated side chain. A total-spray coating solution was developed to control thickness of both SEBS primer and SABC top-coat. The total-spray solution increased ease of use and will further improve adhesion.

TRANSITION PLAN: A final report will be issued which provides an objective assessment of the viability of using the copper free fouling release coating system created in this project. Once the goal for establishing the success of the strategies for a non-fouling coating in a marine environment as outlined in the proposal is achieved, testing in natural and simulated conditions is envisioned.

PROGRAM SUMMARY

PROJECT TITLE & ID: Environmentally Acceptable Alternatives for Non Destructive Inspection with Fluorescent Penetrant Dyes; PP-1275 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Bradley Grunden; METSS Corporation – Westerville, OH

FY 2002 COMPLETED PROJECT

DESCRIPTION: The Department of Defense (DoD) currently uses synthetic and petroleum based oils as carrier fluids for fluorescent dye penetrants (FDP) used during the nondestructive inspection (NDI) of metal parts (during manufacture and in-service). Current DoD handling and disposal costs associated with these processes are estimated to be approximately $4 million per year. The primary objective of this project was to develop and transition environmentally acceptable fluorescent dye penetrants for use in existing NDI techniques and reduce the time required to perform NDI via FDP techniques.

Based upon the critical performance parameters of existing FDP materials, METSS Corporation formulated a series of alternative carrier fluids and cleaners for FDP materials and constructed a design matrix from which the viability of these FDP replacement formulations can be evaluated with respect to performance, environmental impact, and cost. The general physical and chemical requirements of the candidate materials will drive the initial materials selection efforts.

BENEFIT: The products developed under this project will not only be non-toxic, safe to use, and environmentally friendly, but will also be cost effective. By emphasizing the development of direct replacement fluid technologies, METSS efforts will have a significant and immediate impact on the reduction of waste streams generated by existing FDP techniques, while at the same time making it possible to use existing systems in a manner that is safer to personnel and the environment

ACCOMPLISHMENTS: Formulations were reviewed to determine those with the most significant environmental impact and to target these for initial formulation efforts. The post-emulsifiable products contain little to no surfactant and were removed after application by a surfactant based cleaner. These products contain a surfactant system to allow them to be removed with water alone. Initial formulation and screening efforts were completed for a post-emulsifiable (PE) fluorescent penetrant dye by preparing blends containing the same level of fluorescent dye and optical brightener used in the current level 4 (most sensitive) FPD.

TRANSITION PLAN: Magnaflux's support of the proposed efforts will ensure the products developed are viable replacement materials for FDP via NDI techniques by providing industry specific expertise and by supporting meaningful and practical evaluation of the candidate replacement fluids. Magnaflux will also provide a commercialization vehicle for the technologies developed under the proposed program, thereby ensuring technology transition and commercial availability.

PROGRAM SUMMARY

PROJECT TITLE & ID: Safe and Environmentally-Acceptable Sol-Gel-Derived Pyrophoric Pyrotechnics; PP-1276

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Randy Simpson; Lawrence Livermore National Laboratory – Livermore, CA

FY 2002 COMPLETED PROJECT

DESCRIPTION: The current manufacturing process and materials used to make pyrophoric decoys introduces a considerably toxic component to the waste stream. The "sol-gel" methodology intends to produce nano-structured energetic materials (i.e., pyrotechnics) while minimizing or eliminating the health and environmental hazards associated with their current fabrication. This sol-gel approach for preparing pyrotechnic formulations involves a fundamental change in the conventional manufacturing and fabrication processes of energetic materials. It is believed that low temperature reduction of high surface area porous sol-gel-derived iron(III)oxide with molecular hydrogen will result in the formation of porous pyrophoric iron metal that is suitable for use in pyrophoric decoy flares.

BENEFIT: Implementing sol-gel-derived pyrotechnics will eliminate the toxic waste streams and worker safety hazards caused by the fabrication and use of current decoy flares.

ACCOMPLISHMENTS: The project employed sol-gel methods to generate high surface area, porous iron(III) oxide-based solids. The result is the production of a very fine-grained, porous iron powder that does not ignite spontaneously upon contact with air. The general observation is that, when the temperature of reduction is low enough to reduce the materials and still retain their pseudo-skeletal iron(III)oxide framework, they can be initiated with a point heat source and propagate a burn throughout the material. This project is in the process of completing their testing and writing their final report.

TRANSITION PLAN: The Naval Surface Warfare Center, Crane, IN, will test and evaluate the materials and will provide the guidance for product development. They will also provide an interface with the production facilities that would ultimately manufacture the sol-gel. The focus of this work will be on pyrotechnic needs for existing and anticipated infrared countermeasures.

PROGRAM SUMMARY

PROJECT TITLE & ID: Control of Biofouling Using Biodegradable Natural Products; PP-1277 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kathleen Fallis; Naval Air Warfare Center Weapons Division – China Lake, CA

FY 2002 COMPLETED PROJECT

DESCRIPTION: Biological fouling of seawater piping and heat exchange equipment impacts nearly all oceangoing vessels, both commercial and military, resulting in poor performance and excessive maintenance costs. The current approach used by the U.S. Navy for the control of biofouling is well above Clean Water Act and Uniform National Discharge Standards. In order to comply with these requirements, and those that may be imposed in the future, it has become necessary to look to alternative methods for the prevention or control of biofouling. The objective of this research was to investigate the use of biodegradable, naturally occurring substances as additives to eliminate or inhibit the biological growth present in shipboard heat exchange equipment. Three candidate plant extracts were examined for their effectiveness in preventing biofouling of designated metallic materials in seawater systems. The testing of these additives for use in shipboard heat exchange systems was performed, taking into account the many variables. Testing will be undertaken to evaluate biocidal performance under a wide range of conditions in order to obtain realistic results.

BENEFIT: The results from testing will indicate the potential for the use of plant extracts as biofouling inhibitors. Substantial cost savings may be realized from the reduced manpower required to maintain shipboard heat exchange and plumbing systems. Performance of these systems will also be positively impacted if biofouling is minimized. In addition, significant environmental impacts may be realized if these substances prove to be suitable as replacements for chlorination.

ACCOMPLISHMENTS: More than 30 different compounds were tested for rapid toxicity to Pseudomonas Aeruginosa and/or Klebsiella Pneumoniae using a respiration-based toxicity test. Those compounds demonstrating high levels of toxicity were examined to determine minimum effective concentration levels. The most promising compound was used in a long term study to evaluate possible corrosive effects on stainless steel.

TRANSITION PLAN: Based on a successful laboratory/field test regimen, the results of this study will be evaluated, and if the concept deemed feasible for further development, a proposal dealing with such will be submitted to SERDP for additional funding.

PROGRAM SUMMARY

PROJECT TITLE & ID: Pulsed Acoustic Sparker Bio-Fouling Control in Heat Transfer Equipment; PP-1279 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Raymond Schaefer; Phoenix Science & Technology, Inc. – North Chelmsford, MA

FY 2002 COMPLETED PROJECT

DESCRIPTION: Biological fouling is a problem in U.S. Navy ships and submarines (heat exchangers, condensers and seawater piping systems) and for the U.S. Army Corps of Engineers (dams, locks, and hydroelectric plants). Biofouling adversely effects system performance by decreasing heat transfer and blocking the flow of water. Chlorination is an effective antibiofouler, but has negative environmental impacts and does not meet federal and state regulations. The project technical objective was to demonstrate the feasibility of using pressure pulses from sparker acoustic sources to replace chlorine as the major means for controlling biofouling. The proposed concept was to use short high peaked pressure pulses generated by a sparker acoustic source to prevent biological fouling inside of pipes of heat exchanger equipment. The sparker is controlled remotely powered through cables and does not touch the pipe, so that it can be used with any pipe material.

BENEFIT: A successful project will show feasibility of a sparker biocontrol concept by demonstrating microfouling control of slime in a single pipe representing a typical pipe in a heat exchanger. The results will provide the basis for further development in which the sparker will be used to control biofouling of practical heat exchangers and heat transfer equipment in general.

ACCOMPLISHMENTS: Two different sparker implementations, one in a wet well and another in-line, along with three control pipes, were operated in our laboratory in the same configuration as planned for the field test. The system operated well and was shipped to the Navy Corrosion Facility for the field test. The field test was inconclusive.

TRANSITION PLAN: Based on a successful laboratory/field test regimen, the results of this study will be evaluated, and if the concept is deemed feasible for further development, a proposal dealing with such will be submitted to SERDP for additional funding.

PROGRAM SUMMARY

PROJECT TITLE & ID: Elimination of Chlorine Containing Oxidizers from Pyrotechnic Flare Compositions; PP-1280

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Caroline Wilharm; Naval Surface Warfare Center – Crane Division, IN

FY 2003 FUNDS: $230K

DESCRIPTION: This research effort will identify feasible approaches for reformulating a variety of pyrotechnic compositions to reduce or eliminate toxic reactants. Current flare compositions use inorganic perchlorate compounds that react to form highly objectionable hydrogen chloride (HCl) as a combustion product. The objective of this research is to formulate and test improved pyrotechnic compositions, which contain high-energy metallic fuels and alloys and non-chlorine-containing inorganic oxidizers, instead of the currently used chlorine-containing oxidizers. Because the replacement nitrate or oxide oxidizers are less reactive than those that contain chlorine, high-energy fuels will be used to make up for the loss in energy. These high-energy fuels will be using Mechanical Alloying (MA) technology. This novel approach permits the creation of fuel particles which combust to generate metal oxides, ultrafine reactive metal droplets, and the hot combustion gases needed to disperse them. Compositions meeting acceptance criteria will be scaled up to prototype scale, and performance tested under static conditions, as well as under simulated flight conditions.

BENEFIT: The new compositions will produce equal or superior emission intensities in the visible and/or infrared regions, as appropriate to the pyrotechnic application. They will also eliminate or reduce the quantity of HCl generated, reducing the burden of HCl pollutants on the environment.

ACCOMPLISHMENTS: Ignition sensitivity data was obtained for three pyrotechnic mixes containing nitrate oxidizers and for a sample of Mechanical Alloy (MA) received from the New Jersey Institute of Technology (NJIT) during the previous quarter. The electrostatic, impact, and friction ignition sensitivities of the pyrotechnic samples were comparable to those of other pyrotechnic mixtures routinely handled at Crane. The electrostatic and impact sensitivities of the NJIT material were somewhat higher than for the magnesium commonly used in compositions at Crane. However, these materials may be safely handled with appropriate precautions.

Several series of compositions were prepared for testing. These series of tests focused on achieving a formulation for a spectrally balanced flare using potassium nitrate as an oxidizer, glycidyl azide polymer (GAP) as a binder, and boron with various other “additives” as fuels. The additives investigated in these series of tests include Electro-exploded Aluminum (Alex), Alex pre-coated with Viton, Aluminum Nanocomposite (ALNC), and commercially available 200 mesh magnalium. Compositions containing the potassium perchlorate as an oxidizer, with no additives, were also prepared as a baseline for data comparison. In addition, one composition with mechanical alloys was prepared and tested.

TRANSITION PLAN: Potential sponsors for the transition of this project include Naval Air Systems Command (PMA-272), Office of Naval Research, Joint Technical Coordinating Group on Aircraft Survivability/AS, and Army and/or Air Force Mixed Expendables follow-on projects, all of whom are interested in improving spectrally balanced flares. Also, the Naval Sea Systems Command, who is funding a related project to design and test environmentally acceptable colored signal compositions, and ESTCP are potential sponsors.

PROGRAM SUMMARY

PROJECT TITLE & ID: Lead Free Initiator Materials for Small Electro-Explosive Devices for Medium Caliber Ammunitions; PP-1306 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. R. W. Millar; QinetiQ Inc. – Kent, United Kingdom

FY 2002 COMPLETED PROJECT

DESCRIPTION: A current aim in the science for initiators for explosive devices is the elimination of lead and other toxic heavy metals from the compositions required for these devices. The Department of Defense (DoD) recognizes that heavy metal contaminants are a critical environmental problem and has committed to reduce its use of lead (Pb) in medium caliber munitions. This project focused on synthesizing and characterizing up to eight replacement compounds for lead azide and lead styphnate. These new initiatory type compounds cannot contain lead or other heavy metals known to be toxic or posses carcinogenic materials in their manufacture. The compounds proposed for examination fall into three categories - inorganics, light metal derivatives of organics (salts & Meisenheimer complexes), and metal-free organic compounds.

BENEFIT: The primary outcome of this research will be initiatory compounds that do not release toxic heavy metals (particularly lead) when they function in a munition or civilian blast application. The major benefits of substituting such compounds in electro-explosive devices for medium caliber munitions include: (1) reduced health risks to workers during production processes; (2) reduced environmental risks during the production process; (3) reduced health and environmental risks to operational users; and (4) cost avoidance through reduced clean-up at both manufacturing and operational sites.

ACCOMPLISHMENTS: This is an FY 2002 late New Start.

TRANSITION PLAN: QinetiQ will select a successful candidate for a second phase of the project that will involve collaboration with a device manufacturer in the U.S. or Canada to establish the functional capabilities of the respective compounds. A synthesis scale-up capability will form an integral part of this phase that ultimately will lead to fully qualified heavy metal-free initiatory devices for DoD.

PROGRAM SUMMARY

PROJECT TITLE & ID: Investigation of Alternative Energetic Compositions for Small Electro-Explosive Devices for Medium Caliber Ammunition; PP-1307 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. John Hirlinger; U.S. Army Armament Research, Development, and Engineering Center – Picatinny Arsenal, NJ

FY 2002 COMPLETED PROJECT

DESCRIPTION: A basic component required for the efficient and effective functioning of medium caliber rounds is the detonator, the electrochemical device that initiates the explosive event. The current standard device being used in these designs is the M100 detonator that consists of separate initiating, transition, and output charges. The M100 currently performs the detonator function well, but the initiating and transition charges are hazardous, heavy metal compounds. The objective of this effort is to evaluate and test DAHA (1,1-diamino-3, 3-5,5,7,7-hexaazidocyclotetraphospazene), a material recently synthesized as a new primary explosive to be used in small electro-explosive devices for this application. This novel compound has the impact, friction, and electrostatic properties of a strong primary explosive. Preliminary tests on DAHA have shown practical application in small arms ammunition, but is untested in medium caliber munitions.

BENEFIT: The development of environmentally friendly detonators will reduce or eliminate range contamination, mitigate the long-term exposure effects on plant, wildlife, and water systems, and drastically curtail the use of toxic materials at the various 20mm-60mm manufacturing facilities. It will also result in reduced exposure of both user and production personnel to harmful levels of contaminants and combustion products that occur in the material handling during production, test, and operational use of medium caliber detonators.

ACCOMPLISHMENTS: This is an FY 2002 late New Start.

TRANSITION PLAN: More extensive testing will be required as a follow-on project to fully demonstrate that the new detonator satisfies all requirements at the required environmental conditions.

PROGRAM SUMMARY

PROJECT TITLE & ID: Environmentally Acceptable Medium Caliber Ammunition Percussion Primers; PP-1308

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Michael Ellis; U.S. Army Armament Research, Development, and Engineering Center – Picatinny Arsenal, NJ

FY 2003 FUNDS: $243K

DESCRIPTION: Percussion primers are used to ignite the propelling charge in medium caliber cartridges. In order to achieve the required reliability, extremely sensitive primary explosive compositions are selected as the initiating materials. Medium caliber percussion primers typically consist of lead azide, lead syphanate, and NOL130 (Naval Ordinance Lab) as well as barium nitrate and antimony sulfide. Although highly effective, these heavy metal compounds have been identified as hazardous, toxic materials and should be replaced. The objective of this effort is to identify, characterize, evaluate, and test environmentally benign candidate materials as potential replacements for the hazardous lead, antimony, and barium compounds in medium caliber ammunition percussion primers. This effort will enhance a new class of non-toxic energetic materials called Metastable Intermolecular Composites (MIC) originally developed by the Los Alamos National Laboratory (LANL) for this application. LANL and TACOM-ARDEC will analyze and characterize the basic structure of MIC materials to fully understand the material properties and behavior. The program will investigate the controlling reaction propagation mechanism of MIC via laboratory experimentation and analyses at LANL. Simultaneously, efforts will be made to enhance the output and stability of the basic MIC formulation with energetic additives and material coatings to make it suitable for the strenuous medium caliber ammunition environment.

BENEFIT: The development of environmentally friendly primers will reduce or eliminate range contamination, mitigate the long-term exposure effects on plant, wildlife, and water systems, and drastically curtail the use of toxic materials at the various medium caliber manufacturing facilities. Economic benefits include reduced ammunition, training and production site cleanup costs.

ACCOMPLISHMENTS: This is an FY 2002 late New Start.

TRANSITION PLAN: Upon successful completion of this phase of the project, more extensive fabrication, loading, and testing will be required to qualify the green primers for medium caliber application. If successful, the candidate material(s) will be incorporated into the Technical Data Package by Engineering Change Proposal action for use by the Tri-services.

PROGRAM SUMMARY

PROJECT TITLE & ID: Medium Caliber Lead Free Electric Primer (LFEP) Program; PP-1331

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Ron Jones; Naval Air Warfare Center – China Lake, CA

FY 2003 FUNDS: $590K (follow-on of SEED project PP-1183)

DESCRIPTION: The Lead Free Electrical Primer (LFEP) program is designed to eliminate the use of heavy metals in the production of electric primers used in military medium caliber ammunition. Beyond the environmental contamination that occurs during the manufacture of the lead styphnate and its use in the production of lead containing primers, lead styphnate is known to produce hazardous by-products when the primer is fired. These hazardous by-products are initially airborne and are capable of polluting the surrounding ground, aquifers, and facilities.

The objective of this program is to develop a reliable and effective electrically initiated medium caliber ammunition primer that does not contain harmful constituents. The follow-on full SERDP Program effort consists of three phases. The first phase will be focused on research into candidate metastable interstitial constituents (MIC) materials and their properties, as well as the advantages/disadvantages of the two candidate primer design concepts. The first phase of the program will also include a down select between the two alternate primer configurations. The second phase of the program will be focused on the integration and test of these MIC materials in the selected primer configuration. The third and final phase of the effort will be focused on a thorough evaluation of the selected primer design in the intended application and will involve the fabrication and subsequent test firing of all-up rounds of ammunition to determine their ballistic performance (chamber pressure, muzzle velocity, and action time) in a broad range of environmental conditions.

BENEFIT: Major benefits derived through the substitution of MIC materials in medium caliber ammunition primers include: (1) reduced health and environmental risks to factory workers during primer mix manufacture and ammunition production processes; (2) reduced risk to operational users who may be confined in spaces contaminated by residual weapons system gases containing lead; and (3) cost savings from the avoidance of cleanup processes at manufacturing and operational locations.

ACCOMPLISHMENTS: This is an FY 2002 late New Start.

TRANSITION PLAN: Following successful development and demonstration of a medium caliber LFEP, the Navy, and the Army, will pursue the follow-on development, qualification, and production of environmentally favorable primers for military ammunition applications. These follow-on efforts could include the implementation of an ESTCP or a development program, depending on the maturity of the LFEP concept at the end of the subject program.

PROGRAM SUMMARY

PROJECT TITLE & ID: Chromium-Free Coating System for DoD Applications; PP-1341

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Wim Van Ooij; University of Cincinnati – Cincinnati, OH

FY 2003 FUNDS: $347K

DESCRIPTION: The current corrosion control strategy in the Department of Defense (DoD) relies on hexavalent chromium to protect the 2024 and 7075 series aluminum substrates of its legacy aircraft. Hexavalent chromium is a known human carcinogen that is strictly regulated. New coating technologies are required to preserve existing assets against corrosion losses and to minimize the potential for negative environmental impacts. The proposed effort will develop an integrated organosilane coating system for metal alloy structural components in DoD systems. The coating will be chromate-free and will contain little or no volatile organic compounds (VOCs). The proposed technology is based on recent University of Cincinnati invention termed superprimer. The proposed system, consisting of silane, organic resin and nano-particle filler, is amenable to dipping, spraying, wiping or brushing onto any clean metal surface. No conversion coating, either phosphate or chromate, is required. The key innovation underlying this technology is the hydrophobicity transition exhibited by organosilanes. While the unpolymerized silanes are hydrophilic and water soluble, they become highly hydrophobic on desposition, resulting in extremely low water transmission rates. The coating system will work on all major engineering metals such as carbon steel, galvanized steel, stainless steel, aluminum alloys and magnesium alloys.

BENEFIT: The successful development of the coating system will eliminate or dramatically reduce volatile organic compounds (VOCs), hazardous air pollutants (HAPs), and the generation of hazardous waste streams during coating application and removal processes. The current DoD corrosion control strategy utilizes large amounts of hexavalent chromium, a known human carcinogen, in conversion coats and primers. A chrome-free primer with sufficient performance for use in DoD applications is not currently available. The favorable environmental attributes of the proposed system will significantly improve worker exposure and safety and reduce the life cycle cost of the total coating process.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION PLAN: Throughout the project, DoD end users will be involved to ensure technology transfer to DoD applications.

PROGRAM SUMMARY

PROJECT TITLE & ID: Zeolite Conductive Polymer Coating System for Corrosion Control to Eliminate Hexavalent Chromium from DoD Applications; PP-1342

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Yushan Yan; University of California – Riverside, CA

FY 2003 FUNDS: $381K

DESCRIPTION: Corrosion costs associated with corrosion prevention and correction of corrosion-generated failures account for approximately twenty-five percent of the armed services' annual maintenance budgets, or more than one billion dollars a year. Current effective corrosion control coating systems for alloys especially aluminum alloys used in Department of Defense (DoD) applications rely on extensive use of hexavalent chromium in conversion coatings and/or in primers. Unfortunately, chromium is toxic and carcinogenic. Therefore, regulations regarding its use and disposal have become increasingly stringent. A new chromium-free coating system is required to meet corrosion protection performance requirements in all DoD applications.

The overall objective of the project is to develop a new environmentally friendly zeolite system for corrosion control to eliminate hexavalent chromium in DoD applications without sacrificing performance. Zeolite coating systems will be evaluated as "plug-in" replacements for the surface pretreatment and primer layers that are currently used for paint adhesion and corrosion inhibition in Military coating systems. The project will have four major thrusts: (1) development of zeolite coatings on DoD relevant alloys; (2) demonstrate compatibility of zeolite coatings with current Military water-dispersible, polyurethane topcoats; (3) characterization and standard testing of zeolite/topcoat, bi-layer composite/topcoat, and nanocomposite/topcoat systems with benchmarking obtained from performance of current chromium-coating systems; and (4) technology transition.

BENEFIT: The successful development of the proposed zeolite and zeolite conductive polymer (CP) composite coating system for effective corrosion control will eliminate heavy metals exposure to personnel and to the environment, and reduce hazardous waste disposal costs. The environmentally compliant formulation of novel zeolite and zeolite CP composite coating system will provide the DoD community with an attractive alternative to the current pretreatment and primer layer used in Military coatings system while ensuring mission readiness and worker safety.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION PLAN: For this effort, a national team has been assembled to tackle an environmental pollution problem affecting all branches of the services. The current team consists of materials developers and DoD end-users (Naval Air Depot/North Island, San Diego, CA). This effort closely integrates materials researchers and end-users. Thus, this teaming will promote a quick transition from materials synthesis and formulations to material qualification and on to direct use by the DoD community.

PROGRAM SUMMARY

PROJECT TITLE & ID: Electrochemical Oxidation of Alkylnitro Compounds; PP-1345 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Thomas Highsmith; ATK Thiokol Propulsion – Brigham Young, UT

FY 2003 FUNDS: $99K

DESCRIPTION: Energetic materials containing geminal and vicinal dinitro functionalities all arise from chemical oxidation of nitronate anions. This conversion is traditionally accomplished utilizing oxidizing reagents such as the halogens, hypohalide iron (OX^-), and iron II-III/persulfate, among others. All of these reactions are labor intensive and dirty, producing numerous organic and inorganic byproducts. The use of strong chemical oxidizers is particularly troublesome, producing large amounts of active chemical byproducts. These processes result in a significant amount of time and money spent to separate out, treat, and subsequently dispose of these hazardous/toxic waste streams. The objective of this proposed project is the development of general technology for the synthesis of gem- and vic-dinitroalkanes using clean electrochemical oxidation methodology. This approach eliminates the use of strong chemical oxidizing agents and thus their byproducts. This project will result in the demonstration of a general method for the clean, electrochemical preparation of nitrocarbons of Department of Defense (DoD) significance.

BENEFIT: Current chemical oxidative methods for the production of dinitroalkanes yield large amounts of chemical process waste in the form of corrosive inorganic salts. The oxidizing reagents themselves are also costly. The use of electrochemical oxidation for the production of defense-related polynitroalkanes will eliminate large waste streams and produce energetic ingredients in more efficient and environmentally responsible fashion.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION PLAN: This preliminary demonstration of the electrochemical synthesis of these materials will be evaluated in the context of their ability to be economically, environmentally, and responsibly scaled to production levels. Following the successful demonstration of this technology at the bench (25 gram) scale, the processes will be evaluated for their ability to fit in such a facility. This project should provide the fundamental chemical process information to require a follow-on project to fully scale up the process.

PROGRAM SUMMARY

PROJECT TITLE & ID: Novel Approach for Welding Stainless Steel Using Cr-Free Consumables; PP-1346 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Gerry Frankel; The Ohio State University – Columbus, OH

FY 2003 FUNDS: $100K

DESCRIPTION: Stainless steels are selected as materials of construction for their corrosion resistance. When they are fabricated into structures, stainless steel components are often joined by shielded metal arc welding. In order to ensure that the welds exhibit sufficient corrosion resistance, filler metals rich in chromium must be used. Evaporation and oxidation of chromium from molten weld pools results in generation of carcinogenic hexavalent chromium (Cr^6) in the welding fume. It has been well documented that significant quantities of Cr^6 can form when using conventional stainless steel filler metals, resulting in a health hazard for the welder.

The objective of the this project is to demonstrate the viability of a novel approach for welding stainless steel using chromium-free welding consumables. This approach will utilize Nickel-Copper welding electrodes that will effectively eliminate chromium from the molten weld pool thereby significantly reducing the potential for Cr^6 generation. It is anticipated that this will result in a weld metal that has equivalent mechanical properties to the base metal and is cathodically protected by the stainless base metal, thereby ensuring adequate corrosion protection.

BENEFIT: Release of carcinogenic chromium fumes by welding operations will be greatly reduced if a suitable chromium-free welding electrode and welding process can be developed.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION PLAN: Following successful proof-of-concept of a chromium-free welding rod, it will be necessary to pursue follow-on work studying optimization of the welding process and proof that such structures have sufficient metallurgical stability, mechanical properties, and corrosion resistance. Considerable work will also be required in a subsequent phase of this project to complete the process development and prove its suitability for adoption in the field.

PROGRAM SUMMARY

PROJECT TITLE & ID: All-Organic Supercapacitors as Alternatives to Lithium Batteries; PP-1359 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Nickolas Prokopuk; Naval Air Warfare Center- Weapons Divison – China Lake, CA

FY 2003 FUNDS: $100K

DESCRIPTION: The current standard batteries used for many types of ammunitions contain both lithium metal, and thionyl chloride and sulfonyl chloride as the electrolytes. Both of these materials are extremely caustic and pose serious environmental risks to worker safety. The objective of this project is to demonstrate at the laboratory scale a supercapacitor using conductive polymers for the electrodes separated by an environmentally benign electrolyte such as propylene carbonate and tetraethyl ammonium triflate. The first phase of this project will synthesize organic polymers with significantly different reduction potentials for applications as the supercapacitor electrodes. The second phase will focus on the electrical discharge properties as a function of the polymer/dopant ion combinations. Finally, the third phase will focus on assembling a supercapacitor displaying the required voltage and currents within the size constraints.

BENEFIT: Once a successful test is demonstrated, this material would hold promise as an alternative to the current lithium metal battery technology. This technology can provide the Department of Defense (DoD) DoD with an environmentally friendly alternative to the current lithium battery technology. The costs would be significantly less than the current technology without the associated environmental risks.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION PLAN: Upon successful proof-of-principle, the project would be transitioned into a full SERDP project. Additionally, a Cooperative Research and Development Agreement (CRADA) will be pursued to obtain industrial partners to market this product to the DoD user community.

PROGRAM SUMMARY

PROJECT TITLE & ID: Lambda-MnO_2 Solid Cathode for High Energy Reserve Batteries; PP-1360 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. David Chua; MaxPower, Inc. – Harleysville, PA

FY 2003 FUNDS: $100K

DESCRIPTION: Oxyhalide-based primary reserve batteries have been the technology of choice for most of the fuse batteries for strategic and tactical applications. Common to this technology are environmental hazards. Even a slight presence of moisture will cause corrosion and the generation of toxic hydrochloride acid gas. This project proposes the use of Lambda-MnO_2 as the cathode for baseline lithium reserve batteries and for newer magnesium-based reserve batteries. The project includes two basic efforts for development of primary reserve batteries, both of which utilize the Lambda-MnO_2 as the solid state cathode. The first effort will focus on the Lithium/Lambda-MnO_2 reserve battery, and the second effort focuses on the Magnesium/Lambda-MnO_2 reserve battery.

BENEFIT: This project will provide benefits such as lower toxicity, established recycling method, and economic and environmental acceptability. In addition, Lambda-MnO_2 can also be extended to applications requiring longer operational time whether in reserve mode or in the active mode. For the latter, Lambda-MnO_2 can be a unique cathode for the Land Warrior (LW) application. Targeted technology transition can be broad-based; as both active and reserve batteries for the military and, in the case of Lithium/Lambda-MnO_2, it can represent an improved version with respect to energy and broader operational capability over the conventional Lithium/MnO_2 cells used in cameras.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION PLAN: Upon successful proof-of-principle, the project will be transitioned into a full SERDP project.

PROGRAM SUMMARY

PROJECT TITLE & ID: Environmentally Benign Impact Initiated Devices Using Energetic Sol-Gel Coated Flash Metal Multilayers; PP-1362

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Alexander Gash; Lawerence Livermore National Laboratory – Harleysville, PA

FY 2003 FUNDS: $401K

DESCRIPTION: Current medium caliber (20-60mm) munitions are detonated through the use of impact sensitive (stab) detonators. Stab detonators are mechanically activated by forcing a firing pin through the closure disc of the device and into the stab initiating mix. The stab mix, NOL-130, is a mixture of lead styphnate (basic) 40%, lead azide (dextrinated) 20%, barium nitrate 20%, antimony sulfide 15%, and tetrazene 5%. Alternative impact initiated devices (IIDs) that do not use lead and other environmentally hazardous materials are critically needed. The proposed effort will demonstrate that environmentally acceptable energetic sol-gel coated flash metal multilayer nanocomposites can be used to replace the hazardous and toxic components utilized in current IIDs. The proposed IIDs will be made up of a precision energetic foil of metal multilayers (flash metal), along with a ceramic-based energetic sol-gel coating made up of non-toxic and non-hazardous components, such as ferric oxide and aluminum metals. The multilayer foils can be produced using magnetron, physical vapor sputtering techniques. Both the multilayer and sol-gel technologies are versatile commercially viable processes that allow the tailoring of properties, such as stab sensitivity and energy output. Successful completion of this proposed work will result in IIDs that include innocuous compounds, have sufficient output energy for initiation, meet current military specifications, are small, cost competitive, and perform as well as or better than current devices. Flash metal multilayer and sol-gel are expected to be generic technologies applicable to a wide range of devices, especially in small caliber ammunition and submunitions.

BENEFIT: The development of environmentally benign stab detonators and igniters will result in the removal of hazardous and toxic components associated with their manufacturing, handling, and use. This will lead to improved worker safety during manufacturing as well as reduced exposure of Service personnel during their storage and or use in operations. The implementation of energetic sol-gel coated metallic multilayers as new small IIDs will result in dramatically reduced environmental risks and improved worker and user safety risks without any sacrifice in the performance of the device.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION PLAN: This will be a joint effort between Lawrence Livermore National Lab (LLNL) and the U.S. Army's Research Development and Engineering Center (ARDEC) at the Picatinny arsenal. Following successful completion of the Strategic Environmental Research and Development Program effort, the Energetics and Warhead Division of ARDEC at Picatinny has committed support for the transition of these materials to Army systems.

PROGRAM SUMMARY

PROJECT TITLE & ID: Environmentally Friendly Advanced Gun Propellants; PP-1363

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jeff Akester; ATK Thiokol Propulsion – Brigham City, UT

FY 2003 FUNDS: $241K

DESCRIPTION: The main energetic component of military gun propellants is nitrocellulose (NC). Where a more energetic propellant is required, NC may be impregnated with nitroglycerine (NG). In addition to this basic formulation, most military gun propellants also require a coating of deterrent plasticizer for burn rate control, and a surface application of inorganic compounds that serve as ignition aids or to provide flash reduction. Stabilizing additives are also added to prolong propellant shelf life. Diphenylamine (DPA), a suspected carcinogen, acts as a stabilizer in the propellant to prevent the deterioration of the nitrocellulose. Barium nitrate, a heavy metal and also a hazardous material, is used in some medium caliber propellants as an oxidizing agent to make the propellant more readily ignitable.

The primary objective of this proposed work is to identify a suitable replacement for medium caliber ammunition propellants that is more environmentally acceptable, has safer properties, provides an increased level of performance, and maintains a reasonably low cost. This effort will use thermoplastic elastomer (TPE)-based propellants as a substitute to current medium caliber ammunition propellants. TPEs are suggested for this work since they do not require oxidizing agents such as barium nitrate nor do they require stabilizing agents such as DPA. TPEs may also be manufactured in advanced geometries, do not have plasticizer migration issues, and are immune to moisture problems. The technology used to produce the new TPE propellants is centered on twin screw extrusion.

BENEFIT: TPE propellants offer advantages over typical NC propellants in that they may be manufactured into advanced geometries, do not have plasticizer migration issues, are immune to moisture problems, and may be warmed and re-extruded into new geometries. TPE propellants may be recycled, minimizing propellant waste. Demilitarization work on TPE propellants has suggested that propellant ingredients are largely recovered.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION PLAN: Two propellant candidates will be identified through formulation development and initial screening at the R&D center located within the Thiokol Propulsion branch of ATK in Utah. All propellant ingredients and manufacturing processes will be examined and modified such that they adhere to the most environmentally friendly approach. Military oversight of the ammunition-testing phase of the program will be administered by personnel from the U.S. Army Research Development and Engineering Center, Picatinny Arsenal, NJ.

PROGRAM SUMMARY

PROJECT TITLE & ID: New Explosive Development for Medium Caliber Stab Detonators; PP-1364

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. John Hirlinger; U.S. Army Armament Research, Development, and Engineering Center – Picatinny Arsenal, NJ

FY 2003 FUNDS: $150K

DESCRIPTION: Current medium caliber high explosive projectiles employ an impact sensitive (stab) detonator. The initiating mixture in these detonators is composed of lead styphnate, lead azide, tetracene, and barium nitrate. All of these compounds contain heavy metals that are either mild toxins or produce toxins upon decomposition. It is estimated that over the next five years, 2500 pounds of these hazardous materials will be employed for detonators, excluding waste materials. The objective of this effort is to evaluate potential replacements for environmentally objectionable energetic materials used in small stab detonators for medium-caliber ammunition. Two new primary explosive compounds will be synthesized in large laboratory quantities and tested for run-up to detonation distance as a direct substitute compound for the critical detonator transfer charge. TACOM-ARDEC will be the project lead for this project and will provide technical assistance in the synthesis process of the polyazidocyclophosphazene compound 1,1-(N,N'-ethylenedinitramino)-3,3,5,5-tetraazidocyclotripphosphazene (ENTA). The Naval Surface Warfare Center, Indian Head Division, will provide technical assistance in the synthesis process of the other compound, diaminoazotetrazole-n-oxide (DAAT-NOx), plus perform the assembling and testing of the compounds in the M-59 detonator hardware. Pacific Scientific will synthesize both explosive compounds. The effort will result in a feasibility demonstration of these new explosives in the M-59, a representative medium-caliber stab detonator, used in the M-430, 40mm high-velocity grenade.

BENEFIT: The development of environmentally friendly detonators will reduce or eliminate range contamination, mitigate the long-term exposure effects on plant, wildlife, and water systems, and drastically curtail the use of toxic materials at 20mm-60mm manufacturing facilities. It will also result in reduced exposure of both user and production personnel to harmful levels of contaminants and combustion products that occur in the material handling during production, test, and operational use of medium caliber detonators.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION PLAN: A final report will be issued which provides an objective assessment of the viability of using the developed small stab detonators for medium caliber ammunition. Based on the results of this final report, it will be determined whether the project will be given follow-on funding.

APPENDIX E
UXO Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Statistical Methods and Tools for UXO Characterization; UX-1199

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Brent Pulsipher; Pacific Northwest National Laboratory – Richland, WA

FY 2003 FUNDS: $200K

DESCRIPTION: Many Formerly-Used Defense Sites (FUDS) slated for clean up and transfer to the public for other uses potentially contain UXO. Often the exact location of the UXO within the site is unknown and exhaustive sampling is not possible or prohibitively expensive. The risks associated with Unexploded Ordnance (UXO) in soils at the sites are a significant concern. Risks must be managed to acceptable levels commensurate with hazardous clean-up activities and intended future use. There are two types of risks that must be considered: (1) risk of leaving unidentified UXO that could be discovered after clean up has been completed, and (2) risk of spending scarce resources on characterization with a non-optimal characterization scheme or when there is no real threat present. The latter can result in delays for clean up of truly hazardous sites.

This research program is evaluating and developing statistical methods and tools that can be used to produce characterization and verification plans and data evaluation schemes that will appropriately account for these two types of errors. Significant research on UXO detection system performance has been conducted and continues. Pertinent estimates of probabilities of detection and false positive error rates will be extracted from these programs to incorporate reasonable expectations of available data. The performance of acceptable methods relative to user-specified tolerance of the two risks (cost and hazard) will be evaluated. Once the methodologies are selected, statistical algorithms that are easy to apply or lend themselves to software implementation will be developed. Finally, prototype tools will be developed and demonstrated using existing data or as part of a characterization scheme on a particular UXO site.

BENEFIT: It is envisioned that the statistical methods developed will provide a mechanism for designing sampling schemes that will result in an acceptable level of confidence that UXO is or is not present on certain portions of a site. The methods will allow the stakeholders to analyze the tradeoffs between sampling requirements and risk of incorrect decisions. A statistically based sampling approach could avoid significant costs of characterization. Specific payoffs will be the availability of methods and tools in the form of technical reports, publications, software, and presentations.

ACCOMPLISHMENTS: During FY02, progress was made on developing and establishing statistical sampling methods that would be relevant to typical UXO characterization applications. The appropriate approach to sampling depends on the Conceptual Site Model (CSM) and the phase of characterization. In FY02, progress was also made towards the establishing a functional CSM that could incorporate the methodologies developed under this effort.

In FY02, programming continued to incorporate additional functionality within Visual Sample Plan (VSP), a software package that helps the user determine the number and location of samples/swaths required to adequately protect against decision errors. The ability to calculate the probability of traversing and detecting a target area of a critical size, shape, and density given a bivariate distributional pattern of anomalies was completed. The approach was added within the UXO module of Visual Sample Plan (VSP) and demonstrated to SERDP Staff. The methods were documented in a draft report. In addition, the Bayesian methods to be used in VSP for assessing the success of a geophysical survey conducted to detect target areas of interest were further developed. Other activities have focused primarily on completing the Bayesian methods and documenting and testing the compliance sampling algorithms. The project also explored the effect of site-specific obstacles on the calculated probabilities and detection rates.

Several other features that will make the VSP UXO module more practical and useful have been developed, including a draft automatic report generator, on-line help, ability to import or specify obstacles where transects are not feasible (trees, cliffs, etc.), and output of transect coordinates.

TRANSITION: The statistical methods and prototype tools developed under this project will be applicable to many users at DoD facilities where UXO is a concern. Statistical methodologies will be exercised during extended testing on simulated data. A joint PNNL/Sandia proposal was accessed for FY03 funding under ESTCP to perform initial demonstrations on existing data from completed and characterized sites, followed by final validation in conjunction with a full scale remediation effort at a UXO-contaminated site. Working with UXO site characterization managers regulators and stakeholders to apply the methods will be an excellent opportunity for transitioning the expertise developed. Development of a prototype software tool incorporated into the EPA-sponsored visual sample plan software suite will greatly enhance the transition of the methodologies to practice.

PROJECT SUMMARY

PROJECT TITLE & ID: Bayesian Approach to UXO Site Characterization with Incorporation of Geophysical Information; UX-1200

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Sean McKenna; Sandia National Laboratories – Albuquerque, NM

FY 2003 FUNDS: $200K

DESCRIPTION: The occurrence of unexploded ordnance (UXO) on DoD controlled sites is of critical importance as these sites are prepared for return to the public sector. Efficient characterization and remediation of UXO at these sites is necessary. The current practice of statistical characterization of UXO sites is based on classical statistical approaches derived from assuming the occurrence of UXO is the result of a Bernoulli process. This assumption does not allow for spatial correlation of the UXO density, and it is difficult to incorporate ancillary information provided by geophysical techniques and archival site records in an objective manner.

This effort implements an approach for the characterization of the intensity (density) of UXO across a site that can make use of archival site records and geophysical information. A doubly stochastic Poisson process defines the occurrence of UXO. The spatially varying intensity of this Poisson process can be estimated with spatial statistical algorithms. The result of this description is that the determination of the precise locations of any individual UXO in the subsurface will require sampling at its specific location. However, determination of the variable UXO intensity across a site does not require exhaustive sampling and can make use of less precise, or subjective information through a Bayesian updating approach.

Bayesian updating produces a map of the site displaying the probability of exceeding a specified clean-up goal. This probability of exceedence is the probability of failing to meet the clean-up criteria. A data worth framework is applied to the characterization/remediation alternatives being considered to optimize the sampling locations and determine the number of samples that lead to the lowest total project cost. This approach will be developed using an exhaustively known data set. The approach will be validated and compared to current UXO site characterization guidelines on a separate data set.

BENEFIT: This project will provide a new, validated, UXO characterization protocol that can be applied to DoD sites. This protocol will significantly improve currently available techniques used to characterize UXO sites by incorporating prior information through a Bayesian approach, by using geostatistical techniques to update that prior information, and by optimizing the characterization using a data worth approach. This protocol is designed to take advantage of the recent investment in detailed geophysical survey technology that has been made by SERDP and other branches of DoD. The overall benefit of this project will be to provide a more efficient and defensible protocol for the characterization of UXO sites.

ACCOMPLISHMENTS: In FY02, key progress was made in establishing the *Data Worth Framework*. Work on this task is focused on the two major aspects of the data worth framework: where to sample and when to stop sampling. Primary work was focused on the placement of subsequent sampling transects after the data from the initial transects has been processed and on answering the question of when enough sample transects have been collected. These questions have been addressed through a recently developed variance minimization approach. This approach is general and works for either straight or meandering transects and can be applied to determining the locations of initial transects or to the problem of locating an additional transect given any number of existing transects.

Additional work was done on the incorporation of imprecise geophysical sensor information into the estimation process. The project is using hypothetical sites created with a UXO simulator and choosing probability of detection and false alarm rates that are consistent with sensor performance at different sites and in the laboratory to "survey" the hypothetical sites and to provide input to the geostatistical estimation routines. Results show that sampling the site with sensors having different characteristics can bias the proportions of the estimated UXO and clutter away from the true values across the site and impact the site characterization decisions made at the site. We also worked on investigating the effect of the sensor performance on decisions made from exhaustive sampling coverage.

Furthermore, progress was also made towards the establishing a functional conceptual site model that could incorporate the methodologies developed under this effort.

TRANSITION: The statistical methods and prototype tools developed under this project will be applicable to many users at DoD facilities where UXO is a concern. Statistical methodologies will be exercised during extended testing on simulated data. A joint PNNL/Sandia proposal was accessed for FY03 funding under ESTCP to perform initial demonstrations on existing data from completed and characterized sites, followed by final validation in conjunction with a full scale remediation effort at a UXO-contaminated site. Working with UXO site characterization managers regulators and stakeholders to apply the methods will be an excellent opportunity for transitioning the expertise developed. Development of a prototype software tool incorporated into the EPA-sponsored visual sample plan software suite will greatly enhance the transition of the methodologies to practice.

PROJECT SUMMARY

PROJECT TITLE & ID: Spatial Statistical Models and Optimal Survey Design for Rapid Geophysical Characterization of UXO Sites; UX-1201

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. W.E. Doll; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2002 COMPLETED PROJECT

DESCRIPTION: Modern geophysical sensor array technologies are being used to fully characterize large potential UXO sites around the world. While the cost per acre for these array-based surveys is often an order of magnitude better than conventional ground surveys, the sheer size of the problem is such that the total end price is still untenable. Statistically valid sampling approaches need to be developed to further reduce the survey footprint.

The approach makes use of the unique advantages of sensor arrays in order to reduce the sampling area requiring to achieve definition of ordnance distribution. Rather than dividing a homogeneous sector into small grids for detailed investigation (as is currently done in ground-based statistical surveys), a distribution of array swaths is proposed to delineate the boundaries of contamination with higher confidence and lower cost. When a regular pattern of swaths from a sensor array is employed, ordnance density within a sector can be mapped as levels of contamination at a specific measure of uncertainty. This removes the assumption of homogeneity within a sector and can form the basis for remediation decisions and risk assessment. This sub-sampling approach is applicable to any array of sensors collecting a swath of data, whether magnetic or electromagnetic, ground or airborne.

While the technology to conduct these surveys exists, the mathematical foundations and statistical protocols have never been developed. This effort has developed solutions based on the point process theory of spatial statistics. While the locations of UXO are described by spatial point pattern, these locations are not measured directly but are instead observed by an instrument in the proximity of the location (such as a magnetometer) that responds to a physical property of the UXO. Advanced geophysical modeling integrated into the study translates statistical spatial models into measurable parameters.

Ultimately, the purpose of a statistical survey is to reduce the cost of clean up while retaining high confidence of lowering risk posed by UXO. Throughout the process, an assessment of practicability and reliability of the technology has been included.

BENEFIT: The short-term benefits to DoD of this SERDP project include the development and demonstration of a statistically-valid survey methodology for large scale UXO detection and mapping that is technology independent; significant cost reduction for site analysis related to UXO characterization; and the availability of an analysis package to be used by members of the UXO community. The long-term benefits of this project are a potential reduction in the cost of UXO characterization on millions acres of potentially contaminated land in the U.S.

ACCOMPLISHMENTS: In FY02, this project team and the other project teams from Sandia National Laboratory (SNL) and Pacific Northwest National Laboratory (PNNL) were coordinated. Progress made by the ORNL team involved methods for assigning statistical values to geophysical results, in order to discriminate between target-related and target-unrelated anomalies. This method was used to build Ordnance Intensity Maps (OIM) and Threshold Intensity Maps (TIM). The project team developed a methodology that formalizes the notion of similarity and utilizes for calibration a training data set representative of the area, ordnance types, and measurement technology to be applied. Anomalies can be prioritized for subsequent investigation according to similarity to ordnance. During FY02, the team applied the approach to data sets from the Badlands Bombing Range, South Dakota; Aberdeen Proving Ground in Maryland; and the Pueblos of Laguna and Isleta in New Mexico.

Work on sampling design also continued. Survey design procedures were structured to give consideration to the statistical properties of the data that are collected. Geophysical instruments are used for most UXO surveys and, in addition to UXO, these instruments will also detect other metallic and non-metallic objects including cultural artifacts, geology, and soils. Each type of geophysical instruments will have site-specific capability to detect UXO and other objects, and can acquire data in different geometries, and at different acquisition rates, depending on the platform on which the instruments are deployed. The team has developed a procedure for survey design which allows the user to include survey instrument and platform performance in the analysis of survey parameters. This approach allows the user to assess trade-offs between sampling strategy and instrumentation in a site-specific fashion. The incremental benefit of survey choices or equally effective choices can be assessed with respect to probability of missing a target.

TRANSITION: This project will provide techniques and algorithms in the form of research software. Final validation of these techniques and algorithms would require a full-scale demonstration at a UXO-contaminated site. The commercialization of individual results, as well as the overall acquisition and statistical methodology, will be examined for transfer to the private sector during appropriate phases of the project, and an appropriate commercialization plan will be provided as part of the project final report.

PROJECT SUMMARY

PROJECT TITLE & ID: Detection and Classification of Buried Metallic Objects; UX-1225

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. H. Frank Morrison; DOE, Lawrence Berkeley Laboratory – Berkeley, CA

FY 2003 FUNDS: $544K

DESCRIPTION: The project is performing basic research to develop a systematic approach for design and fabrication of an optimum active electromagnetic (AEM) system based on the methodology employed in the minerals exploration industry in the search for metallic ore bodies. The intent of the optimum system, bounded by practical and theoretical limitations, is to detect, discriminate and classify unexploded ordnance. The design of the optimum system will be achieved through the integration of: (1) a comprehensive set of simulators for determining the responses of arbitrary conducting, permeable bodies; (2) a simple algorithm that determines the principal moments of a target and computes the band-limited frequency spectrum or the transient decay of the response in the principal axis directions; (3) a technical assessment of the current systems and the proposed optimal system, with particular emphasis on the ambient and geological noise levels; and (4) the design parameters for the construction of an optimal prototype.

BENEFIT: The project intends to develop an active EM system that can extract the measurements for the best possible estimates of the location, size, shape and metal content of a buried metallic object in the presence of an interfering response from the ground and/or non-UXO metallic objects. The objective is to design an optimum system which provides the best detection of UXO with the lowest field survey cost.

ACCOMPLISHMENTS: In FY02, the project team developed a general inversion code for determining the depth and principal polarizabilities of an arbitrary target. A forward modeling code for calculating the response of solid spheroidal conductive and magnetic bodies has also been developed to simulate the response of elongate bodies of the size and aspect ratio of typical UXO. UXO of concern for remediation at Ft. Ord, California, have been used for test objects in the inversion and to guide the design of a prototype next-generation AEM system. The inversion code has been used to compare several different current AEM systems as well as proposed systems. The code returns the uncertainties in the depth and polarizability estimates using noise estimates derived from performance analysis of existing systems.

The project is also exploring the implementation of multi receiver AEM systems predicated on the feasibility of using small dipole-like receivers rather than the large air-cored loops currently in use. The criteria for evaluating any receiver is that its internal noise, converted to an equivalent magnetic field strength, must be at least equal to or lower than the ambient magnetic field at the measurement site. During FY02, experimental evaluation of a small (12 cm) ferrite-cored solenoidal induction coil has shown noise levels at or below the ambient noise at a quiet site near Berkeley. The final stage of the design process is the determination of the bandwidth and filter characteristics necessary to recover the spectral information in the response that is necessary to characterize the size, metallic properties and possibly wall thickness of the UXO. The choice of the feedback sensors with their characteristic flat bandwidth response has necessitated development of a simulator for the entire transmitter-receiver system. A numerical simulator code has been developed that will be used to predict system performance.

TRANSITION: The project intends to transition the EM prototype design to the Environmental Security Technology Certification Program (ESTCP) for full scale demonstration and validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Signal Processing and Modeling for UXO Detection and Discrimination in Highly Contaminated Sites; UX-1281

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Leslie Collins; Duke University – Durham, NC

FY 2003 FUNDS: $285K

DESCRIPTION: Until recently, detection algorithms could not distinguish between buried UXO and clutter, leading to many false alarms. Over the last several years modern geophysical techniques have been developed, merging more sophisticated sensors, underlying physical models and statistical signal processing algorithms, with such approaches yielding reduced false alarms. In particular, for sites where anomalies are well separated, it has been shown that the combination of phenomenological models and advanced signal processing can markedly decrease the time required to remediate a site by classifying UXO and non-UXO items correctly. For highly contaminated regions, however, the signatures of multiple anomalies often overlap, vitiating the utility of many of the newer techniques. To address this problem a synergistic use of advanced phenomenological-modeling and signal-processing algorithms will be employed.

The proposed research program has two principal objectives: (1) the development of new physics-based signal-processing approaches applicable to scenarios in which responses from multiple UXO and clutter items co-exist in a sensor signal, with the goal of discrimination; and (2) the use of information-theoretic measures to define the types of scenarios for which UXO and clutter density is too high to reliably perform classification, necessitating a direct mechanical excavation of an entire region. The first objective will be met by the parallel development of phenomenological models and statistical signal processing algorithms. The latter topic will address circumscription of those regions, presumably in the vicinity of a former bull's-eye, for which discrimination of individual UXO and clutter is intractable due to the high density of target/clutter overlap and the limited information in available sensor data.

BENEFIT: The algorithms that will be developed will provide the ability to separate the signatures associated with different subsurface objects from a composite signature measured by a sensor. Accurate separation of such signatures will permit remediation of sites that cannot currently be considered using conventional techniques. The output of such algorithms can be transferred to discrimination algorithms that have already proven to improve discrimination of UXO from clutter. The signal processing research will result in performance bounds that allow assessment of sensor performance as a function of site parameters. These bounds will also be useful for circumscription of areas for which predicted discrimination performance falls below acceptable levels.

ACCOMPLISHMENTS: In FY02, modeling efforts have revealed that a multiple-dipole EMI model fits signatures from complex ordnance substantially better than the traditionally used single dipole model. In addition, the research team has shown that the field interaction term must be considered when trying to predict EMI data for closely spaced objects. The strength of the interaction term is a function of the proximity of the multiple targets and their distance from the sensor. When the objects are closely spaced or shallow, the interaction term is not negligible. Experimental data have supported the modeling conclusions. Current efforts will determine precisely how detrimental it is to ignore the interaction term when the separation algorithms are applied.

Signal Processing efforts in FY02 were divided into two arenas: prescreening and Bayesian object separation. The team developed a simple prescreener to determine whether a single object or multiple objects are present in EMI data that has been collected spatially. Efforts involved the evaluation of the performance of this prescreener using simulated data in which a number of objects present, object separation, and relative object size are varied. Preliminary results indicate that this prescreener performs quite well at discriminating the case of a single object present from the case of multiple objects present. An additional prescreener formulated on Bayesian principles which considers the number of single-dipole objects as an uncertain parameter will also be considered. Overall, the Bayesian classifier has performed quite well – performance for classification when two objects are present is close to that obtained when only one object is present when the system noise is held constant. Comparisons will be made between this performance and that obtained with a simple template matching procedure and to the independent components analysis (ICA)-based classifier.

TRANSITION: The project will pursue teaming relationships and will transition algorithms and model codes to the sensor developers and users in the field as they mature. Collaborative relations so organized will provide focus for developments of practical systems. Moreover, these organizations, which are responsible for hardware design and measurement campaigns, will gain insight from phenomenological models to assure that the systems are designed and deployed in the most salutary fashion.

PROJECT SUMMARY

PROJECT TITLE & ID: UXO Discrimination in Cases with Overlapping Signatures; UX-1282

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kevin O'Neill; U.S. Army Corps of Engineers Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory – Hanover, NH

FY 2003 FUNDS: $424K

DESCRIPTION: The intent of this project is to perform basic research on the use of electromagnetic induction (EMI) sensors and ground penetrating radar (GPR), together, to develop the means for substantially improving buried UXO discrimination at highly contaminated sites where different signatures overlap. The assumption is that detection has been accomplished and detailed surveying is to be performed around an indicated location. Instrumentation, measurement techniques, modeling and signal analysis will be further developed to enable ultra-wideband (UWB) sensing in multi-position survey schemes around suspected target clusters.

Specific problems addressed are: (1) the case of two or three UXO-sized objects, (2) the "fragment cloud" consisting of many small clutter items that could have the same amount of metal as a UXO, and (3) the screening problem when a single UXO-sized object is amidst or beneath a distribution of smaller fragments. Both EMI and GPR will be used to address all three cases.

BENEFIT: The results of this project will: (1) support development of subsurface sensing and processing systems that will take advantage of broadband data in both electromagnetic induction sensing and ground penetrating radar; and (2) enhance our ability to discriminate UXO from clutter, particularly in areas of high density contamination. This will result in cheaper, more efficient, and especially more reliable surveying for UXO site cleanup.

ACCOMPLISHMENTS: During FY02, new configurations and deployment strategies for both EMI and GPR sensors were devised. First versions were tried out and some down-selections made. A tiltable 3-D GEM EMI receiver will be developed further, with at least a software-based conversion to time domain data, so that both time domain and frequency domain data can be obtained in real time. A first rendition of "subsurface side-looking" GPR was also achieved, and will be developed further in FY03.

Specifically, measurements were made on canonical objects (cylinders of various compositions, including heterogeneous composition, and small UXO) in various configurations relative to one another, and to a screen of small randomly distributed surface clutter. The new measurement systems were successfully simulated, as was their use when 2 or 3 objects are present in the sensor's field of view. Facile models for well distributed clouds of metallic fragments were developed further and tested against measurements. Progress was also made on identifying parameters to extract from the data when there are multiple targets present. To illuminate the best research path for the future, work has proceeded -- particularly seeking a simpler model-based EMI processing scheme that will exploit new analytical models -- to address the data in a more tractable manner.

TRANSITION: This project will perform basic research applying electromagnetic physics to provide an improved basis for discrimination of UXO from clutter in highly contaminated sites, that is, where signatures of different objects overlap. The result will be further development of instrumentation measurement techniques, modeling and signal analysis to enable ultra-wideband sensing in multi-position survey schemes around suspected target clusters.

PROJECT SUMMARY

PROJECT TITLE & ID: Physics-Based Modeling and Signal Processing for SAR Detection of Former Bombing Ranges and Burial Pits; UX-1283

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Lawrence Carin; Duke University – Durham, NC

FY 2003 FUNDS: $178K

DESCRIPTION: There is significant interest in developing sensors that can effectively interrogate large areas for UXO detection in the presence of realistic rough and/or vegetated terrain. For this problem, detection of each UXO at a significant standoff would be ideal. However, more realistically, a large standoff sensor is required to interrogate thousands of acres quickly, with the goal of circumscribing those areas that are most likely to be contaminated by UXO. In this context, rather than requiring detection of each UXO, the goal is detection of a former bombing range (i.e., detection of a high enough percentage of individual UXO to delineate a former bombing range). Similar issues hold with regard to detecting a burial pit. One of the few sensors that affords wide area surveillance, at a significant standoff, is synthetic aperture radar (SAR). While SAR is not in general appropriate for detecting each individual UXO, particularly those that are small and/or deeply buried, it can detect shallow buried and surface UXO. The principal challenge is detection of a high percentage of such UXO, at a low false alarm rate, such that one can circumscribe a region for subsequent ground-based detection.

The approach studies the utility of SAR for wide area detection of UXO in the presence of naturally occurring clutter. It is understood that, even for this limited problem class, SAR will not be appropriate for all environments. Therefore, rigorous electromagnetic models will be employed with state of the art signal processing tools to investigate UXO detection in the presence of various soil types, surface roughness, vegetation and subsurface inhomogeneties.

BENEFIT: The electromagnetic models, having been developed and refined for many years, represent a significant asset that will be brought to bear on any future SAR-based UXO program, significantly furthering the transition from optimal sensor design to subsequent sensor deployment. Utilization of the software developed under this program is very inexpensive, given computer resources. Moreover, use of the insight from the software, in the design of an optimal SAR system and associated processing algorithms, can be very cost effective in assuring that the system is properly designed and deployed. Insights gained computationally are far less expensive and time consuming than those learned empirically.

ACCOMPLISHMENTS: During FY02, the Multi-Level Fast Multi-Pole Algorithm (MLFMA) software was implemented and rigorously tested. It is completely scalable, meaning the size of the problem that can be considered simply scales with the number of available computer processors. Current efforts have involved using the code to generate synthetic SAR data for comparison to field collected data. The team has also focused on processing data collected on a simulated UXO site at Camp Navajo by the DARPA Foliage Penetrating (FOPEN) system.

TRANSITION: The algorithms will be tested using available SAR imagery from previous ARL data collections, recent collections from DARPA's FOPEN system, as well as future measurements from other projects. Based on this modeling, and the associated signal processing, the utility of SAR for wide-area detection of UXO in the presence of naturally occurring clutter will be assessed. It is understood that, even for this limited problem class, SAR will not be appropriate for all environments.

PROJECT SUMMARY

PROJECT TITLE & ID: Application of Wavelets for Detection and Discrimination of UXO; UX-1284 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Brian Damiano; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2002 COMPLETED PROJECT

DESCRIPTION: Airborne methods for detecting unexploded ordnance (UXO) can realize large cost and time savings compared to ground-based detection methods. However, existing data processing tools may not enable this data collection to be as sensitive to small objects as it is capable of being, or as sensitive as methods that use surface deployed instrumentation. The aim is to use wavelet analysis of magnetic signatures acquired from airborne platforms to remove noise and discriminate between clutter and targets.

Two approaches, each using wavelet analysis, have been investigated. In the first approach, profile data collected at sites with seeded anomalies were analyzed by using current signal processing methods and the discrete wavelet transform (DWT). It is anticipated that the DWT-based method will be easier and faster to apply, result in noise removal, and probably be superior to that obtained by existing methods. A variety of wavelet types will be used to determine which wavelet is best suited to the analysis of the profile data.

The second approach will apply the continuous wavelet transform (CWT) to profile data. This application results in a three dimensional representation of the signal; the “x” direction represents time and the “y” direction represents inverse frequency, and the “z” direction represents signal strength. By using a color map to represent the signal strength, the result of the CWT is an image in which signal features appear as “blob-like.” The aim is to use image processing techniques to extract and classify image features, with the intent being to discriminate between clutter and targets.

BENEFIT: The application of wavelet analysis to profile magnetic data is a novel alternative to current filtering techniques. The increase in the signal-to-noise ratio is expected to result in a more accurate and detailed description of stronger targets that are currently detectable. This increase in available detail may make it easier to distinguish between multiple overlapping targets as well as discrimination between targets and clutter.

ACCOMPLISHMENTS: During FY02, the research team completed development of a preliminary strategy for applying wavelet filtering to airborne magnetic data. The results appeared to be superior to current filtering techniques, and the application of the wavelet filtering method may be simpler than the current filtering method. Also, the team obtained data for several examples of true targets and common clutter. Preliminary work has shown some promise for extracting descriptors that can be used to discriminate between these two classes. Execution of the project has extended into early FY03. Complete results will be available in the Project’s Final Report.

TRANSITION: A significant number of tangible products and results will be provided that will have direct application to DoD and other ordnance-laden land. The commercialization of individual results, as well as the overall acquisition strategy developed through this project, will be examined for transition to the private sector during this project. Improved processing techniques could be readily implemented in the airborne systems operated by ORNL.

PROJECT SUMMARY

PROJECT TITLE & ID: Evaluating the Effects of Magnetic Susceptibility in UXO Discrimination Problems; UX-1285 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Yaoguo Li; Colorado School of Mines – Golden, CO

FY 2002 COMPLETED PROJECT

DESCRIPTION: Magnetic and electromagnetic surveys have a well-documented ability to locate UXO but are prone to false alarms, which increases the cost of cleanup. The key to reducing false alarms is the development of algorithms that can discriminate between an intact UXO and other items such as scrap metal or geological features.

The purpose of this study is to determine how magnetic soils affect the recovered parameters from magnetic and electromagnetic (EM) inversions and, if significant, to explore techniques to mitigate their effects. Forward modeling of magnetic and EM data for UXO items embedded in media with arbitrary distributions of susceptibility will be used to understand the effects of susceptibility on the two data types. Results will be used to assess conditions under which such noise affects the results of inversion calculations. Methods for removing susceptibility noise from magnetic and EM data will be investigated.

BENEFIT: The focus of the project is on characterizing situations where the susceptibility of the soil significantly degrades the ability to discriminate when using the recovered parameters from magnetic and time-domain EM inversions. The study will: (1) quantitatively evaluate the effects of background susceptibility and determine under what conditions inversion algorithms can work; (2) determine how the data can be modified so that the current inversion algorithms will work in the presence of background susceptibility; and (3) if necessary provide an explicit action plan for future inversion research that must contend with recovering information about the background susceptibility and the UXO at the same time.

ACCOMPLISHMENTS: During FY02, the research team's key achievement has been the recognition that magnetic susceptibility of soils is frequency dependent (or complex). The time-dependent EM decay curve for these magnetic soils falls off as 1/t rather than $1/t^{5/2}$. Thus, the team determined that all inferences about shape and size of the UXO can be significantly in error when magnetic soils are present. The researchers acquired time-dependent EM field data from Kaho'olawe and are currently analyzing these data with the goal of designing a strategy to estimate the magnetic properties of the soil using time-dependent EM responses away from UXO. Execution of the project has extended into early FY03. Complete results will be available in the Project's Final Report.

TRANSITION: The project intends, if the technology is developed, to provide an effective means to minimize false alarm rates in UXO clean-ups. Potential users of the technology may include the U.S. Army Corps of Engineers or the Navy at such problematic areas as Fort Ord or Kaho'olawe.

PROJECT SUMMARY

PROJECT TITLE & ID: Algorithms for Discriminating UXO from Non-UXO Based on Mathematical Morphology and Fuzzy Sets; UX-1286 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Paul Gader; University of Florida – Gainesville, FL

FY 2002 COMPLETED PROJECT

DESCRIPTION: The goal of the proposed research is to investigate the applicability of the methods of mathematical morphology and fuzzy sets to the problem of discriminating UXO from non-UXO signatures using data from state-of-the-art sensors. These methods can offer the advantages of feature computation over a spatial extent and multiple frequency bands, fusing information that can identify complex relationships between information sources, and decision-making based on fuzzy sets that can be robust based on limited training data. These methods have been applied with success to similar discrimination problems in the past, including the closely related landmine discrimination problem, and preliminary studies suggest that they will be useful for UXO discrimination.

The methods of mathematical morphology and fuzzy sets will be applied to signature data acquired from state-of-the-art sensors, such as EMI, magnetometer, or GPR sensors. Algorithms will be developed that process sensor data and make determinations as to the likelihood that the data was measured on a UXO item or not. Existing archived data sets will be used for proof-of-concept development. Standard evaluation measures, such as receiver operating characteristic curves will be used to determine the performance of the methods and enable comparison to other methods.

BENEFIT: Improved discrimination techniques have the potential to mitigate costs that result from high false alarm rates in UXO detection. The methods being investigated have the potential to improve discrimination in a variety of commonly used sensor modalities.

ACCOMPLISHMENTS: During FY02, the research team received data sets collected using a GEM-3 sensor and began analysis. Methods of mathematical morphology and fuzzy sets were applied to the signature data and algorithms development was initiated. Execution of the project has extended into early FY03. Complete results will be available in the Project's Final Report.

TRANSITION: Upon demonstration of enhanced capability utilizing the algorithms, the work will be transitioned to contractors who collect the data to perform further processing.

PROJECT SUMMARY

PROJECT TITLE & ID: Improving UXO/Clutter Discrimination Performance through Adaptive Processing; UX-1287 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Thomas Bell; AETC, Inc. – Arlington, VA

FY 2002 COMPLETED PROJECT

DESCRIPTION: Buried unexploded ordnance (UXO) is one of the Department of Defense's most pressing environmental problems. Current technology has shown the ability to detect individual sub-surface UXO but not to reliably discriminate UXO from other items in the ground that pose no risk. To address this problem, this project intends to introduce an adaptive processing approach that incorporates sensor position adjustments into the fitting algorithms used to invert electromagnetic induction (EMI) data. It is anticipated that this will improve discrimination performance in the face of inaccurate sensor location data.

Past discrimination performance from the Naval Research Lab (NRL) and Geophex will be evaluated. In developing the position adjustment algorithms, the focus initially will be on the EM61 system since there is less information to deal with. Various techniques for correcting errors in the sensor position measurements will be assessed. The idea is to determine which works best, since each will have its own qualities relating to robustness and convergence rates. At a minimum, three approaches will be considered: (1) Adaptive and low-pass filtering, (2) Application of hidden Markov models to track and predict the system motion, and (3) Application of simultaneous hidden Markov models to the system motion and tilt. These techniques will first be applied to simulated data, in which the sources of error and ground truth are known so that the performance of the various algorithms can be compared. The algorithms will then be applied to measured data that has been collected with a cart-based system in order to evaluate the robustness of the performance.

BENEFIT: The project intends to incorporate sensor position adjustments into the fitting algorithms, and improve target classification and discrimination performance beyond the limits imposed by the inherent errors in sensor location measurements. Performance of processing algorithms for discrimination are limited by errors introduced by positioning problems. Once these effects have been alleviated, more complex signal models can be used.

ACCOMPLISHMENTS: During FY02, the research team initiated the following tasks: (1) methods to describe the motion of the sensor, and (2) simulation studies to determine effect of a baseline low-pass filter and linear predictive filters on removing positional errors. Key accomplishments include determination that: (1) a Quaternion formulation simplifies the orientation error modeling of the sensor and provides a means for efficient path description and modification; (2) the baseline rectangular low-pass filter outperforms all other low-pass filters considered, as well as the linear predictive filter, and is comparable to a non-causal linear predictive filter; and, (3) curvature in the tracks adversely affects performance across the board, and that low positional error levels and/or high filter order increases sensitivity to the curvature in the track. Execution of the project has extended into early FY03. Complete results will be available in the Project's Final Report.

TRANSITION: The track compensation procedures developed under this project will be directly transitioned into the Multi-Sensor Towed Array Detection System (MTADS) Data Analysis System, as well as other software packages. This will allow more sophisticated processing algorithms that include multiple target and non-dipole models.

PROJECT SUMMARY

PROJECT TITLE & ID: Standardized UXO Technology Demonstration Sites Program; UX-1300

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. George Robitaille; U.S. Army Environmental Center – Aberdeen Proving Grounds, MD

FY 2003 FUNDS: $400K

DESCRIPTION: Advancements in UXO detection and discrimination technologies are necessary to support the operation, restoration, and transfer of the DoD's ranges. UXO characterization technologies can be affected by variations in site terrain, geology, vegetative cover and weather conditions encountered. The establishment of standardized UXO technology demonstration sites will allow users and developers to define the range of applicability of specific UXO technologies, gather data on sensor and system performance, compare results, and document realistic cost and performance information.

In order to satisfy both the research and development community and the technology demonstration community, the standardized sites are made up of three areas; a calibration grid, a blind grid, and an open field. The calibration grid will allow demonstrators to test their equipment, build signature library, and determine the effects of site-specific variables on a known target set. In the blind grid, the performance of sensors can be determined independent of the effects of navigation, geolocation and site coverage uncertainties. The open field will document the performance of entire systems in operations representative of real world survey conditions.

BENEFIT: This program will ensure that critical UXO technology performance parameters such as detection capability, false alarm rate, discrimination, capability target reacquisition, and system efficiency are determined through standard test methodologies, procedures, and facilities. The Standardized UXO Technology Demonstration Site Program will provide an invaluable resource to both the R&D community and clean up project managers evaluating potential technologies.

ACCOMPLISHMENTS: Progress was made towards the opening of two sites in Aberdeen Proving Ground (APG) in Maryland and Yuma Proving Ground (YPG) in Arizona. The APG site was opened in the summer of 2002 while the YPG site is currently under construction and is expected to host the first UXO demonstrator in the second quarter of FY03. Extensive progress was made in the development of the *Standardized UXO Technology Demonstration Site Protocols* and developing standard performance scoring software.

TRANSITION: The Standardized UXO Technology Demonstration Site Program will provide the UXO technology developer with "turn key" standardized sites for UXO sensor technology testing and demonstration. Other products resulting from the program include a screening matrix of system performance, a series of standardized site protocols, a standardized target repository, and a variety of technology transfer and marketing materials.

PROJECT SUMMARY

PROJECT TITLE & ID: UXO Classification Using a Static TEM Antenna Array; UX-1309

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Donald Snyder; Zonge Engineering – Tucson, AZ

FY 2003 FUNDS: $206K

DESCRIPTION: Contemporary unexploded ordnance (UXO)-detection literature suggests that precision broadband electromagnetic induction (EMI) measurements, either in the time domain (TEM) or frequency domain (FDEM), provide useful classification information. However, full classification of a target with EMI requires the illumination of the target with a primary magnetic field in three independent directions in order to excite all the principal modes of the target. Current EMI survey methods rely on movement of the transmitter antenna to different locations to provide target illumination from different directions, and measurements are acquired dynamically at speeds that generally preclude the acquisition of precision transients or broadband spectra. Moreover, target classification based on EMI data acquired from moving platforms is further complicated by even small errors in antenna position. As a result, target classifications based on data from a moving platform do not realize the potential suggested by broadband EMI measurements under static conditions.

This project will develop and test an apparatus based on the concept of acquiring static broadband EMI measurements with an antenna array for classification of UXO.

BENEFIT: This system addresses the need for development of non-intrusive, cost-effective, cued object identification and detailed site characterization for targets previously identified by systems that provide rapid but imprecise surveys of UXO ranges and/or under conditions of clutter or ambiguous characterization. Static free-air measurements have encouraged many researchers with the prospect that broadband EMI can be used as a basis for target classification, and this system will offer a means of acquiring data having the quality of the static free-air measurements over unknown targets resting in situ. With this system, all of the factors presently identified as degrading the quality of target classifications using data acquired from moving platforms (i.e., antenna platform motion, position and attitude, and signal-to-noise ratio) will have been significantly reduced or eliminated.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: Zonge Engineering has a nearly 30-year history of designing and manufacturing innovative field instruments for geophysical measurement of electrical and electromagnetic fields. This project will leverage existing technology developed by Zonge Engineering. Zonge Engineering will collaborate with the University of Arizona on the development of knowledge-based classification software to characterize targets. If the project is successful in demonstrating the efficacy of static TEM characterization, the hardware and software will be commercially available through the manufacturing arm of Zonge Engineering. Zonge Field Services will also provide the measurement capability as a commercial service.

PROJECT SUMMARY

PROJECT TITLE & ID: Sensor Orientation Effects on UXO Geophysical Target Discrimination; UX-1310

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Foley; Shaw Environmental – Lowell, MA

FY 2003 FUNDS: $75K

DESCRIPTION: The goal of this project is to develop the required technologies for broad application of existing, emerging, and future UXO discrimination methods in typical field environments, where sensor data is often acquired under conditions far less ideal than these experienced in typical prove-out sites.

Preliminary EM modeling methods that allow height and orientation variation have been developed with promising results. However, survey specifications for implementation of these techniques have not been developed, nor has a performance evaluation been conducted to define the relationship between the sensor state and inversion results. This performance evaluation is necessary to answer fundamental questions regarding UXO detection and discrimination capabilities under site conditions that become increasingly dissimilar to controlled "Proveout" tests. This research and development effort will focus on two technical areas including (1) the collection of advanced auxiliary sensor orientation and position data and (2) development of forward and inverse modeling techniques to exploit auxiliary information. The activities take parallel tracks at the outset of the project. First, the data requirements associated with capture of orientation data are defined through field-testing. Orientation sensors are specified, and a data acquisition system is developed. Second, modifications are made to existing UXO discrimination techniques that model targets as EM dipoles. These modifications exploit the orientation data collected concurrent with EM field survey data. These hardware and software paths come together in the testing phase of the system. Here, EM and orientation data are collected under a range of field conditions to quantify improvements to UXO detection and discrimination capabilities using this approach.

BENEFIT: The technologies developed under this program will have a significant impact on DoD UXO clearance activities by facilitating deployment of new and emerging discrimination methods at live UXO sites. By quantifying the realities of field conditions, making appropriate concurrent measurements with geophysical observations, and adapting analysis procedures to model the effects of site heterogeneity, these technologies will bring sophisticated UXO discrimination methods into wide use. The UXO false alarm rate (often quoted as contributing to 70 percent of the clearance cost) is the dominant financial factor that can be directly addressed by research and development. As such, technologies leading to routine field application of cost-reducing UXO discrimination methods are essential.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: The transition plan has two elements: (1) full documentation of technical details through reports, journal publications and technical conference presentations, and (2) transition of developed technology to ESTCP for test and demonstration. Regarding documentation, the project plans to transition all developed technology to the UXO academic and industry community through public-domain report, publications and presentations. Regarding ESTCP, the team expects that this research will mature to the level of field demonstration, and plans to apply to the ESTCP program in future years to fully test, develop, and transition the technology to wide use.

PROJECT SUMMARY

PROJECT TITLE & ID: Efficient, Realistic, Physics-Based Modeling for Buried UXO Based on Time-Domain Electromagnetic Scattering Signatures; UX-1311

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Peter Weichman; ALPHATECH – Burlington, MA

FY 2003 FUNDS: $210K

DESCRIPTION: The aim of this effort is to deliver a software product suitable for immediate transition to time-domain electromagnetic (TDEM) sensors currently used for UXO discrimination. The methodology will simultaneously address the requirements of high fidelity physics-based modeling for realistic target shapes and vastly accelerated CPU efficiency for forward modeling and inversion, and subsequent discrimination.

The TDEM method has good detection capability for UXO, but interpreting the scattering signature is difficult due to the complicated nature of interaction between low frequency EM signals and conducting targets and the propagation of the signal in the ground. A broad-based theoretical and numerical effort will be undertaken to vastly enhance the physics-based TDEM modeling capability. A highly efficient "mean field" formalism for high contrast EM scattering will be applied. This numerical code, together with the enhancements, will be designed to interface with existing EM aircoil and magnetosensor array tools and to extract basic physical characteristics from sensor observations by efficient solution, ultimately in real-time, of the global optimization problem. The mean field approach is based on the fact that the electrodynamics of any compact conducting body may be represented as a superposition of exponentially decaying eigenmodes. These modes are intrinsic properties of the target that may be precomputed and stored in a data base. The approach uses a Green function formulation of the Maxwell equations, combined with a novel representation of the EM field in terms of a smooth set of vector basis functions. This allows the Maxwell equations to be reduced, via appropriate truncation, to a finite-dimensional matrix eigenvalue problem. The eigenvalues represent the decay rates, and the eigenvectors the mode shapes. By combining this data with extrinsic data, extremely rapid voltage and magnetic field predictions can be made and compared with measurements. The extremely fast forward computation enables the practical use of a genetic algorithm (GA) to discover the best fitting target model. The estimated parameters represent a highly efficient and informative input feature vector to a classifier that selects the best match from the target database or rejects the detection as clutter.

BENEFIT: The economic benefit of this work will be reductions in remediation costs due to reductions in false alarm rates from real-time on-site discrimination. The scientific benefit is a completely new method for rapid EM computations that should eventually find application in other areas such as the mining industry and public infrastructure evaluation.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: The final software product will contain all required instrument characteristics (transmitter and receiver loop dimensions, orientation and relative position; transmitter current waveform; receiver time gates; etc.) for a wide variety of TDEM instruments, easily augmentable to new configurations as they become available. The PI has been in contact with instrument manufacturers, with whom he has had associations in the past, who have expressed great interest in using the product to enhance their instrument capabilities.

PROJECT SUMMARY

PROJECT TITLE & ID: Multi-Sensor CSEM Technology for Buried Target Classification; UX-1312

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mark Everett; Texas A&M University – College Station, TX

FY 2003 FUNDS: $390K

DESCRIPTION: The objective of this project is to develop a prototype, time-domain EMI multi-receiver sensor along with its supporting interpretation software. The research consists of three major tasks including (1) prototype development, (2) forward modeling and inversion, and (3) integrated system tests. Transmitter (TX) and receiver (RX) components and antennas, the digital signal processor, and the display unit will be analyzed, designed, fabricated and tested. The hardware will be constructed using integrated circuit technology. A fast turn-off TX loop antenna featuring step-recovery diodes and temperature-controlled crystal oscillators will generate a large transient signal that interacts with the conductive ground including any buried targets. The transient response due to eddy currents induced in the subsurface will be sensed by multiple RX coils. The forward modeling and inversion will involve the following components: three-dimensional finite element analysis for evaluating theoretical transient responses, checking faster semi-analytic solutions and resolving hardware design issues; target feature extraction software for matching observed transient signals to known type-curve parametric representations; and nonlinear parameter estimation using smart homotopy methods to match the extracted response parameters with actual target parameters such as UXO burial depth, orientation, length, aspect ratio, conductivity, and background soil conductivity. The hardware and software will then be integrated into a final, fieldable sensor configuration with a user interface, and tests will be conducted at Texas A&M Riverside and standardized UXO test sites.

BENEFIT: This research will provide the Department of Defense with an innovative tool for UXO detection and clearance operations, enabling a reduction in remediation costs through increased probability of detection with lowered false alarm rates. The multi-RX transient EMI prototype is envisioned to be a cued sensor designed primarily for detailed interrogation of buried UXO-like targets that have already been detected using wide-area or production ground survey geophysics.

The larger near-surface applied geophysics community will benefit from this research as the instrument and its supporting software package can be used for a wide range of environmental, hydrogeological, shallow resource and geotechnical applications. Understanding the complexity of the EMI response of natural media demands the development of smart multi-RX geophysical technology.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: Significant interest in the research product is anticipated from defense and environmental agencies as well as private companies and academic scientists. The prototype sensor will be fielded at our test site at Texas A&M University, and standardized UXO test sites. At the conclusion of the project, the developed sensor will be delivered to the sponsor, ready for its deployment at actual UXO-contaminated sites. We will contact private companies to discuss possible collaborative efforts to commercialize the sensor. We will interact and share information and technology with the applied geophysics and geotechnical scientific communities. Finally, we will widely disseminate the results of our research through presentations at national meetings and through published articles in leading scientific and engineering journals.

PROJECT SUMMARY

PROJECT TITLE & ID: Quantification of UXO Variability for Target Discrimination; UX-1313

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Jonathan Miller; AETC, Inc. – Arlington, VA

FY 2003 FUNDS: $334K

DESCRIPTION: The objective of this project is to characterize and quantify inherent variability in the EMI response of a wide variety of real UXO objects and to understand the implications of these results for discrimination. Data analysis schemes generally assume signals from a particular target class will be the same, but UXO as found in the field exhibit differences from one example to the next due to damage on impact, determination over time, or differences or design and manufacturer. The project will establish statistics describing underlying variability of UXO by collecting data from a large number of items excavated from sites around the country.

Discrimination between UXO and clutter is accomplished by applying decision rules to target-specific parameters derived from site survey data. Within the dipole model framework, these parameters are the EMI response vectors associated with each principal axis of the target (ß values), and the decision rules are regions in parameter space. Measurement and modeling errors, as well as inherent variability among the UXO themselves, cause derived parameters to smear and form a cloud in parameter space. The decision rules must be relayed to encompass them, thereby degrading discrimination performance. This research will reveal and quantify the degree of ß parameter spreading (distribution) which is attributable to inherent UXO variability.

BENEFIT: Results provided by this program, combined with ancillary ongoing and future research, will provide the user community with the tools and information required to reduce false alarms while maximizing detections. Target variability represents both a fundamental limit on the best possible performance of all EMI-based discrimination schemes, and also an important input for optimizing such schemes.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: The product of this project will be a concise, easily transferable statistical database. It is expected that it will be highly leveraged and utilized in current and future UXO-discrimination projects. Results will be directly useful for ongoing discrimination work at AETC.

PROJECT SUMMARY

PROJECT TITLE & ID: Three-Dimensional Steerable Magnetic Field (3DSMF) Sensor System for Classification of Buried Metal Targets; UX-1314

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Carl Nelson; Johns Hopkins University Applied Physics Laboratory – Laurel, MD

FY 2003 FUNDS: $218K

DESCRIPTION: The objective of this project is to develop an active electromagnetic induction sensor system to measure the three components of a metal object's magnetic polarizability tensor for object classification.

To accomplish the objective, a sensor with a time-domain, three-dimensional (3D), steerable magnetic field (SMF) antenna will be developed. The 3D antenna will be modeled, designed, and fabricated to excite the metal object with directionally varying magnetic field vectors without the need to move the antenna spatially over the object. The horizontal field antennas will use approximations to a sheet current. The vertical field will be generated via a loop. A magnetic field receiver system will measure the object's time-decay response as a function of the excitation magnetic field vector. The sensor will take measurements in the time range of 2 μs to 20 ms (i.e., a frequency range of 50 Hz to 500 kHz). With this wide bandwidth, the sensor system may be able to cover targets as small as plastic landmines and as large as 1000-pound bombs. An algorithm will be developed to classify the object based on the collected data. Validation experiments will be conducted in laboratory and field trials.

BENEFIT: The portable sensor system will provide improved target response data for enhanced classification of buried metal targets. The improved target classification capability of the 3DSMF sensor system has the potential to reduce the false alarm rate associated with UXO site cleanups, leading to reductions in the cost of site remediation efforts.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: The sensor data will be provided to the research community for alternative algorithm development. Information gathered during the prototype sensor system development will determine the next step in the transition plan. Next steps include: (1) Develop concept of operation; (2) Design or construct improved sensor for transition to Demonstration and Validation testing.

PROJECT SUMMARY

PROJECT TITLE & ID: EMI Sensor Optimized for UXO Discrimination; UX-1315

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Herbert Nelson; Naval Research Laboratory – Washington, DC

FY 2003 FUNDS: $691K

DESCRIPTION: The objective of this project is to develop and produce a prototype ordnance-specific electromagnetic induction (EMI) sensor optimized for UXO detection, classification, and identification.

Advanced technology demonstrations have shown that UXO discrimination information can be extracted from the signals of commercial EMI sensors, even though their design objectives were other than UXO. However, limitations in parameters such as coverage rate, depth of use, size of UXO that can be examined impose limitations in the available information.

There are three key design issues that will be considered in the initial and subsequent designs of the prototype sensor. These are the trade-offs of frequency- vs. time-domain systems (or a hybrid approach if warranted), the details of coil design and deployment strategy to yield optimum classification performance (especially for the case of closely spaced targets), and the reduction of system noise. The optimum sensor for UXO discrimination will be specified, and a practicable system that can be transitioned to the commercial sector will be designed, produced, and tested. The existing Multi-Sensor Towed Array Detection System (MTADS) will be used as a testbed for studying deployment issues arising in the course of the research and development activities.

BENEFIT: The benefit of the sensor development will be primarily economic. Costs of a typical UXO remediation are driven by investigation of non-UXO metallic objects. A reduction in the number of non-UXO targets will result in a large reduction in the cost of remediation projects.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: In the final year of the program, regular meetings are scheduled with engineers from the major manufacturers of geophysical instruments to keep them up-to-date on development progress. At the conclusion of the program, we intend to seek funding for a Demonstration/Validation of the sensor or, if appropriate, transition results to one of these commercial firms.

PROJECT SUMMARY

PROJECT TITLE & ID: Development and Evaluation of an Airborne SQUID-Based Magnetic Gradiometer Tensor System for Detection, Characterization, and Mapping of Unexploded Ordnance; UX-1316

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. T. Jeffrey Gamey; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2003 FUNDS: $370K

DESCRIPTION: This project will explore the viability of deploying a Superconducting Quantum Interference Device (SQUID) sensor array in an airborne platform. Current airborne magnetometry systems using CS-vapor sensors are several constrained to very low altitude by inherent sensitivity. The SQUID could allow stand off to increase from less than 1 m to 5-10 m, multiply axis vector measurements will provide unique information for set discrimination and localization.

The research approach will focus on developing and demonstrating the capability of high temperature superconducting (HTS) SQUID multi-axis magnetometers and gradiometers for standoff detection of surface and buried UXO. To meet these objectives, the following issues will be systematically addressed: (1) HTS SQUID sensor performance when exposed to large fields and field changes; (2) Compensation of magnetic noise generated by movement of the cryogenic vessel; (3) Active real-time compensation of HTS SQUID sensors based on linear movement through the Earth's field; (4) Development and construction of an extremely stable boom for mounting the SQUID on a helicopter platform; (5) Integration of HTS SQUID electronics packages with current ORNL airborne magnetometer positioning, navigation, and recording systems; and (6) Determination and quantification of detection footprint from a single HTS SQUID array.

BENEFIT: The SQUID array is expected to provide a level of sensitivity and detection previously unavailable in airborne-based systems, thus enabling the detection and mapping of smaller ordnance items than possible with current cesium vapor magnetometer arrays. As a corollary, this system is expected to enable detection and mapping from greater standoff distances than with current airborne platforms. Vector anomaly attributes also have the potential to improve classification.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: The transition approach is based on providing for the implementation of demonstrated/validated SQUID-based sensor technology upon completion of appropriate limited field-testing. The techniques in this project and associated hardware/software that are developed will require additional testing in a full scale field application. Subsequent funding from ESTCP would be pursued to perform the required demonstration/validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Broadband Electromagnetic Detection and Discrimination of Underwater UXO; UX-1321

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. I.J. Won; Geophex, Inc. – Raleigh, NC

FY 2003 FUNDS: $307K

DESCRIPTION: The objective of this project is to advance the current state-of-the-art in broadband electromagnetic sensor technology for underwater detection and discrimination of UXO. A major effort is to extend the sensor detection range so as to widen the sensor footprint.

Broadband discrimination methods applicable to underwater UXO will be developed based on the EM induction spectroscopy (EMIS) technology pioneered by Geophex. A promising phenomenon, called the current-channeling effect, will be investigated to extend the underwater detection range and extensive field experiments will be conducted to verify such effects. Required sensor parameters and a configuration to maximize the detection range will be determined. Signal processing algorithms accommodating both the eddy current response and the current channeling response will be developed for underwater UXO detection and discrimination. Sensor deployment schemes based on available platforms will also be recommended.

BENEFIT: Clearing underwater UXO poses technical challenges in many different aspects including detection, discrimination, survey platform, navigation, and logistics. This research in underwater EMI detection and discrimination will have a major impact in the development of detection strategies for underwater UXO by providing a new sensor technology not only for remediating underwater UXO sites but also for many other applications in marine geotechnical engineering.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: All codes will be made available through SERDP to interested parties. Geophex will also commercialize the codes along with the instruments it sells. Geophex has a long history and track record of marketing its R&D products.

PROJECT SUMMARY

PROJECT TITLE & ID: Technology Needs for Underwater UXO Search and Discrimination; UX-1322

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jim McDonald; AETC, Inc. – Arlington, VA

FY 2003 FUNDS: $501K

DESCRIPTION: The primary objective of this project is to develop techniques for the deployment of extended arrays of magnetometer and EMI sensors and dynamic control of their depth and orientation at a fixed distance above the bottom sediments in 0 to 15 feet of water while surveying at a vessel speed of several knots. Secondarily, new EMI sensor designs must be developed that have the required detection sensitivity at a standoff distance of 1 to 2 meters to detect even small UXO targets while still maintaining the time resolution to extract object shape information that can be used for target classification. Finally, high-frequency sonar imaging technology must be adapted for use in bottom mapping, depth profiling (in real-time), and providing shape information for targets proud (or partially proud) of the bottom.

Many system components developed for the Airborne MTADS can be directly adapted for the Marine MTADS platforms. These include the data acquisition and pilot guidance systems, the magnetometer sensors, the navigation control and attitude sensors, the data analysis algorithms and software Graphical User Interface, and the output graphics, interfaces, and remediation support documentation. In this project, a study will be completed to define the support vessel (i.e., deployment concept) and develop engineering design plans for the vessel-sensor platform interface and the two sensor array platforms. Additionally, an EMI modeling study will develop the engineering design plans for the new marine EMI array and define the high frequency sonar system required to support the marine UXO survey system.

BENEFIT: This project will produce the engineering design information necessary to develop and deploy a fully functional, marine UXO search system appropriate for the shallow water environment.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: The team expects that after 1.5 years of addressing the specific R&D issues, the project will transition to an ESTCP effort. Following ESTCP demonstration, AETC, who is not a direct provider of UXO services, will seek as a transition partner, an A&E firm specializing in UXO services, to commercialize the system and put it into service.

PROJECT SUMMARY

PROJECT TITLE & ID: Ordnance/Clutter Discrimination by Electromagnetic Induction; UX-1323

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Steven Norton; Geophex, Inc. – Raleigh, NC

FY 2003 FUNDS: $280K

DESCRIPTION: The objective of this project is to develop signal processing algorithms that employ broadband electromagnetic induction (EMI) data for the purpose of discriminating between UXO and clutter.

Algorithms will be developed and tested for processing both multi-frequency and multi-positional EMI data for UXO/clutter discrimination. Two discrimination approaches will be investigated, including: (1) EMI spectroscopy in which the spectral signature of an unknown object is compared to a library of known UXO spectra, and (2) derivation of geometric features characteristic of UXO from multi-positional EMI data. As a derivation example, axial symmetry and a large aspect ratio can be identified as UXO-like, whereas an object with a small aspect ratio or irregular shape can be identified as clutter-like. These algorithms will be evaluated on a variety of buried UXO and clutter items in standardized test ranges with the goal of determining how discrimination accuracy (probability of correct classification and false alarm rate) is affected by geologic noise and other uncertainties in the data such as sensor position errors.

BENEFIT: The product of this research will be computer software for processing both multi-frequency and multi-positional EMI data that will identify objects as UXO or clutter with an estimated level of confidence. The software will be designed to process either UXO survey data acquired over an area containing many items or data acquired from one item at a time (i.e., in real time immediately upon detection). A reliable method of discrimination would eliminate the need for removal of harmless items, thereby significantly reducing excavation costs. This new technology may have applications in other areas as well; a notable case is the problem of discriminating between landmines and clutter.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: At the completion of this work, Geophex will provide SERDP with all discrimination software and documentation. The software and data sets will be made available through SERDP to interested parties. The software can be marketed with, or independently of, the Geophex GEM-3 multi-frequency sensor.

Geophex has a long history and track record of marketing its R&D produces. For example, the multi-frequency GEM-2 and GEM-3 electromagnetic induction sensors are undergoing commercial production.

PROJECT SUMMARY

PROJECT TITLE & ID: An Improved High Power Transmitter for Surveys Using Time-Domain Electromagnetics; UX-1324

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Donald Snyder; Zonge Engineering – Tucson, AZ

FY 2003 FUNDS: $132K

DESCRIPTION: Performance of current Time-Domain EM System is often limited by signal to raise ratio. One way to increase SNR is to increase the power of the transmitters. The objective of this project is to design and test a proof-of-concept transmitter that will provide a transmitter current moment 5 to 10 times greater than that of existing TEM systems used in UXO surveys. In addition, the step wave form employed in conventional systems will be replaced by an impulse wave form.

The transmitter design will be based on resonant circuit principles that allow the transmitter circuit components to perform as if they were connected to a tuned circuit operating at its resonant frequency, thus transmitting power to a resistive load. With a resistive load, the transmitter power can be substantially increased as compared to a reactive load presented by the more common untuned transmitter loop. Pulses of current are generated by suspending the state of the circuit with solid-state switches. The circuit generates a current pulse in the shape of a half-cycle of a sine wave. A half-sine waveform resembles an impulse function. In contrast, a conventional TEM transmitter generates a waveform that approximates a step in the current. The spectral content of an impulse is constant whereas the spectral content of a step function decreases with increasing frequency. The change in signal shape alone will improve the SNR even if the transmitted power were not increased. Critical circuits will be designed to attach to an existing transmitter for the purposes of proof-of-concept and to carry out a demonstration/test at a standard UXO test site.

BENEFIT: The SNR is usually enhanced in existing systems by stacking or filtering. Either of these techniques require lower survey speeds. Generally speaking, there is a practical limit that establishes the slowest possible surveying speed. It follows, therefore, that there is a practical limit to the best obtainable SNR. The benefit of this technology will be to obtain better SNRs than is attainable with conventional TEM transmitters and to acquire the data at faster surveying speeds. A higher SNR will provide better detection, lower false-alarm rates, and an increased depth of investigation.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: The project report will provide the basics needed by any manufacturer to design and implement the technology in their own design. If this development is successful, Zonge Engineering will certainly invest in development of a marketable product following completion of this proposed work.

PROJECT SUMMARY

PROJECT TITLE & ID: Detection of UXO in Underwater Sites Using Towed-Array, Resistivity/Induced Polarization Measurements; UX-1325

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Donald Snyder; Zonge Engineering – Tucson, AZ

FY 2003 FUNDS: $150K

DESCRIPTION: This proof-of-principle project will investigate the detection and discrimination of UXO in underwater sites using a towed-array resistivity/induced polarization (IP) system. In the latter part of World War II, the Office of Naval Research produced a mine detector based on the IP method. It was reported anecdotally having been successfully used, but it was not pursued.

A few laboratory experiments and tests have demonstrated a measurable IP response team isolated installed targets. IP responses associated with a few specimens of UXO (e.g., grenades, mortar rounds, rockets, etc.) will be measured in the laboratory, and a full-scale experiment will be conducted using an instrument system previously assembled by Zonge Engineering & Research and deployed for shallow sub-bottom resistivity profiling for environmental applications. The effort is expected to confirm that there is a measurable IP response associated with isolated metal objects that are either lying on the bottom in shallow water or buried immediately beneath the sub-bottom. If these experiments demonstrate that the IP response is associated with UXO and that it can be easily measured with an appropriately designed electrode cable, a more comprehensive effort will be undertaken to develop a system designed specifically for the task of UXO detection.

BENEFIT: If it is demonstrated that IP is useful for UXO detection in shallow-water environments, a relatively low-cost method will have been identified that can be deployed either for wide area assessment or, alternatively, for the detection of individual UXO targets.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: This research will be directed by personnel employed by Zonge Engineering and Research Organization. Zonge Engineering specializes in instrument manufacture and field services for geophysical methods. If this research proves useful, Zonge Engineering is in a position to market the technology to the DoD and its contractors as well as to provide contract field services.

PROJECT SUMMARY

PROJECT TITLE & ID: High Resolution Inductive Sensor Arrays for UXO Detection, Identification, and Clutter Suppression; UX-1326

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Neil Goldfine; JENTEK Sensors Inc. – Waltham, MA

FY 2003 FUNDS: $432K

DESCRIPTION: The goal of this project is to develop inductive arrays for high resolution UXO imaging and discrimination. Existing MWM-Array sensor and instrumentation technologies will be leveraged to provide estimates for performance against UXO as a function of depth and ordnance properties. The technical approach for the base program is to: (1) adapt JENTEK's parallel architecture impedance measurement instrumentation and high resolution imaging sensor array for use with large scale MWM-Arrays for UXO detection and image generation; (2) establish MWM-Array object size and depth measurement capabilities for simple objects and UXO in the laboratory; (3) complete an initial field test of the prototype MWM-Array with adapted instrumentation at an approved test site; and (4) develop criteria for enhancements and provide recommendations for follow-on efforts. JENTEK's MWM-Array technology is based on unique designs for electromagnetic induction sensor arrays that use a single drive winding with multiple sense elements. The drive creates a shaped magnetic field pattern, which provides a continuous variation in the orientation of the magnetic field relative to the buried ordnance. Arrays of small inductive coils placed throughout the shaped field sense the field variations from conducting or magnetic UXO and clutter. Images obtained from scans over buried objects provide a basis for spatial filtering and signal processing for discrimination. Adaptations may include increasing the number of sensing elements, adding a second sensing element array at a second location within the applied field to provide additional "views" of the buried objects, and adding a second drive with a different spatial wavelength to provide a second depth of sensitivity.

BENEFIT: This project will demonstrate the current capability of the original prototype MWM-Array as a UXO detector. If successful, the program will demonstrate the value of high resolution imaging and model based methods for UXO detection, clutter suppression and object discrimination based on depth, shape and size. The data collected will support UXO-specific modifications to enhance the impedance instrumentation, sensor arrays and discrimination methods. The long-term benefit of the program is the fielding of a practical and robust solution for discrimination between UXO and non-UXO targets.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: The transition plan from the base program will be an optional follow-on program for enhancing the instrumentation and sensor array technologies. The base program includes both research and development of new methods for UXO detection and discrimination and integration with proven technology being utilized by commercial and military customers in other markets. JENTEK has a successful record for commercializing technology resulting from previous government and privately funded development efforts. JENTEK expects to commercialize the instrumentation, data acquisition/analysis software and UXO imaging systems. JENTEK also plans to work with UXO clearance service providers and experienced DoD prime contractors to define near and long term clearance requirements and to accelerate the transition to wider use.

PROJECT SUMMARY

PROJECT TITLE & ID: Advanced Magnetic System for UXO Detection and Discrimination; UX-1327

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Yacine Dalichaouch; Quantum Magnetics – San Diego, CA

FY 2003 FUNDS: $1,069K

DESCRIPTION: This project will develop a hybrid passive and active man-portable Magnetic Tensor Gradiometer (MTG) capable of operating with unprecedented versatility and performance in production ground surveys. The new system, which exploits recent advances in sensor hardware and algorithms, will be based on magnetoresistive chips and will provide broadband [direct current (DC) to greater than 100 kHz] characterization of subsurface targets. When the broadband information is processed with advanced algorithms, it will enable the detection and discrimination of UXO with very high detection and low false alarm rates.

The man-portable sensor will be capable of collecting multi-component magnetic and electromagnetic (EM) data simultaneously in rocky, hilly, and vegetated terrain. The DC magnetic signature will be used to localize the target, using a traditional fit to a static magnetic dipole, and derive a multi-dimensional map of targets on the fly, using a matched filter algorithm. The magnetic-dipole fit will yield the target location as well as the strength and orientation of the associated dipole moment. Successful implementation of the tensor gradiometer measurement, will allow calculation of target parameters from sparser data sets and greater standoff distances than current instruments. Once the target depth is fixed, the wideband EM (frequency-dependent) response for different incident field profiles will be collected to characterize buried UXO, and a frequency-dependent model will be used to extract the magnetic susceptibility, electrical conductivity, shape, and orientation parameters. Discrimination algorithms based on target attributes determined from their magnetic and EM signatures will be used to distinguish UXO from clutter and fragments and to resolve multiple, offset targets.

BENEFIT: By virtue of its dual alternating current capability, the new system will allow collection of magnetic and EM data in just a single sweep, thereby reducing scanning time by 50 percent. This will significantly improve efficiency and reduce labor hours and associated survey costs. In addition, this new technology will maximize the survey efficiency by allowing random search paths rather than requiring constant-pitch raster scans and allowing certain site areas to be identified rapidly as devoid of targets without detailed and time-consuming surveys. Major benefits of this new system, however, may be a significant improvement in the ability to discriminate UXO from clutter and fragments and to resolve multiple targets.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: This project will culminate in a prototype instrument and data interpretation software. The techniques developed in this project and associated hardware/software will require additional testing in a full field application. Subsequent funding from ESTCP would be pursued to perform the required demonstration/ validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Evaluation, Modification, and Testing of the VETEM System, the HFS, and the TMGS for UXO Detection, Imaging, and Discrimination; UX-1328

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. David Wright; USGS – Denver, CO

FY 2003 FUNDS: $711K

DESCRIPTION: This project aims to improve the state of the art in detection, imaging, and discrimination of UXO by evaluation, modification, and testing of existing magnetic and EMI prototype systems originally designed for other geophysical applications that are closely related to DoD needs for UXO. The objective of this project is to demonstrate that a combination of modified instrumentation and new interpretation algorithms for EMI and magnetometer data, considered separately and together, can result in high probability of detection with reduced probability of false alarms.

This project will evaluate three prototype geophysical instruments. The Very Early Time Electromagnetic (VETEM) system is a time-domain EMI system that records both while the transmitter is transmitting and during very early times following transmitter turn-off. It records the magnetic field, rather than the more common time derivative of the magnetic field, with an expected benefit of better target-to-background response ratios. It is expected that the combination of multiple-component early- and late-time data will enhance target discrimination through analysis of differential vector eigencurrent decay rates. The High Frequency Sounder (HFS) is a frequency-domain EMI system with great flexibility in frequency range. The Tensor Magnetic Gradiometer System (TMGS) is a magnetic system that uses ring-core 3-axis, flux-gate sensors so that not only the gradients of the total magnetic field are recorded but also the gradients of the magnetic field vector components.

BENEFIT: Typically, in excess of 70 percent of removal action project costs are for the removal of non-UXO items using current technology. The achievement of the objective of high probability of detection with decreased probability of false alarms by means of enhanced EMI and magnetic sensors and new appropriate modeling and interpretation algorithms can save the DoD billions of dollars.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: This project will culminate in prototype advanced systems optimized for UXO target. The techniques developed in this project and associated hardware/software will require validation in a full field application. Subsequent funding from ESTCP would be pursued to perform the required demonstration/validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Modeling for Sensor Evaluation in Underwater UXO Test Beds; UX-1329

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Raymond Lim; Naval Coastal Systems Station – Panama City, FL

FY 2003 FUNDS: $309K

DESCRIPTION: This project will adapt the sonar performance prediction capability developed at the Coastal Systems Station (CSS) for mine-countermeasure purposes to support design testing and evaluation of sonar systems to locate and identify UXO in shallow waters. Because underwater UXO is likely to be buried, a primary focus of this work will be to build and validate a prediction capability for buried and partially buried targets with high fidelity over a broad frequency range.

Among the sensor technologies being developed for shallow water UXO remediation, acoustics (sonar) is likely to be one of the most important, since it is less range-limited than more traditional magnetic sensor technologies in seawater. The use of sonar to detect and classify underwater targets has a long research history at CSS, which is responsible for research, development, test, and evaluation of underwater mine-countermeasure sensor systems. CSS has developed the Shallow Water Acoustic Toolset (SWAT), a set of acoustics computer routines that have been used to aid performance evaluation of mine-countermeasure sonar in littoral environments. Central to extending SWAT to accommodate the environmental conditions and sonar concepts envisioned for UXO remediation is the accurate modeling of scatter by UXO shapes in buried configurations. The approach will involve an application of the Kirchhoff approximation with generalized theory of diffraction corrections for target edges at high frequencies (>10kHz). At low frequencies (<10kHz), scattering algorithms applicable to elongated axisymmetric targets based on the transition matrix will be adapted. The validation of these routines applied to imaging of UXO shapes in realistic underwater environments will be confirmed with data collected from ongoing efforts at CSS. Subsequent updates to SWAT will contain these routines and be used to assess specific UXO sonar concepts.

BENEFIT: This work will provide the Department of Defense a capability to simulate sonar performance, permitting informed decisions on the relative merits of competing systems prior to their fielding. Sonar designers will be able to optimize design requirements (e.g., frequency, aperture, etc.), optimize operational requirements (e.g., scan rate, tow speed, etc.), and predict operational limits under various conditions.

ACCOMPLISHMENTS: This project was funded under SERDP's FY 2002 Supplemental Solicitation. Consequently, it was approved as an New Start in the middle of FY 2002 and received funding very late in the fiscal year. Accomplishments will be fully noted in the FY 2003 SERDP Annual Report.

TRANSITION: The SWAT tool in its current configuration is freely provided to sonar researchers and designers. The sonar performance prediction capability that would be developed under this project will be as well. Following completion of this effort, sonar designers would be able to optimize design requirements (e.g., frequency, aperture, etc.), optimize operational requirements (e.g., scan rate, tow speed, etc.), and predict operational limits under various conditions.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of the GEM-3D; UX-1353 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kevin O'Neill; U.S. Army Corps of Engineers Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory – Hanover, NH

FY 2003 FUNDS: $98K

DESCRIPTION: The objective is to construct, debug, and demonstrate, at the bench and "backyard" level, a new sensor configuration that we will designate as the GEM-3D. When the sensor head is horizontal, it will be capable of measuring vertical magnetic secondary magnetic fields, as in the existing GEM-3, but will be modified to record horizontal secondary field components as well. The instrument will do this using a concentric coil arrangement for the horizontal coils (two transmitters, one receiver); and the centers of the vertical coils will reside over the common mid-point of the horizontal coils. The instrument will possess the same advantages in spatial resolution as the existing GEM-3. New model-based signal processing will be developed and applied to data from the device, to infer the shape of metallic targets relevant to subsurface UXO sensing. This will be done in a small number of cases sufficient to demonstrate the potential of the instrumental innovations: some canonical shapes (homogeneous sphere, elongated object, plate-like object), a couple of complex objects in the near field, and a couple of cases with two or three objects.

BENEFIT: Improved discrimination of subsurface UXO from widespread metallic clutter is at the heart of the research needs for improvement of UXO cleanup assessment and execution. At many real (as opposed to test) sites, false alarm rates are enormous, and as much as 75 percent of the cost of remediation may go to excavating innocuous items. Recent experience in both the field and lab, using both measurement and rigorous simulation, has highlighted the potential discrimination benefits of using ultra-wideband (UWB) sensors and analyzing the spatial dependence of their signals, in a variety of orientations.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION: The PI is an integral member of the USACOE/ERDC/EQT team, working on development and demonstration of a new generation of UXO sensing capability. If this SEED project is successful, the results will be directly linked into the EQT-funded efforts. Results will also be published in conference and journal forums. Geophex Ltd, the maker of the GEM-3 system, will be directly involved so that any successful advances in the state of the art will be moved immediately and directly into private sector implementation.

PROJECT SUMMARY

PROJECT TITLE & ID: Use of Shape Representation and Similarity in Classification of UXO in Magnetometry Data; UX-1354 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jim McDonald; AETC, Inc. – Arlington, VA

FY 2003 FUNDS: $100K

DESCRIPTION: In this project, we propose to go beyond the use of physics-based fitting parameters to make decisions about ordnance classification. We will use target images created from high-density mapped sensor data and pattern recognition techniques (using shape representation and similarity) to extract and exploit image features to provide an additional input for a classification decision. Shape information is a primary component of the visual decision-making process used by the human analyst in the current MTADS interactive data analysis approach. Because this information is so important to the human in-the-loop, if it can be quantified and incorporated into the machine analysis of the data, it will provide an important additional classification tool for the analyst.

We will use new machine-learning algorithms and techniques that are promising candidates for automatically capturing visual clues for sorting UXO from ordnance scrap. Several inductive leaning algorithms have been shown to be successful in interpreting imagery data in other applications. Differences in the algorithms determine the concepts the algorithms will induce and the types of data they are well suited for. Multiple algorithms will be explored to determine those best suited to separating UXO from scrap using data as it is available in the real world.

BENEFIT: If successful this approach has the promise of improving the target analysis process to make it more time efficient and automated.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION: The transition is expected to be direct. If successful this work could be incorporated into the highly successful MTADS survey platform.

PROJECT SUMMARY

PROJECT TITLE & ID: UXO Target Detection and Discrimination with EM Differential Illumination; UX-1355 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Foley; Shaw Environmental – Lowell, MA

FY 2003 FUNDS: $100K

DESCRIPTION: Geophysical target signatures recorded from electromagnetic induction (EMI) sensors, such as the Geonics EM-61, contain extreme levels of background noise caused in large part by magnetically permeable soils in some geological conditions. The spatial variation of the soil effects is not separate and distinct from the signatures of buried UXO at a single frequency or time gate. This minimizes the effectiveness of spatial filtering for separating UXO signatures from soil effects. Existing fixed-geometry, transmitter/receiver coincident EMI systems have not produced data sufficient to reliably detect UXO in the presence of strong geologic effects.

The goal of this project is to develop methods and technologies to isolate target signatures from geologic effects in geophysically hostile environments using diversity in transmit/receive geometry and time gates. To achieve these project objectives: (1) a working model for effective differential illumination based on review of theoretical aspects of electromagnetic response to soils will be defined, (2) a series of parametrically constrained EMI data sets will be collected to explore the range of responses, and (3) data will be subsequently analyzed, to establish the utility of the concept.

BENEFIT: The project will improve UXO target discrimination in environments where local geologic effects have a strong influence on geophysical signatures. This improved performance will lead to reductions in the false alarm rate and produce cost savings related to UXO clearance activities.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION: Upon demonstration of enhanced capability utilizing the algorithms, the work will be transitioned to contractors who collect the data to perform further processing.

PROJECT SUMMARY

PROJECT TITLE & ID: Reducing False Alarms: The Physics of Scrap Discrimination for Magnetic Data; UX-1356 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. David Leiblich; SIV Technologies, Inc. – Worcester, MA

FY 2003 FUNDS: $100K

DESCRIPTION: This project will evaluate the potential for discriminating scrap occurring within the top foot of the soil using physics of the near field, for magnetic UXO investigations. This approach seeks to reduce costs by recognizing and removing a specific subset of easily recognizable non-UXO signatures, instead of finding a means of distinguishing the set of UXO signatures from non-UXO signatures. It is expected that this method will provide a basis and methodology for discrimination against false alarms.

Existing magnetic models treat the dipole field, which is the asymptotic limit of all fields, at large range. Although geometrical parameters can be defined for specific shapes, these parameters cannot be recovered with sufficient precision to provide a reliable discriminator between UXO and scrap. Additionally, these parameters treat only the simplest geometrical shapes (spheres, and ellipsoids), which may be appropriate for UXO, and thereby neglect the complexity of structure expected from scrap. The proposed theoretical analysis incorporates the geometric complexity of UXO and scrap, exploring the contributions of higher order moments, as expressed in the near-field, and begins to build a database of results, which is expected to provide the basis for scrap discrimination. Experiments will provide initial evaluation of theoretical results on actual targets.

BENEFIT: It is anticipated that these results will indicate that substantial reductions in scrap-based false alarms can be obtained, by accounting for near-field effects. Experimental tests will demonstrate the principle of the method, as it could be applied in actual field operations and will form the basis for the future development of a field system.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION: Upon demonstration of proof of concept, algorithms will require validation in a large scale real world demonstration, after which the work would be transitioned to the UXO contractor community.

PROJECT SUMMARY

PROJECT TITLE & ID: 3D GeoPhysical Data Collection and Analysis for UXO Discrimination; UX-1357 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. T. Jeffrey Gamey; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2003 FUNDS: $100K

DESCRIPTION: The objective of this project is to create a practical basis for extension of geophysical techniques from 2D to 3D measurements in order to improve detection and discrimination of UXO targets. Existing geophysical field techniques already utilize "discrete" 3D elements by collecting vertical gradient magnetic data or multiple coil electromagnetic (EM) data. Although this is an improvement over single sensor technologies, this approach is limited by 2D thinking and presentation (i.e. sensors are carried over the ground, readings taken at multiple heights are subtracted to produce a single parameter, and the results are forced onto a single planar grid at a nominal sensor height). Rather than measuring "discrete" 3D data and "forcing" it into 2D interpretations, we propose to extend the process to measuring "continuous" 3D data for 3D interpretation tools.

Digital geophysical mapping (in 2D over a standard grid) has evolved sufficiently that it can be relied upon to detect UXO at most sites with enough accuracy to allow simple reacquisition (e.g., JPG, Ft. Ord, and other field tests). Reacquisition is usually accomplished with a handheld magnetometer or electromagnetic instrument that is "waved" about the general anomaly location until a more precise location is determined. By modifying this process to cover the three-dimensional space above an anomaly in a regular pattern and recording the sensor output and position with sufficient accuracy, this project will provide the basis for more reliable inversion and analysis prior to excavation. Recent advances in the accuracy and recording speed of navigation equipment make this three-dimensional positioning possible and commonplace. Software tools to take advantage of this can then be developed to keep pace with these hardware/firmware innovations.

BENEFIT: This project intends to demonstrate an innovative proof-of-concept that can be applied with available hardware. While care is required in the data collection (unlike previous inversion and discrimination techniques), this approach makes use of the lack of uniformity to enhance the results. The central innovation is a fundamental break from two-dimensional thinking/control/presentation of three-dimensional phenomena. Recent advances in commercial navigation and tracking equipment will now provide instrument positions in three dimensions for small open areas to centimeter accuracy. By tracking the sensor position in three-dimensions with sufficient accuracy, and analyzing the data in an appropriate manner, the anomaly signature and its source can be represented and analyzed in its true form.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION: The techniques developed in this project and associated software that can be developed will require additional work to reach an appropriate level of maturity suitable for field application. Additional modules for advanced filtering and inversion will need to be developed and tested with actual field data. Subsequent funding from SERDP and ESTCP will be required to research and implement these changes before attempts at commercialization could begin. The general concepts of 3D data acquisition and processing will be provided through public technical presentation and peer-reviewed papers. If appropriate, the software will be transitioned through commercial vendors who have the capabilities to market and maintain the product for the UXO market.

PROJECT SUMMARY

PROJECT TITLE & ID: Dual Mode Operation of GEM-3 as TD/FD Sensor; UX-1358 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. I.J. Won; Geophex, Inc. – Raleigh, NC

FY 2003 FUNDS: $100K

DESCRIPTION: The project intends to develop new operating software for the GEM-3 electromagnetic induction sensor that will run the sensor in both frequency-domain (FD) and time-domain (TD) modes. This will be accomplished by interleaving TD and FD measurements. The unit time of one data collection operation is called "based period." In a simplest way, the GEM-3 may work in FD for one base period and in TD for another base period through a SW modification of the wave form. In this way, the sensor will collect both the FD and TD data at a sampling rate of 15Hz, which should be sufficient for most UXO surveys.

The project will develop, implement, and test the dual mode operation. A major effort will be aimed at developing algorithms for detection and discrimination of UXO using the dual-mode data. The system will be evaluated for utility using data collected at a UXO test site.

BENEFIT: The GEM-3 broadband EMI sensor has demonstrated its potential for UXO/clutter discrimination. The GEM-3 has been operating as a FD sensor. However, the sensor and the accompanying electronics operate basically in TD. Combined FD-TD data from a single EMI sensor would provide challenging and exciting opportunities for new data interpretation schemes for UXO detection and discrimination. Application of the frequency-time domain sensor is expected to improve the UXO detection and discrimination capabilities of the GEM-3 EMI sensor particularly for deep targets.

ACCOMPLISHMENTS: This is an FY 2003 New Start.

TRANSITION: At the completion of this work, Geophex will provide SERDP with all newly developed software and documentation. The software and data sets will be made available through SERDP to interested parties. If successful, these new and improved data interpretation schemes for UXO detection and discrimination would be further tested in a field deployment through funding sought from ESTCP. Ultimately, an improved instrument would be evaluated by Geophex.

APPENDIX F
Statements of Need

This appendix contains brief summaries of all SERDP Statements of Need (SON) released in the past year. The objectives of SERDP are to support environmental research and development projects to meet high priority, DoD mission-related environmental needs. The **"Core"** solicitation occurs each year and provides funding in various amounts for multi-year projects. The **SE**RDP **E**xploratory **D**evelopment, or **SEED**, solicitation usually occurs annually and is a means for researchers to test proof-of-principles concepts during an effort of one year or less. This year, for a variety of reasons, SERDP did not issue a SEED solicitation.

CLEANUP

Page

FY 2004 Core Solicitation:

COMPLIANCE

FY 2004 Core Solicitation:

CONSERVATION

FY 2004 Core Solicitation:

POLLUTION PREVENTION

FY 2004 Core Solicitation:

UNEXPLODED ORDNANCE (UXO)

FY 2004 Core Solicitation:

CORE STATEMENT OF NEED FOR FY 2004
CLEANUP – CUSON-04-01

INNOVATIVE AND LOW COST METHODS FOR MEASURING HYDRAULIC CONDUCTIVITY

OBJECTIVE: The objective of this Statement of Need (SON) is to develop new or refine existing, low-cost technologies and approaches for the characterization of the hydraulic conductivity of contaminated aquifers. Specific objectives include (1) improving upon or develop better tools and procedures for the in-situ measurement of hydraulic conductivity, and (2) developing protocols and guidance for cost-effectively characterizing the hydraulic properties of contaminated aquifers to aid in selection and design of remediation options.

Technologies and approaches should be applicable to a variety of hydrogeologic settings. Results from this research will aid in developing strategies for more accurate characterization of the hydraulic properties of contaminated aquifers, and will also aid in the design of a wide variety of groundwater remedial systems. An added benefit will also be to help facilitate the transfer of the technology to the end users.

BACKGROUND: New methods for measuring hydraulic conductivity in-situ make it feasible to collect large quantities of data at relatively low costs. The success of virtually every technique or technology for the purpose of remediating groundwater contamination depends directly on the hydraulic conductivity of the local formation(s). High quality hydraulic conductivity data can be used to improve the remedy selection process and also to reduce the uncertainty of the performance of certain innovative remedies such as, but not limited to, permeable reactive barriers, groundwater circulation wells, and in-situ chemical oxidation.

The vast majority of federal dollars spent prior to remedy construction are focused on collecting chemical data at groundwater restoration sites. Correspondingly, the amount of physical data collected, such as hydraulic conductivity measurements, is frequently too small to quantify aquifer heterogeneity. Academicians and other scientists have been researching and publishing work about the heterogeneous nature of any aquifer's hydraulic conductivity field, and there are well-accepted mathematical models available to describe these fields. However, the collection of data necessary to define the model parameters for a given site is probably unattainable at most sites.

It should be noted that there are new tools available to the practitioner to collect hydraulic conductivity measurements in a cost effective manner. These tools include pneumatic slug tests for vertical K profiling using direct push equipment, mini-permeameters employed on the same platform, and dipole flow tests in existing wells. The incremental cost of employing these tools during a chemical investigation may be very low or even negligible. However, it is not obvious how much data will be useful to the practitioner. The use of analytical tools such as decision trees may provide a basis during design for identifying the best alternative while systematically accounting for data uncertainty. This concept should be differentiated from design optimization that is intended to identify the best parameters, flowrate, and well location, for example, for a given alternative.

CORE STATEMENT OF NEED FOR FY 2004
CLEANUP – CUSON-04-02

INVESTIGATION OF ABIOTIC ATTENUATION PROCESSES IMPACTING DISSOLVED CHLORINATED SOLVENTS

OBJECTIVE: The objective of this Statement of Need (SON) is to clarify the role of abiotic degradation processes in the attenuation of dissolved chlorinated solvents. Specific objectives include (1) examining the significance of abiotic degradation processes under conditions not normally supportive of reductive dechlorination; (2) defining predominant mechanisms of abiotic degradation processes such as chemical degradation reactions, covalent binding, and/or irreversible sorption; (3) quantifying contaminant removal rates due solely to abiotic degradation processes; and (4) determining geochemical factors that are of primary importance in controlling rates and extent of abiotic degradation processes. Abiotic degradation processes other than dilution, dispersion, volatilization, advection, or reversible sorption are of interest. Studies should focus on the contaminants of concern including tetrachloroethene (PCE), trichloroethene (TCE), and their breakdown products.

BACKGROUND: Monitored natural attenuation has become widely used for petroleum sites, and is becoming more common for chlorinated aliphatic hydrocarbons. There is little doubt that monitored natural attenuation will be used for many DoD sites, either after more aggressive treatment or in some cases as the sole remedy. It is economically attractive when it works, and further, monitored natural attenuation may be the only practical alternative for many plumes that are very large in size and/or extend under structures or urban areas. However, there are significant questions regarding the conditions under which monitored natural attenuation can be used with confidence.

Reductive dechlorination is usually considered the most important attenuation process, and appears to be occurring at many sites. However, many chlorinated aliphatic hydrocarbon plumes are under aerobic conditions, so that reductive dechlorination will not be a major natural attenuation process. Other natural attenuation mechanisms may occur, including dilution, dispersion, sorption, volatilization, abiotic degradation, and aerobic biodegradation. These processes may occur at very slow rates, but still at rates that can be significant in the long term.

Recent evidence suggests that other abiotic processes may play a significant role in the attenuation of chlorinated solvents under conditions that are not normally conducive to reduction dechlorination. Long-term (2 yr) microcosm studies performed by John Wilson (EPA) and Mark Ferrey (Minnesota Pollution Control Agency) indicate that abiotic processes are responsible for substantial decreases in cis-dichloroethene (DCE) at Twin Cities Army Ammunition Plant (TCAAP). Adsorption is not believed to be a predominant factor based on the relatively low organic carbon content of the aquifer solids used in the studies. Further research is warranted to determine whether successful natural attenuation of chlorinated solvents can occur at sites not undergoing reductive dehalogenation.

CORE STATEMENT OF NEED FOR FY 2004
CLEANUP – CUSON-04-03

ASSESSING IMPACTS OF IN-PLACE REMEDIAL STRATEGIES FOR CONTAMINATED SEDIMENT REMEDIATION

OBJECTIVE: The objective of this Statement of Need (SON) is to understand and develop predictive capabilities for the environmental impact of in-place remedial strategies for contaminated sediments. Specific issues include (1) evaluating pathways of contaminant mobility in sediments through which an ecological or human health risk may occur; (2) evaluating the fate and ultimate bioavailability of contaminants in sediments; and (3) determining what characteristics make a site suitable for in-place remedial strategies.

The results from an evaluation of any of the issues above are likely to vary depending on the in-place remedial strategy selected. Therefore, these issues should be evaluated based upon one or more specific in-place remedial strategies, such as monitored natural recovery, in situ capping, or some form of sediment treatment using physical, chemical, or biological processes to destroy, degrade, or immobilize contaminants within the sediment. This SON only seeks to evaluate potential environmental impacts of existing in-place remedial strategies; proposals focused on developing new in-place remedial technologies will not be considered. The focus of this SON is contaminated marine, estuarine, brackish, and fresh water sediments.

BACKGROUND: Marine and fresh water sediments are the ultimate receptors of contaminants in effluent from urban, agricultural, industrial, and recreational activities, both at sea and on shore. Because of past activities, sediments have some level of impact from anthropogenic compounds. As marine sediment and coastal sites fall under increasing scrutiny, the number of sites for which ecological risk assessment and management will be deemed necessary is likely to increase.

A growing body of evidence suggests that sediment removal can at times result in more ecological damage or show no measurable ecological improvement. Because of the large volumes and high costs involved, it seems clear that some sediment sites will be managed in place. While sediment guidance recommends an evaluation of site-specific risks and benefits of management strategies in the feasibility study process, technology-specific or site-specific data on the risks or impacts of sediment remediation is lacking. Many in-place management approaches and technologies are being developed and marketed, but few have been thoroughly evaluated in terms of the effects of the technologies on the bioavailability, toxicity, fate, and mobility of target and non-target contaminants. In addition, data on which characteristics make a site suitable for these approaches are lacking.

Many of the contaminated marine sediment sites that are currently under investigation are in shallow, coastal areas, and are much more likely than more traditionally studied offshore sediments to be impacted by advective processes such as groundwater flow, tidal pumping, wave pumping, and by resuspension via ship and storm activity. While these processes are recognized in the oceanographic community as having significance to chemical fluxes, they are largely unstudied in contaminated systems, and the relative magnitudes of these processes as compared to the traditionally assessed processes such as diffusion and bioturbation have not been determined. If impacted sediments are to be left in place, it is critical to evaluate potential pathways by which contaminants might pose an ecological or human health risk and to monitor, minimize or eliminate these pathways.

CORE STATEMENT OF NEED FOR FY 2004
CLEANUP – CUSON-04-04

DEVELOPMENT OF REMEDIAL TECHNOLOGIES FOR REMEDIATING GROUNDWATER CONTAMINATED WITH HEAVY METALS

OBJECTIVE: The primary emphasis of this statement of need (SON) is to develop a better understanding of the issues associated with remediation of groundwater contaminated with heavy metals in order to improve remediation and/or management strategies for heavy metal-impacted groundwaters. Proposals may address either applied or more fundamental aspects of the issues of heavy metal-contaminated groundwaters.

Selection of a remedial strategy and identification of critical issues that impact remedial performance is a key component of this SON. For example, research issues related to the impact of metal speciation on removal and/or sequestration techniques, the long-term stability of immobilized metal species, and/or the effect of mixed contaminants on remedial strategies may be considered as they relate to specific remedial approaches.

BACKGROUND: Groundwater contamination with heavy metals is a significant concern throughout the United States, with an estimate of over 60% of CERCLA sites containing heavy metals. In addition, further research on the risks of arsenic contamination in groundwater has resulted in more stringent regulations, which will go into affect in 2006. This is likely to result in many more sites that require remediation to meet regulatory standards. Heavy metals present a unique challenge in that they cannot be degraded to less innocuous compounds as is the case with many contaminants, but can only be removed or immobilized.

While many technologies have been proposed and tested for remediation of metals-contaminated groundwater, no single approach has emerged as a clear success. This is primarily due to the tremendous complexity of metal speciation and complexation in the subsurface environment. It is evident that further research is required to gain an understanding of the various chemical interactions that may occur and how these reactions may impact or influence the selection of a remedial approach.

CORE STATEMENT OF NEED FOR FY 2004
CLEANUP – CUSON-04-05

DEVELOPMENT OF BIOREMEDIATION TECHNOLOGIES FOR TREATMENT OF NITROAROMATIC-CONTAMINATED SOIL AND GROUNDWATER

OBJECTIVE: The objective of this Statement of Need (SON) is to seek applied studies to develop bioremediation technologies for the treatment of nitroaromatic-contaminated soil and groundwater. Previous SERDP research initiated in FY01 focused on increasing our fundamental understanding of the microbial processes involved in the degradation of nitroaromatic contaminants and seeking methods to improve on these natural capabilities via metabolic engineering. Proposed research under this current SON should build upon this previous research and should lead to development of new treatment approaches, guidance documents, and/or tools for implementing nitroaromatic bioremediation at a given site.

BACKGROUND: There are nearly 17,000 sites on DoD installations potentially requiring environmental cleanup. The challenges facing those involved in cleanup include developing appropriate remedial actions to address site contamination and treat the contaminated soil and groundwater to established cleanup standards.

Explosives contamination represents a considerable portion of contamination at DoD sites. Much of the explosive contamination of the environment has resulted from manufacturing and load-assemble-package (LAP) processes conducted before and during World War II and the Korean Conflict. Approximately 25 Army sites are or have been involved in explosives manufacturing or LAP activities. About 20 sites are on the National Priorities List and many sites are scheduled for closure under the Base Realignment and Closure Act. Cleanup preparatory to property disposition was initiated in the early 1980s at many sites. Explosives-contaminated soil has often been incinerated, while waste disposal lagoons and washout sumps and ditches have received, or are in the process of receiving, some form of remediation.

Predominant explosives of environmental concern include 2,4,6-trinitrotoluene (TNT) and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), which were often used in combination, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX), and n-methyl-n,2,4,6-tetranitroaniline (tetryl). The amino reduction products of TNT are commonly encountered in both soil and groundwater. The monoamino transformation products of TNT, 4-amino-2,6-dinitrotoluene (4ADNT) and 2-amino-4,6-dinitrotoluene (2ADNT), are more common than the diamino products, 2,4-diamino-6-nitrotoluene (2,4DANT) and 2,6-diamino-4-nitrotoluene (2,6DANT). The triamino product, 2,4,6-trianiinotoluene (TAT), has been observed in the laboratory, but is not reported in the environment. A photodegradation product of TNT, 1,3,5-trinitrobenzene (TNB), is also common in contaminated soil and groundwater, especially on sites where wastes received exposure to sunlight.

CORE STATEMENT OF NEED FOR FY 2004
COMPLIANCE – CPSON-04-01

PREDICTION MODEL FOR WEAPONS NOISE SOURCES FROM AIRBORNE PLATFORMS

OBJECTIVE: The objective of this Statement of Need (SON) is to solicit proposals to develop a computerized prediction model for aircraft-weapons firing noise. Examples of such systems include, but are not limited to, the A10 aircraft with 30mm gun and Maverick missiles; the F-16 with 20 mm guns and various missiles; the F/A-18 with 20mm guns and various missiles; the AH-64 helicopter with the 30mm gun; the AC 130 aircraft with the 105mm howitzer, 20mm gun and 40mm gun. An accurate characterization of the noise generation and propagation from these classes of noise sources is needed.

Development and/or enhancement of noise predictive models are required for noise management on DoD ranges. Specifically, models are needed to ensure appropriate locations for ranges prior to construction, and to enable effective, unrestricted training while minimizing noise impacts on community health and welfare. Models must be fast, accurate, economical, capable of interfacing with and leveraging off emerging and existing computer technologies, and allow for consideration of various terrain and weather conditions. The requirement includes the collection of source emission data from weapons/munitions noise to accurately model the impact of these sources.

BACKGROUND: The sustainability of testing and training ranges is a serious concern to the DoD. In 2001 the DoD Senior Readiness Oversight Council (SROC) examination of range sustainability identified nine areas of concern, one of which is noise. Residential and community growth present conflicts with our training and its associated noise. When installations were established, they generally were in rural areas, remote and isolated from population centers. Over time this has changed as communities have developed around military installations. The sum effect has been that installations, once far from public view, are now often in the midst of densely populated areas. Noise is one of the consequences of military training practices.

Aerial gunnery ranges are located throughout DoD installations, including those of the Army National Guard and Air National Guard. Currently, no model accurately predicts the noise due to firing of guns and missiles from DoD aircraft. Existing military noise models can predict noise of some aircraft (NOISEMAP, RNM and MR_NMAP) and weapons (BNOISE) operating on the ground. However, these models cannot forecast the weapons noise from airborne sources. The current noise management of these operations is not based on any scientific data/predictions. The assessment of air gunnery noise impacts and mitigation is based on subjective information and is very conservative in order to minimize potential impacts. This deficiency can lead to overly restrictive operational limits and distrust by the public during NEPA processes.

The existing Noise Model Simulation (NMSim) is a computer model that generates time histories of noise from moving or stationary sources, accounting for the effects of real terrain on sound propagation. NMSim has existed as a single-event aircraft noise model since the mid-1990s and was originally developed in support of noise propagation studies to run on a PC under MS-DOS. The model has become part of a growing trend toward simulation models for complex situations not adequately addressed by traditional integrated airport noise models. It provides both quantitative analysis in terms of spectra and loudness metrics and descriptive display in the form of color renditions and animations of noise. NMSim calculates a time history for each source as it moves through the study area and generates a complete grid of noise contours for the area and/or calculates the noise at specific locations of interest. With this system, multiple noise events may be run simultaneously. NMSim is currently being developed into a general-purpose noise model for the National Park Service. The final version will (1) include the single-event aircraft noise capabilities of earlier versions of NMSim, (2) include ground noise sources, and (3) be capable of analyzing multiple-source noise environments.

CORE STATEMENT OF NEED FOR FY 2004
COMPLIANCE – CPSON-04-02

IMPROVED METHODS AND MONITORING SYSTEMS FOR IMPULSE NOISE

OBJECTIVE: The objective of this Statement of Need (SON) is to solicit proposals to improve methods for monitoring and analysis of impulse noise. Specific attention should be focused on reducing the recording of false-positives, eliminating labor-intensive data analysis, improving diagnostic software, and providing the capability for date/time data queries, etc. Proposers are expected to understand the full range of noise emissions from military sources and the needed capability for noise monitoring systems. Routine testing and training range operations can generate complaints and damage claims from civilian communities around DoD installations. These claims can result in testing and training restrictions and expenditure of funds for damage.

The results of this project would provide a substantially improved system for monitoring impulse noise around military installations. The improvement of methods and monitoring systems will provide installations an accurate; less labor intensive and efficient means to manage testing and training impulse noise to verify or reject impulse noise complaints and damage claims. Current systems require time consuming and labor extensive data analysis.

BACKGROUND: The sustainability of testing and training ranges is a serious concern to the DoD. In 2001 the DoD Senior Readiness Oversight Council (SROC) examination of range sustainability identified nine key issues. Noise is one of the nine areas of concern. Residential and community growth present conflicts with our training and its associated noise. When installations were established, they generally were in rural areas, remote and isolated from population centers. Over time this has changed as communities have developed around military installations. The sum effect has been that installations, once far from public view, are now often in the midst of densely populated areas. Noise is one of the consequences of military training practices.

Impulse noise is a short duration event (typically less than one second), of high intensity onset and rapid decay, and often exhibits rapidly changing spectral composition. Impulse noise is characteristically associated with such sources as explosions, impacts, the discharge of large caliber weapons (20mm or greater), and sonic booms. Impulse noise monitoring is an important tool for assessing noise impacts from military training and testing activity. Noise sources of concern include large guns (artillery and armor) and explosions (charges, bombs, etc.). These sources have the majority of their acoustic energy at low frequencies, typically below 100 Hertz to as low as a few Hertz.

Wind impacts noise monitoring systems by inducing pressure fluctuations over a microphone or windscreen. These fluctuations produce signals with both temporal and spectral characteristics very similar to actual impulse noise events which result in thousands of false-positive events that obscure real events. This requires time consuming and labor intensive data analysis for individual event queries, self-diagnosis, web-based posting of monitoring data (public outreach), etc. Proposers are expected to develop a cost effective solution to improve installation noise monitoring systems by reducing false-positive events while maintaining accurate logging of real impulse noise events.

CORE STATEMENT OF NEED FOR FY 2004
COMPLIANCE – CPSON-04-03

CHARACTERIZATION AND PREDICTION OF POTENTIAL IMPACT OF MILITARY GENERATED NOISE ON STRUCTURES

OBJECTIVE: The objective of this Statement of Need (SON) is to solicit proposals to characterize, evaluate, and predict noise that is generated by military activity that may have a potentially adverse effect on structures. Proposals are being solicited to specifically advance the state-of-the-knowledge of impulse generated pressure waves by focusing on the following.

- Characterize the pressure waves that are generated by military activities which are propagated through air and/or ground that may affect structures. The conditions to be part of the characterization should include (1) the military sources, such as the variety of guns; (2) the atmospheric conditions, such as inversions and other focusing phenomena; (3) the ground conditions, such as the variety of soil, terrain and geologic conditions; and (4) the variety of structures, such as single-family homes, apartments, and commercial buildings.

- Evaluate the currently-used weighted peak sound level [decibel peak sound pressure (dBP)] that is used to predict vibration, annoyance and probable damage.

- Develop prediction models for assessment of military generated noise on structures.

Proposers are expected to understand the full range of noise emissions from military sources that produce structural vibration.

BACKGROUND: The sustainability of testing and training ranges is a serious concern to the DoD. In 2001 the DoD Senior Readiness Oversight Council (SROC) examination of range sustainability identified nine key issues. Noise is one of the nine areas of concern. Residential and community growth present conflicts with our training and its associated noise. When installations were established, they generally were in rural areas, remote and isolated from population centers. Over time this has changed as communities have developed around military installations. The sum effect has been that installations, once far from public view, are now often in the midst of densely populated areas. Noise is one of the consequences of military training practices.

Shaking of civilian houses by military impulse noise events is alleged to result from earth-borne vibration. Powerful sound waves emitted by military training activities such as firing large guns and detonation of explosives can travel long distances in the atmosphere. These waves can be clearly audible under some propagation conditions, and can even cause buildings to shake and rattle.

Currently dBP is used to evaluate vibration and the probability of damage. The Army has set a very conservative threshold for structural damage (broken windows and cracked plaster) at 136.4 dBP. The Window Manufactures Association of America has a threshold for window damage at 154 dBP. Although dBP has been found to be the best predictor of annoyance and vibration, there is limited scientific data to support the current dBP threshold in military noise evaluation. Without supporting data to correlate noise and vibration to annoyance and damage, the civilian community is reluctant to accept an installation's evaluation.

CORE STATEMENT OF NEED FOR FY 2004
COMPLIANCE – CPSON-04-04

PARTICULATE MATTER EMISSION FACTORS FOR DUST FROM UNIQUE MILITARY ACTIVITIES

OBJECTIVE: The objective of this Statement of Need (SON) is to solicit proposals to identify, characterize, and monitor the airborne emissions of particulate matter (PM) resulting from DoD testing/training activities related to tracked vehicles, fixed-wing aircraft, rotary-wing aircraft, and artillery. PM_{10} and $PM_{2.5}$ emissions need to be characterized for tracked vehicles, rotor and prop wash, and back blasts from range firing positions. Emission factors should be generated for each of these activities and situations and be made adaptable through modeling to localized conditions.

Proposals are being solicited specifically to advance the state-of-the-knowledge by focusing on one or all of the following.

- Determine PM emissions factors from training and operational activities at DoD installations, including quantifying of their variability and uncertainty. PM emissions should be characterized for specific representative activities related to tracked vehicle maneuvers, fixed-wing aircraft landing and take-off, rotary-wing aircraft moving near ground surface and blast emissions from artillery use. PM emissions factors shall be developed for a representative variety of soils and meteorological scenarios to facilitate planning of training and operational activities and to minimize contributions to regional haze or to operational signatures.

- If necessary to meet the above objective, develop or modify innovative instrumentation to identify, characterize, and monitor in real-time or near real-time, the airborne PM emissions resulting from DoD testing/training activities. This characterization should include chemical composition of PM and the distribution of chemical compositions as a function of source type and PM size.

- Develop model components that better describe the generation of the various types of PM listed above. The model components must provide linkage to EPA-approved air dispersion models in order to spatially analyze and display the contributions of natural and DoD-related sources of particulate matter. The model components must be compatible with available military land management and operational models. Dust models are being generated as a part of several SERDP projects. These models will be the basis for incorporation of dust information into existing land management models.

BACKGROUND: In 1997, EPA promulgated revisions to the National Ambient Air Quality Standards (NAAQS) for ozone and particulate matter and proposed regulations to address the impairment of long distance outdoor visibility resulting from regional haze which includes dust. DoD training and testing activities at installations across the U.S. often involve the movement of vehicles and personnel on unpaved surfaces, prescribed burning to clear brush and unwanted vegetation, as well as the use of smokes and obscurants for battlefield simulations. The proximity of installations engaged in training and testing activities to federal air quality class I areas raises a concern about the impact of the Regional Haze Rule on military training and readiness.

The Army Redbook indicates there are about 6,200 miles of roads and trails on Army installations and an equivalent 1200 miles of landing strips. Current costs of controlling dust range from $4,000 to $100,000 per linear mile. Current dust suppression techniques utilized by the Army include application of water, water-based chemicals, and gravel. These dust control techniques are not always effective. The dust generation can lead to non-compliance with state and regional haze and air quality regulations which in turn lead to curtailed or complete stoppage of field training.

CORE STATEMENT OF NEED FOR FY 2004
COMPLIANCE – CPSON-04-05

DEVELOPMENT OF EMISSIONS FACTORS FOR PARTICULATE MATTER (PM), NITROGEN OXIDES (NOx), AND AMBIENT AIR TOXIC COMPOUNDS EMITTED FROM MILITARY AIRCRAFT

OBJECTIVE: The objective of this statement of need is to develop emissions factors to characterize emissions of particulate matter (PM), nitrogen oxides (NOx), and trace air toxic compounds, especially persistent organic pollutants, generated by military aircraft gas turbine and turbo prop engines. Measurements should be made in as near real time as possible and at a high temporal rate. The chemical compounds for which emissions factors need to be developed include PM, NOx, and those urban air toxic (UAT) compounds and mobile source air toxics (MSAT) that are emitted by DoD activities/operations. An emission factor is defined by EPA as a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. They are expressed as a mass of pollutant per a unit volume, distance, or duration of an activity emitting the pollutant. Emission factors developed under this SON should be statistically representative of the DoD activities of concern with quantifiable estimates of their uncertainty.

BACKGROUND: Federal programs to address air toxics nationwide include the Integrated Urban Air Toxics Strategy (UATS), the Mobile Source Toxics Program, the National Air Toxics Assessment (NATA), and the Maximum Achievable Technology Control (MACT) residual risk program. In part, these programs will conduct a national assessment of air toxics, which may lead to mandates for individual source controls or overall air shed requirements for ambient air limits for air toxics. Accompanying the mobile source related sections of the Clean Air Act (CAA) are those sections that more generally focus on toxic release (TRI) emission inventories. Military installations are also required to adhere to Executive Order 12856, Emergency Planning and Community Right-To-Know (EPCRA) in which section 313 reporting requirements for TRI chemicals are accompanied by a goal to reduce releases and toxic chemical transfers by 50%.

Under the CAA Amendments of 1990, EPA is required to regulate emissions of 188 listed air toxics. EPA is currently conducting a National-Scale Air Toxics Assessment that, when complete, will include 33 air toxics that present the greatest threat to public health in the largest number of urban areas. Under the national Urban Air Toxics Strategy program (the Strategy) put forth by EPA (U.S. EPA, 1999), Section 112(k) of the CAA requires EPA to develop a strategy to identify and address risks to the public in urban areas via development of national standards for stationary and mobile sources to improve air quality. The CAA requires EPA to assure that sources accounting for 90 percent of the emissions of area source hazardous air pollutants (HAP) are subject to standards.

Information concerning EPA programs on air toxins may be found at: http://www.epa.gov/ttn/uatw. An overview of EPA's national effort to reduce air toxic substances, including stationary and mobile source standards is located at: http://www.epa.gov/ttn/uatw/urban/fr19jy99.pdf.

CORE STATEMENT OF NEED FOR FY 2004
CONSERVATION – CSSON-04-01

CONTROL OF NON-INDIGENOUS INVASIVE PLANT SPECIES AFFECTING MILITARY TESTING AND TRAINING ACTIVITIES

OBJECTIVE: The objective of this statement of need (SON) is to solicit proposals for developing new or improving existing methods for the control, reduction, and elimination of non-indigenous, invasive plant species while effectively protecting native species and their habitats on Department of Defense (DoD) installations. The scope of the proposed work must be targeted toward methods that specifically address the invasive plant issues while keeping in mind the integration of the ecological management and mission (i.e., testing and training) sustainment requirements of DoD lands.

Proposals responding to this SON will focus on (1) those invasive plant species that are impacting military training, testing, and other activities; and (2) the use of novel integrated control techniques including mechanical, chemical, and biological technologies and/or innovative land and ecosystem management practices.

Proposals must consider (1) the effects and risks of the proposed pest management schemes on threatened and endangered and at-risk species and their habitats including soil and groundwater; (2) the impacts and implications of other land management practices such as prescribed burning, timber management, and agricultural practices of the various land areas within an installation; and (3) the impact of the pest management practices on any training that may take place in the area. Certain management regimes require that areas not be entered for extended periods of time. For example, in areas where burning is employed, use of heavy vehicles may cause erosion before proper land cover is reestablished, and areas that receive pesticides or herbicides may be inaccessible until the application has dried out and is no longer toxic to non-target species.

BACKGROUND: The impact of non-indigenous invasive species on military operations is four-fold. First, expansion of invasive species can negate realistic conditions for training or testing operations. Second, invasive species are the second leading cause of habitat destruction. Third, operations to detect and control invasive species detract from devoting resources to mission activities. Fourth, some invasive species have physical characteristics that can directly limit training activities in areas where they exist.

Many non-indigenous invasive species have devastating impacts on ecosystems of all sizes and types. With few natural enemies, about 1% of non-indigenous (sometimes noxious and/or exotic) species are able to occupy suitable ecological niches, enabling them to spread rapidly, thereby infesting large areas. In the process, they devastate local plant communities by replacing native vegetation and by altering and degrading habitats of native flora and fauna. The presence and spread of non-indigenous invasive plants also present a serious problem for military training. For example, at Fort Hunter Liggett, the yellow star thistle (a noxious weed with ½ inch spines that reaches heights of over 6 feet tall) has invaded parachute landing zones thereby rendering those areas useless for military training.

In the development of control technologies for invasive plant species, extreme care must be taken in exercising these methods. Most herbicides are not specific to any one species or even one genus. Listed endangered and threatened plant species can be adversely affected by these chemical control methods. Even biological controls must be tested against closely related plants to ensure that the control of the noxious and invasive plant does not harm other plant species. Land management practices such as mechanical control (cutting and chain dragging) and fire must also be undertaken in a manner so as to not adversely affect protected plants and animals or their habitats.

CORE STATEMENT OF NEED FOR FY 2004
CONSERVATION – CSSON-04-02

MARINE MAMMAL BEHAVIORAL ECOLOGY AND PREDICTIVE MODELING

OBJECTIVE: The objective of this Statement of Need (SON) is to solicit proposals to determine the fundamental relationships of the physical, biological, and chemical ocean elements that define marine mammal habitat, and to understand how these elements contribute to marine mammal distribution and abundance. The ultimate objective is to be able to predict the location, distribution and abundance of marine mammals based on the determined precursors. The relative importance of the prediction of marine mammal location and abundance of the various species is dependent on the perceived threat to that species from Navy activities. Proposals responding to this SON should address some or all of the following four objectives. (1) Determine the relationships of unique features or properties of the physical, biological and chemical ocean environment and their contribution to the presence, distribution and abundance of marine mammal stocks. (2) Forecast the potential for phytoplankton bloom and the eventual development, growth and movement of prey that is closer in trophic level to marine mammals of interest. (3) Forecast the presence and abundance of marine mammal stock based on ecological factors, habitat and other aspects of their natural behavior. (4) In specified areas of DoD interest, determine the potential for marine mammal habitat changes and associated anthropogenic ecological effects induced by the use of relatively intense underwater sound over short intervals of time, up to use on a near continuous basis.

BACKGROUND: In 1994 the National Research Council identified a clear lack of understanding of how man-made underwater sound could affect marine mammals. Since then, there have been intense studies on this subject, with many issues yet to be resolved. The most effective form of mitigation for the Navy to minimize the potential impact to marine mammals from sound emitted from sonar systems is, when there is an option, to stay out of ocean areas heavily populated by marine mammals. The key to this approach is to know, with reasonable accuracy, where the marine mammals are likely to be.

One essential element that controls the accuracy and usefulness of a risk assessment of the affects of some man-made activity on marine mammals is knowledge of the species; their horizontal distribution and the abundance expected within the ocean region of concern. That ocean region can be several thousands of square miles in size, but usually is an area of about 60 by 60 nautical miles (at various locations). For some highly specialized Navy operations, the area of concern can be less than 100 square nautical miles. In all ocean regions, but particularly in the smaller regions of concern, the expected behavior of marine mammals in strata, along with the overall geographic location and abundance is also valuable, useful information. Presently marine mammal location and abundance data are generally derived from marine mammal survey data obtained from NOAA Fisheries. These data are usually coarse in nature, where the specifications of survey design and data analysis are formulated to assess gross estimates of the health of a marine mammal stock; i.e. are the populations increasing or decreasing. Rarely do these survey results contain associated ancillary physical, chemical or biological ocean data sufficient for habitat investigation.

Using marine mammal abundance data derived from surveys directly, for the purpose of risk assessment, is to overlook the probable changes to these data caused by the ever-changing ocean environment, sometimes in a dramatic fashion as in the case of the El Niño/Southern Oscillation. This situation is further exacerbated when marine mammal survey data from fisheries are used as a form of mitigation, where the objective is to minimize any potential impact by scheduling fleet training in ocean areas where marine mammal abundance is expected to be at a minimum. Marine mammal location and abundance data from surveys are statistical in nature and, unless matched with known habitat, or the physical elements that control habitat, cannot be expected to accurately or reasonably describe the presence and abundance of animals at a specific time and location of interest.

CORE STATEMENT OF NEED FOR FY 2004
CONSERVATION – CSSON-04-03

DEVELOPMENT OF INNOVATIVE INVENTORY AND MONITORING TECHNIQUES FOR HIGH PRIORITY THREATENED AND ENDANGERED SPECIES

OBJECTIVE: The objective of this Statement of Need (SON) is to develop new and innovative techniques for conducting inventory and monitoring of high priority, terrestrial threatened and endangered species on Department of Defense lands. It is anticipated that the techniques developed pursuant to this SON will result in reduced costs to conduct inventory and monitoring surveys of high priority listed species and/or improved accuracy of inventory and monitoring data. Techniques should be capable of being applied at the landscape scale in order to address inventory and monitoring programs at installations up to or exceeding 1 million acres in size. Inventory and monitoring techniques developed pursuant to this SON should be capable of providing population level and demographic data, in addition to confirming species presence or absence.

In order to achieve significant cost reduction, the technology developed should address species that are broadly distributed across numerous Department of Defense installations, species with more localized distribution for which inventory and monitoring costs are very high, or be applicable to multiple species. In addition, for the purposes of this SON, "high priority" species are identified as those that are currently causing, or those that have significant potential to cause, impacts to the training and testing mission of Department of Defense installations.

BACKGROUND: Federal agencies, including the Department of Defense, are required to comply with federal statutes dealing with threatened and endangered species. Most notable of these laws is the Endangered Species Act of 1973, as amended, which in addition to establishing a national policy to conserve threatened and endangered species, mandates that federal agencies take no action that is likely to compromise species covered under the Act.

Department of Defense lands have generally been managed to preserve their biological integrity. One measure of this is the fact that Department of Defense lands are inhabited by a greater number of listed species per acre than lands managed by any other federal agency. Even though the occurrence of these species on Department of Defense lands is well documented, the status of listed populations, and the relationship between population levels and training and testing activities is less well known. In the absence of credible scientific information, the US Fish and Wildlife Service, which administers the Endangered Species Act, has established limitations on training and testing on a number of installations in order to ensure conservation of listed species.

The Department of Defense must establish scientifically defensible inventory and monitoring programs in order to ensure compliance with the Endangered Species Act, verify the relation between population trends and its military training activities, enhance conservation of listed species, and improve access to its limited land base for training and testing purposes.

The costs involved with the inventorying and monitoring process can be prohibitive. For the red cockaded woodpecker, the Army is spending about $5M/year on management of this species, a large portion of which is inventorying and monitoring. Currently, the installation naturalists are individually banding 25% of the hatchlings every year. While there is an inventorying and monitoring method for desert tortoise that has been sanctioned by the USFWS, it is extremely expensive, and more importantly, based on inadequate science. Neither of the endangered species of bats has acceptable inventorying or monitoring methodologies, and due to a combination of broad distribution with low numbers, they represent the greatest technological challenge.

CORE STATEMENT OF NEED FOR FY 2004
CONSERVATION – CSSON-04-04

QUANTIFYING PHYSIOLOGICAL STRESS IN THREATENED AND ENDANGERED SPECIES DUE TO MILITARY ACTIVITIES

OBJECTIVE: The objective of this Statement of Need (SON) is to develop methods or technologies to identify and measure appropriate physiological indicators of stress in terrestrial threatened and endangered species (animal or plant) due to potential disturbance from military operations. Direct impact from military operations on threatened or endangered species and indirect impact through changes in supporting habitats are both of concern. Proposals are sought that investigate (1) identification of appropriate physiological indicators; (2) response of these indicators to military related activities versus non-military related activities; and (3) the relationship between physiological indicators of stress and more traditional endpoints such as individual or population fitness. Additional detail in each of these three areas is listed below.

- Physiological indicators in wild populations of threatened or endangered species which are appropriate for measuring stress due to military training, testing, land management and operational activities are needed. Several physiological indicators of stress have been identified at the cellular and organismal level including, but not limited to, molecular markers (e.g., ATP and mRNA abundance in invertebrates), reproductive suppression in both plants and animals, adrenocortical response, sympathetic-adrenal medullary response, and heart rate, among others. Proposed work under this SON may identify and quantify appropriate indicators or combinations of indicators of stress response or provide improved methods that are measurable, cost-effective, and applicable across taxonomic groups in wild populations and that do not have long-term deleterious effects on sampled individuals.

- Response of physiological indicators of stress to potential disturbance from activities associated with military training, testing, land management and operational activities are needed. Proposed work in response to this SON may identify and quantify those physiological measures that are likely to be elicited by disturbances associated with military or support activities. Proposed work may evaluate variance in physiological response due to military-related disturbances relative to variances attributable to natural environmental or biological factors.

- Relationship between measures of physiological stress and measures of individual fitness (e.g. reproductive success, return rates, survival) that ultimately determine persistence and recovery of endangered species populations and their habitats are needed. Proposed work may provide empirical data or predictive models or a combination of both to provide a framework for evaluating the biological significance of physiological measures of stress in response to military activities in terms of individual fitness and population conservation and recovery.

BACKGROUND: Federal agencies, including the Department of Defense, are required to comply with federal statutes dealing with threatened and endangered species. Most notable of these laws is the Endangered Species Act of 1973, as amended, which in addition to establishing a national policy to conserve threatened and endangered species, mandates that federal agencies take no action that is likely to compromise species covered under the Act. Mission critical military training and testing has been impacted by known, unknown, or potential impacts on threatened and endangered species. In many cases, insufficient information and/or inadequate technology or techniques are available to identify or establish if and/or what effects or impacts may exist as a result of military training activities. Specific military training activities of concern have been identified and include aircraft, vehicle and munitions noise, habitat and behavioral disturbance from military vehicles and personnel, and chemical contaminants.

CORE STATEMENT OF NEED FOR FY 2004
CONSERVATION – CSSON-04-05

DEVELOPING TERRESTRIAL PRODUCTIVITY MEASURES AND A CARBON BUDGET FOR THE FORT BENNING ECOSYSTEMS

OBJECTIVE: The objective of this statement of work is to apply available data for Fort Benning, Georgia, to the development of terrestrial productivity measures and carbon budget for the Fort Benning area. This would require the proposers to synthesize productivity and carbon budget data for the installation using the biomass, productivity and carbon data from various research projects in and around Fort Benning and from forest and vegetation inventories performed at the installation. Overall, the objectives of this effort are (1) to develop two or more 'watershed / mesoscale' landscape status indicators, based upon existing data that provide an estimate of net ecosystem production (NEP) and a carbon budget analysis, relevant to the status of the Fort Benning ecosystems and their carbon sequestration potential; (2) to consider the sensitivity of these "indicators" to land use types and land management activities both on and off the installation lands; and (3) to provide technical documentation regarding the data requirements and analytical steps, including data transformations and alignment of data sets with different scales, required to obtain both the carbon budget and the net ecosystem production indicators, so that similar analyses might be conducted at other military sites. All objectives must be addressed as part of the proposed work, though the comparison of installation to regional indicators (second objective) is of lesser priority than the other objectives. It is not the objective of this statement of need to develop completely new carbon budget cycle models during the analysis of the data.

BACKGROUND: In 1997, the SERDP Program Office sponsored a workshop entitled Management-Scale Ecosystem Research. The workshop attendees, which included many leading academics in ecosystem management as well as several DoD staff, examined the potential feasibility and value of conducting ecosystem research on DoD facilities, and identified a set of key research themes that would both contribute to DoD operations and to ecosystem management science. These themes included ecosystem health (or status); disturbance as a key; ecological thresholds; biogeochemical cycles (and their historic range of variance); knowledge gaps in habitat restoration; and space and time variables in restoration and management. After this workshop, SERDP established a new project, entitled the SERDP Ecosystem Management Project (SEMP). (website https://www.denix.osd.mil/SEMP) Ft. Benning was selected as the initial host site for SEMP research, and three research projects were initiated, with field data collection beginning in 1999, related to ecosystem health (or status) indicators. Also, a long term monitoring program was initiated that same year. Then, in 2000, two additional projects were initiated, relating to "disturbance" thresholds from land use and management activities. The monitoring program and the five research projects all contribute to a common data repository, as well as other projects that have been sponsored by SERDP or the host site, including a project on riparian restoration approaches. SEMP research has produced substantial data on productivity and carbon components of the ecosystems.

While many of the existing projects have collected biogeochemical data, this solicitation represents the first SEMP project focused specifically on understanding biogeochemical cycles. From this relatively rich SEMP carbon and productivity database, which is available in a data repository, the priority is to derive a landscape scale carbon budget and net ecosystem production. Results from stream monitoring research may also lend themselves to this carbon budget integration. Although a considerable quantity of carbon biomass and soil data is available from the SEMP activity, it is expected nonetheless that carbon cycle models (and/or other analysis tools) will be needed to complete the synthesis. One or more functional carbon models of the ecosystems are expected to guide integration of field data and organize and process information. Thus, those proposing to perform the synthesis will need to use existing state-of-the-art carbon cycle models. The second purpose is to identify the key variables of the carbon cycle budget and the net ecosystem production analysis, and determine how Fort Benning management activities, or other ecosystem attributes, might impact these indicators.

CORE STATEMENT OF NEED FOR FY 2004
POLLUTION PREVENTION – PPSON-04-01

ALTERNATIVES FOR AMMONIUM PERCHLORATE IN DOD MISSILE PROPULSION APPLICATIONS

OBJECTIVE: The objective of this program is to develop environmentally benign solid rocket propulsion technologies which do not rely on the use of ammonium perchlorate as an oxidizer. The ultimate objective of this program is to eliminate/reduce future groundwater contamination by ammonium perchlorate (AP) by eliminating the need for the production and use of AP as an oxidizer in solid rocket motors. Proposed technologies must ultimately be capable of meeting or exceeding current DoD-required performance criteria for solid rocket propellants. They must be able to meet or exceed current safety and performance requirements and offer significantly reduced environmental impact. Human health and ecological considerations during the lifecycle of the propellant and during ingredient manufacture must be addressed. It is recognized that there are no known drop-in replacements for AP.

The following guidelines must also be considered. (1) The production of the alternative oxidizer/propellant system must have the potential to be more environmentally benign than the current AP based propellant production processes. (2) The presence of unburned propellant, such as may be found in test and impact areas, must be environmentally benign. (3) The combustion products must be environmentally benign. (4) Anticipated future propellant cost should be competitive with current systems.

BACKGROUND: Perchlorate is the major component in AP that is used as an oxidizing component in most solid rocket propellants. It has been estimated that over 24,000,000 lb of AP is produced each year. This material is used in a great many tactical and strategic systems. There were over 7,400 solid composite rockets and missiles procured in FY99 with range of 10 pounds to 345 pounds of propellant per item.

AP is extremely soluble in water, mobile in subsurface aqueous systems and readily contaminates surface and ground waters in and around manufacturing, processing, and testing facilities if released. It is chemically stable and is able to persist for decades under typical ground water and surface water conditions.

In early 1997, the California's Department of Health Services (DHS) Drinking Water Program first found inorganic perchlorate in some drinking water wells in northern California. Since then, inorganic perchlorates have been discovered in the ground waters and surface waters in several states, including northern and southern California, Nevada, Arizona, Utah, and Texas. The majority of these locations are in California, and are associated with active or formerly active facilities that manufactured or tested solid rocket fuels for the Defense energetic materials community. It has been estimated that AP contamination of groundwater impacts 12 million people in the states of Nevada, California, and Arizona. Perchlorate contamination is of great concern because of its ability to disrupt the endocrine system by inhibiting iodide anion uptake by the thyroid. The mounting weight of the evidence of the extent of perchlorate contamination and the potential human health effects, have prompted EPA to add perchlorate to its Contaminant Candidate List. State regulators have also acted, with the California Department of Health Services adopting an action level for perchlorate in drinking water of 18 g/liter, or ppb. The member countries of the European Community have adopted a maximum admissible guide level of 20 g/liter for sodium perchlorate for drinking water, corresponding to approximately 16 g/liter for ammonium perchlorate.

There are currently no known drop-in replacements for AP, while alternative energetic oxidizers (such as ammonium nitrate (AN), ammonium dinitramide (AND), and hydrazinium nitroformate (HNF)) exist, significant cost, availability, stability and performance issues remain that prevent their use in fielded weapon systems and launch vehicles. Each rocket or missile system has unique performance requirements that will require consideration when attempting to replace the AP.

CORE STATEMENT OF NEED FOR FY 2004
POLLUTION PREVENTION – PPSON-04-02

ENVIRONMENTALLY BENIGN ALTERNATIVE FOR CADMIUM PLATING ON HIGH STRENGTH STEELS

OBJECTIVE: The objective of the proposed work is to develop an environmentally benign cadmium plating alternative for use in high-strength (greater than 180ksi) steel applications on DoD weapon systems. Potential applications include but are not limited to high strength fasteners, pneumatic/hydraulic actuator rods and cylinders, and aircraft engine attach points, thrust pins, and torsion links. Alternative coatings, materials treatments or new materials are all of interest. The proposed alternative must provide corrosion protection for high-strength steels that is equal to or exceeds that provided by the currently used cadmium coatings. In addition, coatings must adhere to substrates as well as or better than electroplated cadmium and not gall if used in threaded applications. Alternative coatings must have a surface that provides adhesion for existing DoD paints/coatings and be compatible with the normal aerospace operational chemicals. Alternative materials or processes must not introduce hydrogen embrittlement/re-embrittlement or otherwise negatively impact the properties or performance of the substrate material, i.e., fatigue.

The proposed research must address technical performance, production, material and operational support costs and environmental safety occupational health (ESOH) issues from a systems perspective. Additionally, the candidate process, if a coating or deposition process, must demonstrate the ability to coat non-line-of-sight components/parts/surfaces. The inner diameter of aircraft landing gear outer cylinders is one example of a specific potential application. Emphasis should also be placed on minimizing processing equipment requirements and the use of part-specific equipment, such as conforming anodes. Ideally, alternatives must equal or improve current material coating performance, production throughput, maintainability, reparability, and cost.

BACKGROUND: Cadmium is a metal found in natural deposits as ores containing other elements such as zinc, lead, and copper. It is used primarily in electroplating, coating operations, batteries, pigments, stabilizers for plastics, nuclear reactor rods, and as a catalyst. Cadmium ores can serve as contamination sources for ground and surface waters, especially when leached by soft, acidic waters. Major industrial releases of cadmium are often due to leaching of landfills, and from waste streams associated with a variety of operations that involve cadmium or zinc. Once these compounds leach through soils into groundwater, they can bind to river sediment where they can bioaccumulate or re-dissolve. Cadmium does not break down in the environment. It forms compounds and has the potential to accumulate in the food chain. Cadmium is a carcinogen, a teratogen, and causes reproductive damage in humans and animals.

Electrodeposits of cadmium are used extensively to protect steel against corrosion. Because cadmium is anodic to iron, the underlying ferrous metal is protected at the expense of the cadmium plate, even though the cadmium may become scratched or nicked, exposing the substrate. Cadmium is usually applied as a thin coating intended to withstand atmospheric corrosion. It is seldom used as an undercoating for other metals, and its resistance to corrosion by most chemicals is low. It is frequently used to coat moving parts and threaded fasteners and assemblies that are made up of dissimilar metals because of its ability to minimize galvanic corrosion. Its excellent solderability is advantageous in many electronic applications.

The DoD currently uses ion vapor deposition (IVD) aluminum as a cadmium alternative for sacrificial corrosion protection in many high-strength steel applications. However, IVD coating is not usable for non-line-of-sight or complex geometries and chamber size and processing times limit its utility. Other alternatives such as electroplated tin-zinc or nickel-tin also have limitations. Proposals should attempt to develop a long term solution that meets or exceeds the performance requirements established for Cd plating, provide a distinct advantage in range and ease of applicability over the current Cd replacement technologies, and be implemented without a significant cost or ESOH penalty.

CORE STATEMENT OF NEED FOR FY 2004
POLLUTION PREVENTION – PPSON-04-03

ALTERNATIVES FOR CLASS II OZONE DEPLETING SUBSTANCE SOLVENTS FOR DOD PRECISION CLEANING APPLICATIONS

OBJECTIVE: The objective of this Statement of Need (SON) is to develop non-ozone depleting, zero HAP, low VOC, non-hazardous materials or processes for precision cleaning DoD systems. Specifically, the goal of this research is to develop qualified replacements for HCFC-141b and other Class II ODS cleaners used for precision cleaning of DoD parts. Areas of research may address the development of alternative cleaning chemistries or the development of process alternatives for parts and cleaning. If alternative chemistries are identified in the proposal, the proposal must include a discussion of the environmental merit of the selection.

Proposed materials and processes must be addressed from a systems level and exhibit lower life cycle environmental impact than current processes. Depot support issues (maintenance and repair) and systems' applications must be considered in the proposed effort. Baselines in materials types, quantities, costs, and environmental impact must be established and tracked during the development effort. Proposed efforts claiming environmental cost savings shall include a preliminary cost analysis focused on actual or realistic future applications and use/compliance requirements for the technology on DoD systems.

BACKGROUND: DoD uses Class II ODS aerosol cleaners such as HCFC-141b during maintenance and repair processes on many weapon systems. Cleaning is typically accomplished to remove contaminants from electronic/avionic and liquid/gaseous oxygen components/systems. HCFC-141b is used because it is non-flammable, evaporates quickly and is residue-free. It is also compatible with most DoD substrates and liquid oxygen systems.

HCFC-141b is a hydrochlorofluorocarbon classified as a Class II Ozone Depleting Substance. The EPA has established a manufacturing and import ban on HCFC-141b effective 1 January 2003.

Electronic/avionic and oxygen system component cleaning is accomplished by spraying HCFC-141b from a pressurized aerosol can onto the surface being cleaned to flush contaminants away. The combination of the solvent action of the HCFC-141b and the pressure stream from the aerosol, combine to flush the contaminants off the surface. Occasionally, mechanical agitation of the surface is also required to remove stubborn contaminants. The components are then allowed to air dry. Typical electronic/avionic components cleaned in this manner are electrical contacts and connectors, contact switches, circuit cards, bearings and various other components. Typical contaminants removed include dirt, moisture, natural or synthetic oils or greases, corrosion products and carbon dust. Oxygen system components cleaned include regulators and gauges, servicing ports and tubing. Primary contaminants of concern are petroleum-based oils and greases, which will cause explosions or fire when in contact with liquid oxygen. Without viable alternatives for these processes, many users are contemplating returning to CFC-113 for liquid oxygen system component cleaning.

CORE STATEMENT OF NEED FOR FY 2004
POLLUTION PREVENTION – PPSON-04-04

ENVIRONMENTALLY ACCEPTABLE INCENDIARY COMPOSITIONS FOR MEDIUM CALIBER AMMUNITION

OBJECTIVE: The objective of this Statement of Need is to develop alternative chemistries to eliminate the use of toxic, heavy metals and volatile organic chemicals (VOC) that are currently used in the manufacture of incendiary compositions for medium caliber (20mm - 60mm) ammunition applications. Proposals shall address technologies, methods, or processes that (1) develop or evaluate the use of alternative fuels and/or oxidizers that are environmentally benign and (2) eliminate or minimize the use of VOCs in the manufacturing process of incendiary materials.

New compositions must provide equivalent or increased levels of performance compared to current formulations. The development of environmentally benign incendiary compositions will result in a significant reduction in the release of hazardous/toxic materials and VOCs during manufacture and use of incendiaries in medium caliber munitions.

BACKGROUND: Incendiary compositions are physical mixtures of finely powdered compounds and elements. The main constituents are (1) oxidizing agents such as chlorates, perchlorates, nitrates, peroxides, oxides, and chromates; (2) fuels such as powdered metals, silicon, boron, sulfur, hydrides, and sugar; and (3) binders and color intensifiers, which are usually organic compounds. These include highly chlorinated organic compounds such as hexachloroethane, hexachlorobenzene, polyvinylchloride, and dechlorane. The binding agents, consisting of resins, waxes, and polymers, are added to prevent segregation and to obtain more uniformly blended compositions. In addition, they serve to make finely divided particles adhere to each other when compressed and help to obtain maximum burning efficiency. Burning rates are exceptionally important in applications utilizing incendiaries as initiating explosives, replacing mechanical fuzing and providing an inherent delay. When in contact with a fuel such as finely powdered metals of magnesium, magnesium-aluminum alloys, and zirconium, the fueling agent acts as a vigorous oxidizing agent producing an exothermal chemical reaction resulting in the formation of its corresponding oxides and the evolution of significant heat and radiant energy. The incendiary material must not only produce hot particles and gases but must also be impact sensitive so as to reliably react on projectile target impact. While highly effective, the heavy metals such as barium, antimony, and lead have been identified as hazardous materials and should be eliminated from all ammunition with suitable replacements introduced. When ignited, these pyrotechnic mixtures readily undergo an exothermal reaction that generates considerable energy in a short period of time. The heat of reaction for pyrotechnic compositions ranges from approximately 200 to 2500 calories per gram. The energy produced is released as heat and light with temperatures ranging from 1000 degrees C to 3500 degrees C.

Pyrotechnic incendiary compositions are also hazardous because of their toxicity and sensitivity. Barium nitrate and antimony sulfide are moderately poisonous materials that can irritate the mucous membranes and the skin producing dermatitis and eye, nose and ear irritation. When heated, the toxic fumes may produce gastrointestinal irritation. Safe disposal of pyrotechnic ingredients is a problem because of the flammable, explosive, or toxic nature of these materials. To minimize the problem, it is necessary to segregate wastes, with the ultimate disposal carried out in strict accordance with the local operating procedures for each laboratory or plant. Approximately 2500 pounds of antimony sulfide and barium nitrate waste are being generated in medium caliber ammunition annually requiring safe disposal. The proposed effort should reduce toxic emissions and minimize hazardous waste streams.

CORE STATEMENT OF NEED FOR FY 2004
POLLUTION PREVENTION – PPSON-04-05

ELIMINATION OF REDWATER FROM TNT MANUFACTURE

OBJECTIVE: The objective of this Statement of Need is to develop a relatively environmentally benign synthesis route to manufacture military grade trinitrotoluene (TNT). Specifically, the proposed process must not generate redwater and should minimize the generation of other hazardous or toxic byproducts. Development of an environmentally benign synthesis route for TNT will enable the U. S. to produce TNT without the need to treat redwater. Approximately 0.5 pound of redwater is generated for each pound of TNT produced.

BACKGROUND: Trinitrotoluene (TNT) is the common designation for symmetrical 2,4,6-trinitrotoluene. TNT is produced by the nitration of toluene with nitric acid in the presence of sulfuric acid. Until recently, it was produced at the Radford Army Ammunition Plant (RAAP). The RAAP process utilized 99% nitric acid and 44% oleum to nitrate toluene in six stages to crude TNT. Along with the symmetrical isomer, unsymmetrical isomers, including dinitrotoluene (DNT), are also found in crude TNT. The crude TNT is then subjected to purification with aqueous sodium sulfate. The purification process consists of two acid washes, three sellite washes and two post-sellite washes.

Wastes associated with the production of TNT include nitrobodies and red water. Nitrobodies include TNT, other unsymmetrical isomers, products from the sellite purification process and by-products from the production process. Sellite washings are high in solids content and are commonly referred to as “red water.” Red water is generated during the purification of TNT. It is not amenable to purification and is considered a hazardous waste by the Environmental Protection Agency. As with any hazardous waste, red water requires treatment and deactivation prior to being discharged. The TNT plant at RAAP is presently inactive due to red water problems. Air emissions from the nitrators, containing various oxides of nitrogen and some toluene, are passed through a fume recovery system to extract NOx as nitric acid and then vented through scrubbers to the atmosphere. Final emissions contain quantities of unabsorbed NOx and trinitromethane (TNM).

In the past, the DoD sold the concentrated red water to the paper industry or burned it in rotary kilns to produce an ash. The paper industry no longer wants TNT red water and the ash from incineration does not pass the EPA leachate test. There currently is no acceptable technology to treat red water.

CORE STATEMENT OF NEED FOR FY 2004
UNEXPLODED ORDNANCE – UXSON-04-01

ADVANCED APPROACHES TO UNEXPLODED ORDNANCE (UXO) DETECTION AND DISCRIMINATION

OBJECTIVE: The goal of this Statement of Need (SON) is to develop technologies that will provide new solutions to the diverse detection and discrimination problems of UXO-contaminated land sites. Proposals under this SON may address the development of new sensors, platforms (including hand-held, man-portable, vehicular and airborne), discrimination techniques, or signal processing approaches. Proposals may also address improved technologies to support detection and discrimination efforts through navigation, geo-location or hazard assessments associated with erosion, migration of ordnance, frost heave, and the like. Advances are needed in all aspects of the procedures for the detection and discrimination of UXO. Capabilities are needed for a wide variety of site conditions, including those with difficult geology, terrain and vegetation, and complex ordnance and clutter distributions. Many sites or sections of sites have sparsely distributed subsurface ordnance and clutter items that can clearly be separated, while other areas have almost continuously overlapping suspected items, which need to be assessed. The research and development proposed under this SON should provide innovative advancements that (1) develop system capabilities to perform rapid assessments of large area sites and (2) develop capabilities to provide detailed site characterization.

Large areas across the United States are potentially contaminated with UXO. A methodology is needed to locate concentrations of UXO, locate areas that can be determined free of UXO with high confidence, and reduce the area required for intensive and intrusive surveys. Such a methodology can enhance the overall management of large sites and significantly reduce the cost of site characterization. Current airborne technologies (helicopter based magnetometry) provide the capability to assess open, flat terrain and to detect large individual ordnance items where sensors may be flown at very low altitudes (2 meters). There is a need to develop systems with significantly enhanced capabilities over these existing systems.

A system is needed to detect individual ordnance items for excavation and disposal. Increased detection probabilities, reduced false alarm rates, and better characterization and discrimination of subsurface UXO can significantly reduce the residual risks and costs of response, and allow more rapid and safer transfer of land. The greatest cost savings can be achieved by eliminating the cost associated with excavating non-ordnance items. Production surveys require ground based vehicle, man-portable and hand held platforms, and may be achievable by airborne platforms on some sites. Vehicle systems that can operate in open areas should survey tens of acres per day. Man-portable and handheld systems are required for areas inaccessible because of terrain or vegetation and should survey acres per day.

BACKGROUND: As a result of past military training and weapons testing activities, UXO is present at sites designated for Base Realignment and Closure (BRAC), at Formerly Used Defense Sites (FUDS) and other closed ranges. The detection and remediation of UXO at closed, transferred and transferring (CTT) ranges, munitions burning and open detonation areas, and burial pits is one of the DoD's most pressing environmental problems. The UXO characterization and remediation activities conducted at DoD sites using currently available technology often yield unsatisfactory results and are extremely expensive, due mainly to the inability of current technology to detect all UXO that may be present at a site and the inability to discriminate between UXO and non-hazardous items. Field experience indicates that often in excess of 90% of objects excavated in the course of a UXO remediation are found to be non-hazardous items (false alarms). As a result, most of the costs to remediate a UXO site are currently spent on excavating targets that pose no threat. The UXO remediation technology program seeks to both maximize the probability of detection and minimize the false alarm rate. The goal is to meet the highest probability of detection desired (near 100%) at each site while reducing the false alarm rate by a factor of up to 100 for highly cluttered sites.

CORE STATEMENT OF NEED FOR FY 2004
UNEXPLODED ORDNANCE – UXSON-04-02

INNOVATIVE TECHNOLOGY FOR IDENTIFICATION OF FILLER MATERIAL IN RECOVERED UNEXPLODED ORDNANCE

OBJECTIVE: The goal of this Statement of Need (SON) is to develop technologies that will provide new solutions to determine explosive hazards posed by unexploded ordnance. Proposals submitted under this SON may be aimed at developing new sensors or signal processing techniques. Primary interest is in technologies applicable to items that have been detected and partially or completely uncovered. Items of interest range from 20-mm projectiles to 2000-lb. bombs.

The task of this system is to correctly identify suspected items as live explosives or inert in as non-intrusive, timely, cost-effective way. The majority of items found on the surface, excavated, partially exposed, or identified for excavation by a production survey often pose no risk. Due to age and condition, unknown items often must be treated as though they contained high explosives or other hazardous material. Often items are not determined to be inert until they have been detonated where they were found, a practice referred to as "blow in place." This leads to unnecessary potential impacts to the environment and communities, as well as costs that could be potentially avoided. Positive identification of subsurface anomalies is currently accomplished by excavation and inspection. Systems that could improve identification of suspected anomalies or partially exposed items during excavation have the potential to significantly lower both the risks to personnel and costs. To be useful, systems must be competitive with manual inspection and blow-in-place in terms of manpower, time requirements, and risk, as well as provide very high reliability.

BACKGROUND: As a result of past military training and weapons testing activities, UXO is present at sites designated for Base Realignment and Closure (BRAC), at Formerly Used Defense Sites (FUDS) and other closed ranges. The detection and remediation of UXO at closed, transferred and transferring (CTT) ranges, munitions burning and open detonation areas, and burial pits is the one of the DoD's most pressing environmental problems. The UXO characterization and remediation activities conducted at DoD sites using currently available technology often yield unsatisfactory results and are extremely expensive, due mainly to the inability of current technology to detect all UXO that may be present at a site and the inability to discriminate between UXO and non-hazardous items. Field experience indicates that often in excess of 90% of objects excavated in the course of a UXO remediation are found to be non-hazardous items (false alarms). As a result, most of the costs to remediate a UXO site are currently spent on excavating targets that pose no threat.

The UXO remediation technology program seeks to both maximize the probability of detection and minimize the false alarm rate. The goal is to meet the highest probability of detection desired (near 100%) at each site while reducing the false alarm rate by a factor of up to 100 for highly cluttered sites. These two metrics are closely coupled and must be tackled jointly. In all technology objectives, the DoD UXO RDT&E program is striving to provide tools and full visibility to site managers, regulators and communities concerning the expected performance and associated cost and impact for any cleanup decision.

CORE STATEMENT OF NEED FOR FY 2004
UNEXPLODED ORDNANCE – UXSON-04-03

SITE CHARACTERIZATION AND REMEDIATION TECHNOLOGIES FOR UNEXPLODED ORDNANCE (UXO)-CONTAMINATED UNDERWATER SITES

OBJECTIVE: The objective of this statement of need is to develop technologies to support characterization and/or remediation actions for unexploded ordnance found on underwater sites. Research and development proposals should focus on (1) novel engineering-based techniques or platforms that overcome the access limitations for locating UXO present in underwater locations (e.g. coastal areas, marine sediments, harbors, estuaries, lakes, ponds and wetlands); (2) improved sensors or signal processing to aid in detection and discrimination in underwater UXO-contaminated areas; (3) characterization and phenomenology of underwater UXO, including migration and depth of burial in various underwater environments; and/or (4) removal and disposal techniques for underwater UXO.

Modern geophysical surveying techniques can effectively be used to characterize sites potentially contaminated with UXO on dry land. For easily accessible sites where signatures are sparse and anomalies are spatially isolated, these tools can guide detection-driven remediation activities and in some cases can effectively screen clutter from ordnance. However, many sites contain UXO underwater, where the environment restricts established and emerging characterization and remediation alternatives.

To direct remediation efforts appropriately and to clean underwater UXO areas reliably, SERDP intends to develop techniques that provide reliable target detection and discrimination, and remediation tools that can cost effectively and safely remove or dispose of UXO. The primary interest of the program is to address UXO that is accessible to people and presents a potential hazard. As such, technologies appropriate for the shallow water (15-60 feet) and very shallow water (<15 feet) environments will be favored.

BACKGROUND: As a result of past military training and weapons testing activities, UXO is present at sites designated for base realignment and closure (BRAC) and at Formerly Used Defense Sites (FUDS). Particularly difficult is the characterization and remediation of those sites where UXO is found in underwater environments. Presently, there exists (1) no effective capability to survey these underwater areas and map the location of UXO for site characterization, (2) little understanding of the UXO or clutter characteristics from which to establish performance requirements, and (3) limited removal and disposal techniques that could be expanded or improved. Factors such as small target size, target burial, shallow water, environmental noise (as from surface waves and reverberation), and water turbidity all impact sensor performance, while the submerged nature of the UXO impedes access.

Many active and former military installations have ordnance ranges and training areas that include adjacent water environments such as ponds, lakes, rivers, estuaries, and coastal ocean areas. Wartime activities, dumping, and accidents have also generated significant unexploded ordnance (UXO) contamination in the coastal and inland waters in the United States and abroad. Dredging projects frequently encounter UXO.

The problem of underwater UXO contamination has commanded more attention in island and coastal nations overseas than in the United States. In these countries, where the ratio of underwater land area to surface land area is higher, the sea floor represents a proportionally greater resource. Frequently, wartime activity was directed at stopping sea commerce, resulting in significant UXO contamination in economically important areas, such as harbors and channels. Much of the U.S. underwater contamination has occurred near military practice and test ranges, which tend to be remotely located with minimal direct economic impact. Thus, clean up efforts at FUDS sites have typically ended at the water's edge. However, sites that were remote 50 years ago are often no longer so, and potential hazards to the public from encounters with underwater ordnance are beginning to arise.

APPENDIX G
List of Acronyms

2ADNT	2-amino-4,6-dinitrotoluene
2,4DANT	2,4-diamino-6-nitrotoluene
2,6DANT	2,6-diamino-4-nitrotoluene
3D	three-dimensional
3DSMF	Three-Dimensional Steerable Magnetic Field
4ADNT	4-amino-2,6-dinitrotoluene
AAR	Annular After Reactor
AATDF	Advanced Applied Technology Demonstration Facility
AEM	active electromagnetic
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AFP	Amplifying Fluorescent Polymer
AFSM	Alternative Future Scenario Modeling
AN	ammonium nitrate
AND	ammonium dinitramide
AP	Ammonium Perchlorate
APG	Aberdeen Proving Ground
APIMS	Air Permit Information Management System
ARDEC	U.S. Army's Research Development and Engineering Center
ARP	Autonomous Recording Package
As	Arsenic
ATC	Aberdeen Test Center
ATOFMS	Aerosol Time of Flight Mass Spectrometer
ATTACC	Army Training and Testing Area Carrying Capacity
B-IBI	Benthic Index of Biotic Integrity
BAA	Broad Agency Announcement
BCVI	Black-Capped Vireo
BMP	best management practice
BRAC	Base Realignment and Closure
CAA	Clean Air Act
CAAA	Clean Air Act Amendments
CAH	Chlorinated Aliphatic Hydrocarbon
CARB	California Air Resources Board
CATS	controlled archaeological test site
CCC	Chromate Conversion Coating
Cd	Cadmium
CE	Capillary Electrophoresis
CER	Consolidated Emissions Reporting
CFD	Computational Fluid Dynamics
CMS	Cylindrical Magnetron Sputtering
CO	Carbon Monoxide
CP	Compliance (thrust area)
CP	Conductive Polymer
Cr	Chromium

Cr^{+6}	Hexavalent chromium
CRADA	Cooperative Research and Development Agreement
CS	Conservation (thrust area)
CSM	conceptual site model
CSS	Coastal Systems Station
CTT	Closed, Transferred and Transferring
Cu	Copper
CU	Cleanup (thrust area)
CWA	Clean Water Act
CWT	Continuous Wavelet Transform
DAQ	data-acquisition
DARPA	Defense Advanced Research Projects Agency
DC	Direct Current
DCE	Dichloroethene
DDR&E	Director, Defense Research and Engineering
DEQ	Department of Environmental Quality
DHANT	2,4-dihydroxylaminotoluene
DHR	Directional Hemispherical Reflectance
DHS	Department of Health Services
DMA	differential mobility analyzer
DNAPL	Dense Non-Aqueous Phase Liquid
DNB	dinitrobenzene
DNT	Dinitrotoluene
DNTS	Dover National Test Site
DOC	dissolved organic carbon
DoD	Department of Defense
DPA	Diphenylamine
DPRB	dissimilatory perchlorate-reducing bacteria
DPV	Diver Propulsion Vehicle
DTAP	Defense Technology Area Plan
DTIC	Defense Technical Information Center
DTO	Defense Technology Objective
DUSD(I&E)	Deputy Under Secretary of Defense for Installations and Environment
DWT	Discrete Wavelet Transform
EAE	Environmentally Acceptable Endpoint
ECD	electrochemical detector
ECMI	Ecosystem Characterization and Monitoring Initiative
eco-SSL	ecological soil screening level
ECRS	Experiment Controlled Release System
EDYS	Ecological Dynamics Simulation
EI	Emissions Index
EIS	environmental impact statement
EIS	Electrochemical Impedance Spectroscopy
EM	Electromagnetic
EM	energetic material
EMI	Electromagnetic Induction
EMIS	EM induction spectroscopy
EMSP	Environmental Management Science Program
EO	Executive Order
EOD	Explosive Ordinance Disposal

EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-To-Know
ERC	explosive-related compound
ERDC	Engineer Research and Development Center
ESA	Endangered Species Act
ESD	Electro-Spark Deposition
ESOH	Environmental, Safety, and Occupational Health
ESTCP	Environmental Security Technology Certification Program
EWG	Executive Working Group
FC	Fort Carson
FDEM	frequency domain
FDP	Fluorescent Dye Penetrant
FISH	Fluorescent In-situ Hybridization
FMI	Foster-Miller, Inc.
FR	Fouling Release
FTIR	Fourier Transform Infrared Reflectance
FUDS	Formerly Used Defense Sites
GA	genetic algorithm
GAC	granular activated carbon
GCWA	Golden-Cheeked Warbler
GIS	Geographic Information System
GMS	Groundwater Modeling System
GPR	Ground-Penetrating Radar
GRFL	Groundwater Remediation Field Laboratory
HCAT	Hard Chrome Alternatives Team
HCI	Hydrogen Chloride
HFS	High Frequency Sounder
HMX	Octahydro-1,3,5,7-Tetranitro 1,3,5,7-Tetrazocine
HNF	hydrazinium nitroformate
HPLC	High-Performance Liquid Chromatography
HSI	Hyperspectral Imaging
HTS	high temperature superconducting
HVOF	High-Velocity Oxygen Fuel
ICA	independent components analysis
ID	Internal Diameter
IER	Ion-Exchange Resin
IID	impact initiated device
IP	induced polarization
IR	intra-red
IRA	Installation Risk Assessment
ISE	ion selective electrode
ITAM	Integrated Training Area Management
ITS	internal transcribed spacer
IVD	ion vapor deposition
JEMP	Joint Engineers Management Panel
JETC	Jet Engine Test Cell
JG-PP	Joint Group on Pollution Prevention

KCP	Kansas City Plant
LANL	Los Alamos National Laboratory
LAP	load-assembly-package
LED	light emitting diode
LFEP	Lead Free Electrical Primer
LHAAP	Longhorn Army Ammunition Plant
LIBS	Laser-Induced Breakdown Spectroscopy
LLNL	Lawrence Livermore National Lab
LM	Liquid Molding
LMS	Land Management System
LOD	Low-Order Detonation
LVPB-H_2	low volume pulsed hydrogen biosparging
LW	Land Warrior
LWSC	Low Water Stream Crossing
MA	Mechanical Alloying
MACT	Maximum Achievable Technology Control
MALDI-MS	Matrix Assisted Laser Desorption Ionization Mass Spectrometry
MARAD	Maritime Administration
MARPOL	International Maritime Organizations Marine Pollution Convention
MCAGCC	Marine Corps Air-Ground Combat Center
MCT	MicoCoatings Technologies, Inc.
MECL	Methylene Chloride
MEK	Methyl Ethyl Ketone
MEP	4-(2-mercaptoethyl)pyridine
MIC	Metastable Intermolecular Composites
MIT	Massachusetts Institute of Technology
MLFMA	Multi-Level Fast-Multipole Algorithm
MMPA	Marine Mammal Protection Act
MNA	monitored natural attenuation
MOI	Multiorifice impactor
MRE	Meal Ready-to-Eat
MSAT	Mobile Source Air Toxics
MSC	Military Sealift Command
MTADS	Multi-Sensor Towed Array Detector System
MTBE	Methyl Tert-Butyl Ether
MTG	Magnetic Tensor Gradiometer
MTH	Magnesium, Teflon, and Hytemp
MTV	Magnesium, Teflon, and Viton
NAAQS	National Ambient Air Quality Standard
NADAG	North American Database of Archaeological Geophysics
NAPL	Non-Aqueous Phase Liquid
NATA	National Air Toxics Assessment
NC	Nitrocellulose
NCMS	National Center for Manufacturing Sciences
NDCEE	National Defense Center for Environmental Excellence
NDI	Nondestructive Inspection
NEP	net ecosystem production
NEPA	National Environment Protection Act
NESHAP	National Emission Standards for Hazardous Air Pollutant

NETTS	National Environmental Technology Test Site
NG	nitroglycerine
NIST	National Institute of Standards and Technology
NLOS	non-line-of-sight
NMSim	Noise Model Simulation
NOAA	National Oceanic and Atmospheric Administration
NO_x	Nitrogen Oxide
NPS	Naval Postgraduate School
NRL	Naval Research Laboratory
NSWC	Naval Surface Warfare Center
NSWCCD	Naval Surface Warfare Center Carderock Division
NTL	National Test Location
NV-LOC	No-VOC Low Observable Coating
O&M	Operation and Maintenance
OAP	Oligoaniline Acrylate Polymer
OB/OD	Open Burning/Open Detonation
ODS	Ozone Depleting Substance
OIM	Ordnance Intensity Maps
ONR	Office of Naval Research
OPC	Optical Particle Counters
ORD	Office of Research and Development
OSHA	Occupational Safety and Health Administration
PAC	Project Advisory Council
PAH	Polycyclic Aromatic Hydrocarbon
PAS	Photoelectric Aerosol Sampler
Pb	Lead
PCDD/F	polychlorinated dibenzo-p-dioxins and dibenzofurans
PCE	Perchloroethylene
PCR	Polymerase Chain Reaction
PED	Photoacoustic Elemental Device
PEL	Permissible Exposure Limit
PI	Principal Investigator
PLA	Polylactic acid
PM	Particulate Matter
PNNL	Pacific Northwest National Laboratory
PP	Pollution Prevention (thrust area)
PPF	Polymer Production Facility
PQL	practical quantitation limit
PRB	Permeable Reactive Barrier
PUVD	polyvinyldioxolane based polyurethane
QA/QC	Quality Assurance/Quality Control
QPL	qualified products list
QSAR	Quantitative Structural Activation Reaction
R&D	Research and Development
RAAP	Radford Army Ammunition Plant
RAM	Radar Absorbing Material
RCRA	Resource Conservation and Recovery Act
RDT&E	Research, Development Test & Evaluation
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine

REMM	Riparian Ecosystem Management Model
REMPI	Resonantly Enhanced Multiphoton Ionization
RF	Radio Frequency
RFLP	Restriction Fragment Length Polymorphisms
ROV	Remotely Operated Vehicle
RPI	Rensselaer Polytechnic Institute
RSim	Regional Simulation Model
RSL	Remote Sensing Lab
RTDF	Remediation Technologies Development Forum
RTm	Real-Time
RTV	Room Temperature Vulcanizing
RUSLE	Revised Universal Soil Loss Equation
RX	receiver
S&O	smokes and obscurants
S&T	Science and Technology
SAB	Scientific Advisory Board
SABC	Surface-Active Block Copolymer
SAMMS	Self Assembled Monolayers on Mesoporous Supports
SCM	Source Characterization Model
SCORE	Southern California Off-Shore Range
SDSS	Spatial Decision Support System
SEBS	Styrene-Ethylene/Butylene-Styrene
SEM	spatially explicit model
SEMP	SERDP Ecosystem Management Program
SERDP	Strategic Environmental Research and Development Program
SERS	Surface Enhanced Raman Sensor
SI	Sequential Injection
SKP	Scanning Kelvin Probe
SMF	steerable magnetic field
SNL	Sandia National Laboratory
SO_2	sulfur dioxide
SOC	Surface Optics Corporation
SOM	soil organic matter
SON	Statement of Need
SPME	solid-phase microextraction
SROC	Senior Readiness Oversight Council
SSL	Sassafras sandy loam
SVE	Soil Vapor Extraction
SWAT	Shallow Water Acoustic Toolset
TAC	Technical Advisory Committee
TAT	2,4,6-trianiinotoluene
TCA	Trichloroethane
TCAAP	Twin Cities Army Ammunition Plant
TCE	Trichloroethylene
TD	time-domain
TD	Total Dissolved
TDEM	time-domain electromagnetic
TDP	Technical Data Package
TDR	Time Domain Reflectometry
TEM	time domain

tetryl	n-methyl-n,2,4,6-tetranitroaniline
TES	Threatened or Endangered Species
TIM	Threshold Intensity Maps
TLM	Test Location Manager
TMGS	Tensor Magnetic Gradiometer System
TNB	1,3,5-trinitrobenzene
TNM	trinitromethane
TNT	Trinitrotoluene
TPE	thermoplastic elastomer
TQG	tactical quiet generator
TRI	Toxic Release Inventory
TSE	Twin Screw Extruder
TSS	total suspended solid
TTAWG	Technology Thrust Area Working Group
TX	Transmitter
UAT	Urban Air Toxic
UNDS	Uniform National Discharge Standards
URI	University of Rhode Island
USDA	United States Department of Agriculture
UV	ultraviolet
UWB	Ultra Wide Band
UXO	Unexploded Ordnance
VC	Vinyl Chloride
VE	vinyl ester
VETEM	Very Early Time Electromagnetic
VOC	Volatile Organic Compound
VSP	visual sample plan
WASI	Wide-Area Spectral Imaging
WHOI	Woods Hole Oceanographic Institution
YM	yellow metabolite
YPG	Yuma Proving Ground
YSZ	yttrium stabilized zirconium
YTC	Yakima Training Center

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