U. S. Coast Guard

Oil Spill Response Research & Development Program

A Decade of Achievement

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Report No. CG-D-07-03

U.S. COAST GUARD
OIL SPILL RESPONSE RESEARCH & DEVELOPMENT PROGRAM, A DECADE OF ACHIEVEMENT

FINAL REPORT
June 2003

This document is available to the U.S. public through the
National Technical Information Service, Springfield, VA 22161

Prepared for:

U.S. Department of Homeland Security
United States Coast Guard
Marine Safety and Environmental Protection (G-M)
Washington, DC 20593-0001

This report does not constitute a standard, specification, or regulation.

Technical Report Documentation Page

1. Report No.	2. Government Accession Number	3. Recipient's Catalog No.
CG-D-07-03	ADA418041	

4. Title and Subtitle	5. Report Date
U.S. COAST GUARD, OIL SPILL RESPONSE RESEARCH & DEVELOPMENT PROGRAM, A DECADE OF ACHIEVEMENT	June 2003
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Peter Tebeau	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Potomac Management Group 510 King Street Alexandria, VA 22314 U.S. Coast Guard Research and Development Center 1082 Shennecossett Road Groton, CT 06340-6048	11. Contract or Grant No.
12. Sponsoring Organization Name and Address	13. Type of Report & Period Covered
U.S. Department of Homeland Security United States Coast Guard Marine Safety and Environmental Protection (G-M) Washington, DC 20593-0001	Final Report
	14. Sponsoring Agency Code
	Commandant (G-MOR) U. S. Coast Guard Headquarters Washington, DC 20593-0001

15. Supplementary Notes

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16. Abstract (MAXIMUM 200 WORDS)

This report provides a comprehensive summary of the Coast Guard oil spill response R&D program undertaken during the period 1990 through 2001 following the EXXON VALDEZ oil spill and in response to the R&D provisions of OPA 90. During this period, the Coast Guard R&D efforts addressed four main focus areas: Spill Response Planning and Management, Spill Detection and Surveillance, Vessel Salvage and On-Board Containment, and Spilled Oil Cleanup and Countermeasures. The specific projects undertaken in each focus area are described, and the longer-term benefits of these projects in enhancing Coast Guard response capability are summarized. Coast Guard R&D contributions in developing oil spill R&D infrastructure, supporting oil spill technology research at universities, and facilitating technology transfer and promoting public awareness are also discussed. In addition, "representative quantitative estimates" are calculated for the potential cost savings that resulted from advances in specific technology focus areas to show the relative "return on investment" for the program.

17. Key Words	18. Distribution Statement
oil spill response, oil spill R&D, oil spill cleanup, oil spill countermeasures	This document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161.

19. Security Class (This Report)	20. Security Class (This Page)	21. No of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	68	

Form DOT F 1700.7 (8/72) Reproduction of form and completed page is authorized.

Executive Summary

The Coast Guard R&D Program has made significant progress over the past decade in addressing the various technological needs to enhance Coast Guard oil spill response capability and further the development of systems and equipment that can be used by the Coast Guard, other oil spill response agencies and private industry. This concerted R&D effort was undertaken following the EXXON VALDEZ oil spill, and in response to the R&D provisions in Title VII of the Oil Pollution Act of 1990. The purpose of this document is to summarize the accomplishments and benefits of the program, and assess the future potential impact of these accomplishments and benefits on the Coast Guard and the nation at large.

Accomplishments are summarized in each of four key technology focus areas: Spill Response Planning and Management, Spill Detection and Surveillance, Vessel Salvage and On-Board Containment, and Spilled Oil Cleanup and Alternative Countermeasures. Accomplishments in Spill Response Planning and Management include the development of computer-based decision tools to facilitate contingency planning and response management, and the development of computer-based systems to enhance the Coast Guard's oil spill training and preparedness evaluation program. Accomplishments in Oil Spill Detection and Surveillance include development, testing and evaluation of oil spill remote sensing systems, such as synthetic aperture radar, infrared sensors, a laser fluorosensor and a frequency scanning radiometer. These systems were evaluated in the laboratory and tested under field conditions to define performance characteristics.

In the area of Vessel Salvage and On-Board Containment, technology assessment studies were undertaken to assess the effectiveness of double-hull tankers and barges in preventing spills, assess the capability of remote sensing systems and AUVs in determining tanker damage and stability, assess the technical feasibility and operational advisability of tanker self-help countermeasures, and determine the feasibility of upgrading the Coast Guard's tanker offloading capability. Accomplishments in Spilled Oil Cleanup and Alternative Countermeasures include the development of an integrated oil spill mechanical recovery system for Coast Guard buoy tenders, an assessment of systems and techniques for recovering oil in fast-current environments, and the further development of in-situ burning as a response countermeasure, including both the testing of fire-resistant booms and the development of tactics and decision tools to support the implementation of in-situ burning in the field. Coast Guard R&D contributions in developing oil spill R&D infrastructure, supporting oil spill technology research at universities, and facilitating technology transfer and promoting public awareness are also discussed.

Finally, program history and funding levels over the period 1990-2001 are summarized, and "representative quantitative estimates" of the potential cost savings that may result from advances in specific technology focus areas are presented to show the relative "return on investment" for the program. These representative cost savings estimates show that a return of up to 1 to 2 billion dollars may be realized subject to the number and nature of future spills. This is a substantial return on investment given the investment of approximately $20 Million over the past decade. The challenge for the future lies in sustaining the program during a period when the threat of oil pollution is less visible in the national agenda, to maintain momentum and preserve oil spill technical expertise within Coast Guard R&D.

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Acronyms and Abbreviations

ADAPTS	Air Deliverable Anti-Pollution Transfer System
AOSS	Airborne Oil Spill Surveillance System
AUV	Autonomous Underwater Vehicle
DSS	Decision Support System
EPA	Environmental Protection Agency
FDSS	Fast-Delivery Sled System
FLIR	Forward-Looking Infrared
FSR	Frequency Scanning Radiometer
IR	Infrared
MATES	Multi-Agency Team Building Enhancement System
MMS	Minerals Management Service
NCP	National Contingency Plan
NIIMS ICS	National Interagency Incident Management System Incident Command System
NOAA	National Oceanic and Atmospheric Administration
NOBE	Newfoundland Offshore Burn Experiment
NSFCC	Nation Strike Force Coordination Center
OHMSETT	Oil and Hazardous Materials Simulated Environmental Test Tank
OPA 90	Oil Pollution Act of 1990
OSC	On-Scene Coordinator
OSPPR	Oil Spill Prevention, Preparedness and Response Program
OSROs	Oil Spill Removal Organizations
OWOCRS	Open Water Oil Containment and Recovery System
PISCES	Pollution Incident Simulation and Control Exercise System
PPS	Precision Planning and Simulation, Inc.
R&D	Research and Development
RRI	Response Resource Inventory
SAR	Synthetic Aperture Radar
SLAR	Side-Looking Airborne Radar
SPEARS	Spill Planning, Exercise, and Response System
T&E	Test and Evaluation
TRACEN	Training Center
TSDs	Temporary Storage Devices
UCS	Unified Command System
VOSS	Vessel of Opportunity Skimming System

Introduction

The Coast Guard R&D Program has made significant progress over the past decade in addressing various technological needs to support the Coast Guard's Oil Spill Prevention, Preparedness and Response (OSPPR) Program. The purpose of this document is to summarize the accomplishments and benefits this program has produced, and assess the future impact that these accomplishments and benefits may have on the Coast Guard and the Nation at large. First, the accomplishments of the Coast Guard oil spill R&D program in the 1970s and 1980s are summarized and the impact of the EXXON VALDEZ oil spill in 1989 and the passage of the Oil Pollution Act of 1990 (OPA 90) are briefly described. Following this, the objectives, accomplishments and benefits of the program are summarized for each of the main focus areas. Next, a strategic level assessment is made of the economic impact that the various technological advances undertaken by the Coast Guard, as well as other agencies and industry, may have over the next decade. This impact assessment is based upon experience over the past decade and projected spill occurrence over the present decade.

Background

The Coast Guard's Oil Spill Research and Development Program has been underway for more than 30 years as depicted in figure 1. The initial oil spill R&D efforts were triggered by two major oil spills: the 1968 TORREY CANYON grounding off the Coast of England and the 1969 well blowout off Santa Barbara, California. During the early and mid-1970s, these initial efforts included the development of the airborne oil spill surveillance system (AOSS), the air-deliverable anti-pollution transfer system (ADAPTS) for removing oil from damaged tankers, the fast-delivery sled system (FDSS) for rapidly transporting equipment to the spill, and the open water oil containment and recovery system (OWOCRS) for removing oil from the water in offshore environments. These systems represented a quantum leap forward in providing a national capability to respond to spills.

The R&D program continued throughout the late 1970s and 1980s, and was expanded to address spill response challenges in offshore environments under extreme weather conditions encountered during the sinking of the tanker ARGO MERCHANT off Nantucket in December 1976. During this time, Coast Guard R&D implemented a program to upgrade vessel damage assessment and offloading technology and further develop and test oil spill containment and recovery equipment. In addition, oil exploration and development activities along the coast of Alaska, particularly in the Beaufort Sea, pointed out the need for developing techniques applicable to ice-infested waters. During the 1980s a wide variety of projects was pursued for Arctic response, including development of systems and techniques for removing oil from ice-infested waters, technologies for detecting and mapping oil under ice, computer models for predicting the behavior and movement of oil spilled in the Arctic, and environmental atlases and comprehensive field guides to support strategy development and response implementation.

By the mid-1980s, it appeared that a "technological plateau" had been reached such that further improvements in techniques and equipment could only be attained at significantly greater expense. With a shift in priority to other demanding Coast Guard mission areas, the R&D oil spill program was scaled back and focused on assessing and documenting the existing

technology and providing the On-Scene Coordinator (OSC) with information and decision tools to more effectively manage spill response.

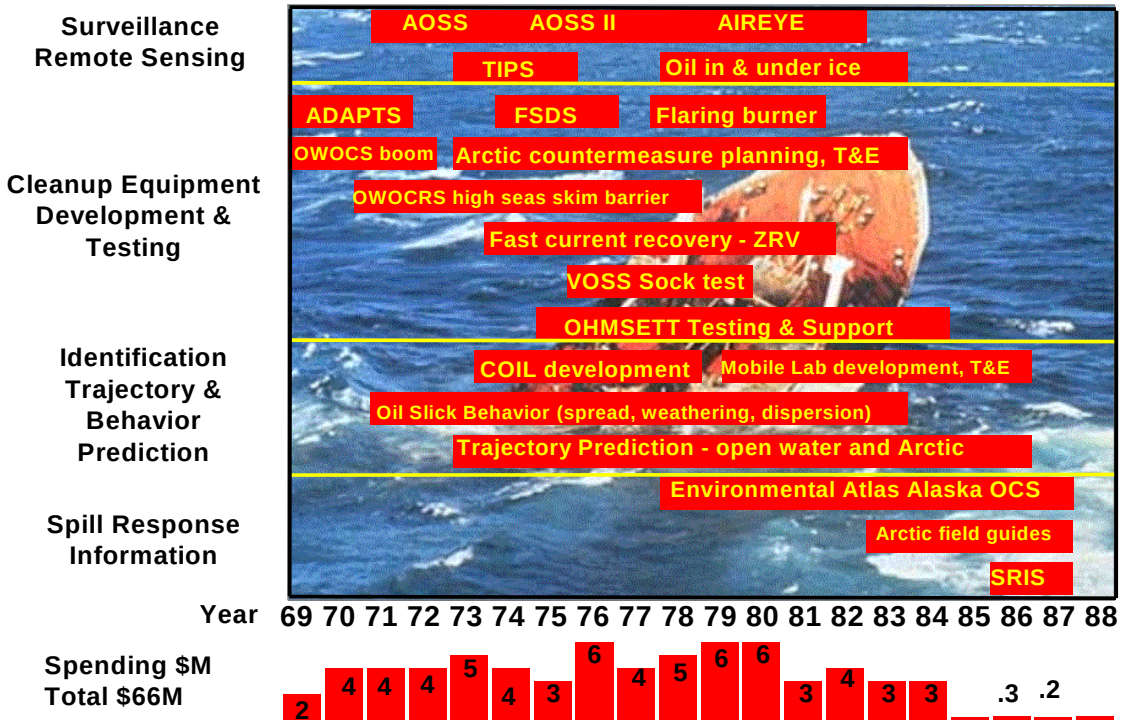

Figure 1. Coast Guard Oil Spill R&D, 1969-1989.

On March 24, 1989, the limitations in oil spill response technology were once again demonstrated when the tanker EXXON VALDEZ ran aground on Bligh Reef in Prince William Sound, spilling 11 million gallons of Prudhoe Bay Crude, the largest oil spill in U.S. history. As a result, a comprehensive Federal R&D Program was mandated by Title VII of the Oil Pollution Act of 1990 (OPA 90), which formalized the Interagency Coordinating Committee on Oil Spill Research. This Act called for a comprehensive national oil spill R&D effort, including research projects undertaken by individual agencies, grants to universities for basic research on oil spill prevention and response, and port demonstration projects to promote technology transfer and acceptance by the maritime community. An Interagency Oil Pollution Research and Technology Plan was developed in 1992, and subsequently updated in 1997. Most importantly, OPA 90 authorized annual Federal funding at an annual level of $25 M.

Coast Guard Oil Spill R&D Accomplishments in the 1990s

Coast Guard oil spill R&D efforts in the 1990s were directed at four main technology focus areas including:

- Spill Planning and Management
- Spill Surveillance
- Vessel Salvage and Onboard Containment
- Spilled Oil Cleanup and Alternative Countermeasures

These areas were defined through initial technology assessments conducted by the Coast Guard R&D Center following the EXXON VALDEZ spill in 1989, and through in-depth discussions with Coast Guard marine environmental protection program managers at Coast Guard Headquarters, spill responders within the Coast Guard and other agencies, and oil spill researchers in other agencies and industry. Consequently, the Coast Guard Oil Spill R&D Program for the 1990s was well underway by the time OPA 90 was passed by Congress. OPA 90 added several additional R&D components, including grants, programs for university research, and port demonstration projects to promote technology transfer and public awareness. The accomplishments and major benefits in each of these areas are outlined below.

Spill Response Planning and Management

One of the most important aspects of oil spill response are planning and management, which includes contingency planning, training of personnel and organizations, and ensuring that the infrastructure and information are available to facilitate decision making and resource management when a spill occurs. Following the EXXON VALDEZ spill, spill planning and management was identified as a key focus area where improvements were needed, particularly in dealing with larger, more complex spills. Within this focus area, three specific program initiatives were undertaken to:

- Provide accurate and accessible information for contingency planning and response operations management;

- Evaluate and develop oil spill response decision support systems; and

- Develop advanced systems to support spill response training and preparedness evaluation.

The specific projects undertaken and accomplishments in meeting each of these three objectives are summarized below.

Oil Spill Response Information Management and Decision Making

National Contingency Plan (NCP) Product Schedule Update

Following the EXXON VALDEZ spill and the controversy that surrounded the use of various chemical and biological agents to treat the spill, it became clear that the EPA's NCP Product Schedule needed to be updated to include all available information about the individual characteristics of approved dispersants and other chemical agents including their benefits and detriments, and potential effect on the environment. This update provided information critical to spill responders for determining when these products should be used and which could be used safely and effectively. This update was accomplished in cooperation with the Environmental Protection Agency, which reviews products and routinely updates the Product Schedule.

Field Guide for Sorbents (Adsorbents, Absorbents, and Gelling Agents)

Sorbents is another group of products that are often used to physically remove oil from the water or pooled oil on shorelines. Prior to the EXXON VALDEZ spill, there was no complete database that described the composition and effectiveness of these products, so the R&D Center developed a field guide of all sorbent products available on the market. The field guide contains a comprehensive listing of all available products, their distribution, methods of handling, their characteristics and properties, and their deployment strategies on beaches and on the open ocean. This information was used in a joint project with Environment Canada to develop standardized tests for the effectiveness of sorbent products.

World Catalog of Oil Spill Response Products

An important category of information needed for evaluating and acquiring equipment for containing and recovering oil are data on what equipment is being manufactured, where it can be obtained, and how well it can be expected to perform under various environmental conditions. The *World Catalog of Oil Spill Response Products* is the standard industry resource for such information. In the years prior to the EXXON VALDEZ oil spill, this catalog had become somewhat out-of-date as funding to support its update declined. To remedy this, Coast Guard R&D undertook a joint effort with Minerals Management Service and Environment Canada to update the catalog. This updated catalog provided the most current listing of all types and brands of oil spill containment boom, skimmers, pumps, sorbents, oil water separators, and beach cleaning equipment available worldwide. It serves as a valuable reference for government and state agencies, and private companies involved in oil spill response operations and technology development.

Response Equipment Database

In addition to knowing the characteristics and effectiveness of equipment, oil spill responders must also know the location and quantity of this equipment around the country. Prior to OPA 90, this information was contained in individual contingency plans; there was no centralized inventory of spill response equipment and resources throughout the United States. The Coast Guard National Strike Force Coordination Center (NSFCC) needed such an inventory to

evaluate the adequacy of Area Contingency Plans and classify Oil Spill Removal Organizations (OSROs) according to their resources and capabilities. The Coast Guard R&D developed an electronic database of information on oil spill cleanup organizations and companies and the equipment that each held in inventory. This database served as the basis for the Response Resources Inventory (RRI), the national inventory of response equipment and personnel, which is currently maintained by the Coast Guard's NSFCC. The RRI is the standard inventory used by the Coast Guard in the Facility Response Plan and Vessel Response Plan reviews required by OPA 90, and in the OSRO classification program.

Spill Histories Database

In order to prepare for future spills, it is important to capture the experience gained in responding to previous spills. This experience will guide future improvements to spill response strategies, provide insight on training requirements, and help identify future technology needs. Prior to OPA 90, information on past spills was contained in numerous On-Scene Coordinators Reports, technical papers and journal articles. Coast Guard R&D and National Oceanic and Atmospheric Administration (NOAA) HAZMAT embarked on an effort to consolidate this information and produced a comprehensive report on major spills that had occurred throughout the world until 1990. It captured information on all aspects of the spill including spill cause, type of oil, response options, response effectiveness, and environmental damages. The report was subsequently made available on the Internet and expanded upon by NOAA HAZMAT using information from NOAA SSC Reports for spills occurring in the 1990s. These spill histories serve as a valuable resource for spill response managers and technical researchers.

Condensed Oil Spill Health and Safety Plan

A critical part of effective spill response management is ensuring the health and safety of the personnel involved in the operation. To accomplish this, the OSC must ensure that Site Safety and Health Plans (SSHPs) are developed and promulgated as required by OSHA. To facilitate this, Coast Guard R&D initiated a project to gather and consolidate information on industrial hygiene risks and protection measures for spill response. This Condensed Oil Spill Health and Safety Plan serves as a template for Site Safety and Health Officers in rapidly developing comprehensive SSHPs in the event of a spill.

Oil Spill Command and Control System - OSC^2

Responding to oil spills, particularly larger ones, requires that the On-Scene Coordinator and staff receive, analyze and retain large volumes of information. To help deal with this issue, Coast Guard R&D developed a computer-based system called OSC^2, a maritime response information management tool. OSC^2 is designed to assist Coast Guard personnel operating under the National Interagency Incident Management System Incident Command System (NIIMS ICS) spill response structure, in managing the large amount of operational information generated during the response effort. The system has been exercised and refined during a number of exercises and actual response operations.

Today, the system is used by the NSFCC, all three Coast Guard Strike Teams, several Coast Guard MSOs, Training Center (TRACEN) Yorktown, and Operations Computer Center Martinsburg. Experience with OSC^2 demonstrated that substantial resource savings and performance improvements resulted by employing such a capability during major incidents. The system has also been adapted by industry to support Responsible Party spill response documentation and planning.

Development of Integrated Oil Spill Decision Support Systems

Having accurate and accessible information and computer-based information management systems can greatly facilitate contingency planning and response operations. Coast Guard R&D has undertaken several exploratory efforts to define system requirements and develop prototypes to produce integrated decision support systems (DSS). These efforts included development of the Spill Response Information System concept, which was carried forward by Coast Guard Headquarters and NOAA HAZMAT in SPEARS (Spill Planning, Exercise, and Response System). The Spill Response System Configuration Study was performed by Stamford Research Institute to define requirements for a logistics management GIS. The architecture for a comprehensive Oil Spill Information Management System was investigated as part of a research grant to the University of Miami. Coast Guard R&D also participated in the development of MAR_TADS, an information management scheme that was developed to allow for information capture, display, and sharing within a multi-agency oil spill response command post. A multi-mission, enhanced version of the concept is currently being incorporated into the Common Situation Display System (CSDS). Many of the concepts embodied in MAR_TADS were also incorporated in OSC2. These efforts laid much of the groundwork in defining system requirements and attributes and can be incorporated into the Coast Guard Operations DSS of the future.

<u>Oil Spill Response Training and Readiness Evaluation</u>

Multi-Agency Team Building Enhancement System (MATES)

The training of oil spill response personnel is complicated by the infrequent occurrence of major spills and the multi-agency makeup of the team that must be rapidly assembled and work together within the Unified Command System (UCS) in the event of a major spill. To address this, Coast Guard R&D initiated an effort to develop a cost-effective prototype training system for employment at the local level to upgrade the decision-making processes of the multi-agency command post team. This study identified the importance of "shared mental models" among the diverse, Unified Command Post team members, particularly among members of the various UCS Sections/sub-team elements. It also identified several training media for further investigation of their potential for upgrading the "shared mental models" and skills of these team members. The study resulted in a training system specification, with implementation recommendations and cost estimates for implementation of MATES. This system has been adopted within the Coast Guard, and has also fostered the development of commercial systems based on the standards developed though MATES.

Pollution Incident Simulation and Control Exercise System (PISCES)

Prior to OPA 90, the evaluation of agency and industry capability to effectively respond to major spills was accomplished through Regional Response Team (RRT) exercises that involved talking through the various spill response issues and decisions based on a specific spill scenario. While these exercises provided familiarity with spill contingency plans and enhanced team-building, they did not rigorously evaluate the level of proficiency reflected by the exercise. To provide for a more objective spill response exercise evaluation, Coast Guard R&D developed an "Exercise Truth" simulation tool for NSFCC to enhance area exercises within the Preparedness for Response Exercise Program (PREP). The exercise evaluation system, known as PISCES, was developed in conjunction with NSFCC, the Naval Air Warfare Center-Training Systems Division, and others. The final PISCES software was completed and delivered in 2002.

Today, NSFCC uses PISCES within the Exercise Planning, Conduct, and Debriefing Phases of its PREP Exercises. TRACEN-Yorktown uses PISCES to enhance its Port Operations, Contingency Planning, and OSC Crisis Management Training Programs. This project also stimulated the establishment of a commercial PC-based maritime response tool within the private sector. Precision Planning & Simulation (PPS) successfully uses a commercial version of the PISCES tool to enhance the oil spill and crisis management exercises that it provides to a wide variety of private sector clients. This would have never been developed without the R&DC investment.

Major Benefits for Spill Planning and Management

- Spill response resource databases provide important information on the characteristics and availability of mechanical recovery equipment, dispersants, sorbents and other spill treating agents for spill contingency planning and response management. This information was used in developing Area Contingency Plans required by OPA 90, and serves as a basis for future oil spill information database development.

- The Spill Histories Database facilitates the archiving of spill histories to capture the experiences and record technical data for future operations planning and technology development. The database is used for research and contingency planning and as a training tool allowing spill responders with limited experience to access the technical data and lessons learned from past spills.

- DSS development facilitates the implementation of computer-based systems in the Coast Guard for capturing, analyzing and managing information to support both contingency planning and response management. This has resulted in the implementation of prototype systems in the Coast Guard (SPEARS and OSC^2) and established system requirements for future DSS development. This has also encouraged the development of similar systems within the private sector, such as the OSRAMS system developed by

Motorola and tested by MSRC. In addition, the functionality of OSC^2 is being incorporated into MISLE, the Coast Guard's general maritime operations DSS.

- MATES and PISCES introduced the use of computer-based systems into the Coast Guard for training and readiness evaluation. These systems support the PREP program established by the Coast Guard and have facilitated the implementation of the NIMS/ICS spill response doctrine and management structure within the Coast Guard. MATES has clarified the major roles of NIMS/ICS components, and PISCES provides objectivity and uniformity in PREP evaluations. There system has also fostered the development of similar systems for use in the private sector.

Spill Detection and Surveillance

To initiate and manage an oil spill response operation, the oil must be located and the extent of the pollution determined. Locating and mapping the thicker portions of the slick allow for the more efficient deployment and operation of recovery resources. Visual observations from an aircraft are the most common means of providing spill reconnaissance. However, detecting, tracking and characterizing oil spills in any weather and 24 hours a day is a challenging task requiring the use of remote sensing technology. To provide and enhance this remote sensing capability within the Coast Guard, three specific program initiatives were undertaken:

- Evaluate overall system requirements and specifications for a Coast Guard oil spill remote sensing system.

- Further develop and test promising sensors for detecting and characterizing oil spills.

- Test and evaluate current Coast Guard airborne surveillance systems, and off-the-shelf enhanced systems, to determine their utility and effectiveness in detecting and mapping oil spills.

<u>Oil Spill Surveillance Requirements Analysis</u>

A key first step in determining how to best proceed in upgrading the Coast Guard's oil spill surveillance capability was the completion of a thorough mission requirements analysis and technology assessment. Coast Guard R&D commissioned the Environmental Research Institute of Michigan (ERIM) to investigate mission requirements and compare these with the capabilities of current remote sensing systems to determine the "technology gap" that needed to be filled. The study encompassed all Coast Guard airborne surveillance missions, not just oil spills, recognizing that the expense and complexity of remote sensing systems dictates a single airborne system for the Coast Guard. In this system, oil spill surveillance capabilities must complement and be balanced against search and rescue and law enforcement requirements. An extensive literature search was conducted and discussions with other researchers and operators were documented to determine the state-of-the-art and promising initiatives for oil spill sensor development.

Oil Spill Surveillance Sensor Development

Development of a Frequency Scanning Radiometer

The objective of the Frequency Scanning Radiometer (FSR) development effort was to develop and test a new oil spill sensor that can detect, and more importantly, indicate the thickness of an oil slick on the water. Coast Guard R&D commissioned Lincoln Laboratories at Massachusetts Institute of Technology (MIT) to undertake this effort. The initial phase of the project involved developing a proof-of-concept sensor that was successfully tested in the laboratory at MIT. Comparison of lab measurements with theoretically predicted results demonstrated the feasibility of the concept.

Subsequent tests with an enhanced prototype were then conducted by the Coast Guard and Minerals Management Service at the National Oil Spill Test Facility (OHMSETT). These tests delineated the capabilities of the sensor to measure oil thickness under actual environmental conditions and with different oil types including emulsified oil (figure 2). It was determined that this capability degraded rapidly with increasing sea state.

Following the OHMSETT tests, the data were analyzed in detail and it was determined that substantial development of the FSR sensor and significant system integration work would be required to produce an operationally practical sensor. Although the FSR remains in the prototype sensor category, its overall potential and prospects for future development have been more fully defined. The Minerals Management Service (MMS) continued the development of the FSR.

Figure 2. A prototype Frequency Scanning Radiometer (FSR) being tested at OHMSETT.

Development of the Laser Fluorosensor

During the decline in oil spill R&D activity in the United States in the 1980s, Environment Canada continued to actively pursue oil spill sensor development using laser technology. Following EXXON VALDEZ and OPA 90, the Coast Guard, along with MMS and industry, supported Environment Canada in the development of a laser fluorosensor and laser thickness sensor. The laser fluorosensor focuses on mapping and positively identifying hydrocarbons on the water and shoreline, and reducing the false identification problems encountered with other sensors. The laser thickness sensor seeks to accurately profile the thickness of an oil slick from the air to assist in locating heavier oil concentrations.

During the 1990s, Environment Canada was successful in developing a scanning laser fluorosensor, which can quickly scan the sea surface or shoreline to positively identify oil with high accuracy and resolution. It can also be used to detect oil in ice. Two operational laser fluorosensor units are currently available through Environment Canada. Although development of the laser thickness sensor continues, an operational prototype is still several years away. Multi-agency support for the laser fluorosensor development effort is an excellent example of how interagency cooperation over a longer period can produce significant R&D breakthroughs.

Test and Evaluation of Operational Oil Spill Surveillance Systems

The Coast Guard currently has several remote sensing systems capable of detecting and mapping oil spills at night, and during adverse weather conditions. These include Side-Looking Airborne Radar (SLAR), Infrared Imagers, and Low-Light Level TV. These sensors are incorporated in Coast Guard aircraft, such as in the AIREYE aircraft, which provided effective oil spill reconnaissance during EXXON VALDEZ and in the Persian Gulf. An

important component of the Coast Guard R&D effort following OPA 90 was the test and evaluation of these systems.

Evaluation of Synthetic Aperture Radar for Oil Spill Response

Synthetic Aperture Radar (SAR) represents a potential technology improvement over the current Coast Guard SLAR systems, although it is significantly more costly to acquire and maintain. In view of this, Coast Guard R&D initiated a study to determine the inherent advantages of SAR over SLAR for oil spill reconnaissance, and assess the cost vs. benefits of acquiring these systems. In conjunction with the Sandia National Laboratories and NOAA HAZMAT, an experiment was conducted using natural oil seeps in the Santa Barbara Channel to evaluate the performance of a state-of-the-art SAR against the existing SLAR, currently installed on the Coast Guard's AIREYE aircraft (figure 3). Oil slick resolution capability and sensitivity to environmental conditions were evaluated with both systems. The study determined that SAR offers a significant increase in performance over SLAR albeit at a cost, and recommended SAR system characteristics for consideration in any future CG airborne surveillance system upgrade.

Figure 3. Coast Guard AIREYE Aircraft used for SAR vs. SLAR Evaluation.

Evaluation of Infrared Sensors for Oil Spill Detection and Mapping

In addition to SLAR, the Coast Guard has Infrared (IR) sensors mounted on several aircraft, primarily for search and rescue and law enforcement purposes. In addition, there are a number of commercially available handheld IRs that could be used aboard Coast Guard aircraft and non-Coast Guard aircraft of opportunity (figure 4). These various IR sensors were tested in field experiments over the Santa Barbara oil seeps and at an oil spill test basin constructed in Canada by Environment Canada for oil spill sensor evaluation. The ability to discriminate between oil and open water was evaluated as a function of oil type, environmental conditions,

and false targets. The tests defined the effective operating conditions for the sensors and increased the awareness of their utility in detecting and mapping slicks.

Figure 4. Handheld infrared sensor being tested for oil detection capabilities.

Major Benefits of Spill Detection and Surveillance

- The FSR development effort more fully defined the potential of microwave radiometers as oil spill sensors. This effort has provided a sensor that can be used in calm water. Its limited capabilities led to additional efforts to identify potential sensors.

- The SAR vs. SLAR evaluation identified the advantages of upgrading to SAR and provided information on system characteristics. It is likely that a SAR capability will be incorporated into future Coast Guard long-range surveillance aircraft under the Deepwater Program. Because SAR has better oil spill detection and resolution capabilities than SLAR, it will provide better oil reconnaissance and cleanup asset monitoring during spill response operations, and facilitate detecting and identifying illegal spills.

- Support for the Environment Canada laser fluorosensor development effort resulted in this sensor reaching the operational stage. Oil spill responders now have a reliable sensor which can discriminate hydrocarbons from background substrates on shorelines and on ice. This can greatly enhance the detection and mapping of oil, especially along shorelines, and facilitate the rapid and efficient deployment of spill response resources.

- Tests of various IR sensors in the field have better defined the effectiveness and operating window for these devices. They have also increased the awareness of and confidence in these sensors as readily available tactical oil spill reconnaissance tools. This will allow Coast Guard responders to more effectively monitor the spread and movement of spills at night and in bad weather, so that cleanup resources can be deployed to areas of higher oil concentration. IR sensors can also be used to detect illegal oil discharges at night.

Vessel Salvage and On-Board Containment

The best response strategy in the event of an impending vessel spill is to attempt to eliminate the threat of pollution at the source, or at least limit and contain the amount of oil that is spilled. The EXXON VALDEZ spill demonstrated this since 80 percent of the oil was off-loaded from the ship using emergency oil off-loading systems, while the remainder impacted the shore, causing a massive cleanup problem. With this in mind, R&D initiatives included work on tanker salvage and countermeasures. The goal was to assess the current technology and develop a suite of integrated technologies to:

- Prevent the release of oil from a grounded or damaged vessel
- Rapidly assess the degree of damage and resulting stability of the vessel
- Contain product in the vessel, and transfer product from the vessel

<u>Tanker Spill Prevention and Mitigation</u>

Marine Board Study on Oil Spill Prevention Through Tanker Design

To address the issue of preventing tanker spills, a major study was conducted by the Marine Board of the National Research Council. This study investigated oceangoing tanker designs, and recommended rules and standards to improve hull resistance to penetration during collisions and grounding, and reduce outflow of oil should the hull be penetrated. To support the Marine Board effort, a separate study was undertaken by the R&D Center to determine oil outflow rates resulting from tanker collisions for various tanker designs and spill scenarios. Both of these studies provided key technical input in formulating the tanker and barge double-hull regulations under OPA 90.

<u>Tanker Damage and Stability Assessment</u>

Tanker Damage Assessment

To support tanker salvage operations, a technology assessment investigated in-tank and remote (electromagnetic and acoustic) methods of determining oil vs. seawater levels in tanks; the location, size, and nature of the tank penetration; and the integrity and strength of the vessel structure. This study, performed by Battelle Memorial Institute, looked at the overall requirements for the assessing tanker damage, described and compared the various sensors and platforms available, and developed a system concept for integrating vehicle, sensors, and navigation systems for performing damage assessment.

Autonomous Underwater Vehicles (AUV) in Spill Response

This study, conducted by the University of New Hampshire, looked at the capabilities and limitations of utilizing Autonomous Underwater Vehicle (AUV) technologies in support of spill response. The capability of the AUV to navigate and maneuver in a transponder network was evaluated. This capability would allow the AUV to operate in a hazardous operational environment where diving operations are too dangerous.

Tanker On-Site Countermeasures

Tanker Self-Help Countermeasures Study and Workshop

Following the EXXON VALDEZ spill, questions were raised about the need for tankers to carry on-board oil spill containment and recovery systems for use in the event of a spill, particularly if the spill occurs in a remote area. To address this issue, a study was conducted by the R&D Center to critically examine the techniques and equipment that might be carried and deployed from a tanker to respond to an oil spill emergency. As this study was being initiated, the R&D Center became aware of a similar study being undertaken by the Canadian Coast Guard and Environment Canada. These studies were coordinated and a joint workshop was held, bringing together researchers, spill responders, and tanker operators to review the results of both studies and reach a consensus on the feasibility of various tanker countermeasures techniques.

The workshop, held in Toronto in April of 1992, was well attended and highly successful. Reports on both technical studies and the workshop were completed. The consensus recommendation was that an extensive on-board containment and cleanup capability was not feasible because of limited manpower on the vessel and the need to focus on protecting personnel and saving the vessel in the event of a vessel casualty.

NSF Tanker Offloading Capability Upgrade Study

The National Strike Force (NSF) has maintained a readily deployable and highly effective tanker offloading system called ADAPTS (Air Deliverable Anti-Pollution Transfer System) since the late 1970s. This system has been successful in offloading oil from damaged tankers in a number of spills including the EXXON VALDEZ spill. Accordingly, Coast Guard R&D investigated how this capability could be enhanced using upgraded technology and materials. This work was conducted in two phases. Phase I investigated the feasibility of using composite materials in existing NSF transfer pumps, hoses and couplings. Composites options were identified and Phase II of the study continued with the drafting of engineering designs, procurement or manufacturing of components, and assembly and testing of prototype systems. This reduction in weight of product off-loading systems could enhance the transport and deployment of these systems. System design and operating specifications were developed and forwarded to Coast Guard Headquarters.

Benefits for Tanker Salvage and Onboard Containment

- The Marine Board Report formed the technical basis for the double hull regulations enacted under OPA 90. These regulations are expected to significantly decrease the volume of oil spilled from tankers and barges in coming years.

- The Tanker Self-Help Countermeasures Study and Workshop clearly defined the limited feasibility of requiring on-board containment and cleanup equipment and manpower, and precluded the development and implementation of additional tanker regulations by the Coast Guard, which in retrospect, would have been unwarranted.

- The NSF Offload Capability Upgrade Study provided technical input that can be used in the next generation NSF ADAPTS system to offload oil from damaged tankers. The development of improved NSFCC smaller, lighter and more effective oil transfer systems is continuing. Given the high response costs and damages associated with oil that reaches the water, this technology represents a high payoff spill countermeasure.

Spilled Oil Cleanup and Alternative Countermeasures

The physical containment and mechanical recovery of oil from the surface of the water is the most commonly used oil spill response technique, despite the fact that prior to EXXON VALDEZ, it rarely resulted in recovering more than 10-20 percent of the oil spilled. The limitations of this technique were further underscored during EXXON VALDEZ and several subsequent major spills in the early 1990s. It was further recognized that mechanical recovery must be viewed as a complete system where oil is contained and concentrated with booms, removed from the water using skimmers, temporarily stored and transported to shore, and disposed of in an environmentally acceptable manner. Impediments at any step in this process severely impact the effectiveness of the operation. Mechanical recovery can be further complicated by fast currents, ice, and oils that have a tendency to sink below the surface. Accordingly, upgrading mechanical recovery capability has been a key focus area for the Coast Guard R&D program. Physical containment and mechanical recovery of an oil spill cleanup is often labor intensive, costly and limited in effectiveness. Under ideal conditions, recovery of only 20 – 30 percent of the spilled oil can be expected. This has prompted investigation into two alternative countermeasures, the use of chemical dispersants to disperse the oil in the water column, and in-situ burning the surface of the water to mitigate environmental impacts. In-situ burning appeared particularly promising as it was successfully used in the first few days of the EXXON VALDEZ spill response and had been under development as an oil spill countermeasure throughout the 1980s, especially as a countermeasure for oil spills in ice where mechanical recovery is limited. For these reasons, Coast Guard R&D focused on this countermeasure, while Marine Spill Response Corporation and others sought to improve dispersant technology.

Specific initiatives included:

- Strategic assessments for upgrading the Coast Guard's in-house mechanical recovery capability;
- Test and evaluation of prototype and commercially available equipment and systems to define capability and promote further technology advances;
- Technology assessment and development to improve the mechanical recovery capability in fast water environments and for special oil types;
- Test and evaluation of ancillary equipment including oil-water separators and temporary storage devices;
- Test and evaluation of the overall methodology and equipment to support in-situ burning of oil spills at sea;
- Development of operations manuals, field guides and other training tools to promote the effective and efficient use of oil spill countermeasures.

Assessing and Upgrading Coast Guard Containment and Recovery Capability

NSF Oil Spill Response Equipment Upgrade Study

This initial study served as a cornerstone for upgrading the NSF's mechanical recovery capability in the early 1990's. An in-depth assessment was made of the current NSF containment booms, skimmers, temporary storage devices and transfer pumps. A worldwide survey of oil spill response equipment was conducted to identify candidate replacement systems. Generic test plans were developed for evaluating candidate system performance against NSF requirements. In addition, an alternative design was proposed for the NSF's high-seas skimming barrier to be considered for future acquisitions.

A follow-on study surveyed Strike Team recovery systems and commercially available systems and equipment to see if the recovery process can be de-bottlenecked through improved viscous oil pumping, debris handling, oil-water separation and the temporary storage of recovered oil. This study was used to identify promising systems and pieces of equipment. Based on this study, an oil-water separator test and evaluation effort was undertaken, along with an effort to evaluate existing temporary storage devices (TSDs).

Oil Recovery Systems for Coast Guard Buoy Tenders

The EXXON VALDEZ spill and subsequent major spills highlighted the need for the Coast Guard to maintain a first-response mechanical recovery capability at the port level. One option for providing this capability was to equip Coast Guard buoy tenders with an oil spill recovery capability so that they can serve as a vessel-of-opportunity for spill response in their operating

areas. Coast Guard R&D conducted a technology assessment study to identify oil spill recovery systems that could be installed on both existing buoy tenders and the new replacement WLM buoy tender. Consideration was given to containment booms that could be deployed from the vessels, skimming systems that could be used effectively, onboard and towed temporary storage systems, and onboard treatment of emulsions.

In all, twelve oil recovery systems were identified as viable candidates for use on CG buoy tenders. Limitations for deploying these systems were also identified including the inherent lack of oil storage capacity on board, and the limited slow speed maneuvering capabilities of the vessels. Oil spill barges and onboard oil water separators were recommended as solutions to limited onboard storage. This led to further testing of an inflatable barge system and efforts to develop a small lightweight oil/water separation system. Bow and stern thrusters were proposed for the buoy tenders to improve maneuverability. Once the Coast Guard selected a system and configured the Vessel-of-Opportunity Skimming System (VOSS), R&D conducted extensive tests of the system both in the OHMSETT Test Tank and at sea to determine the effectiveness and efficiency, durability, and deployability of the system (figure 5).

Figure 5. Candidate CG buoy tender VOSS being tested at sea.

Mechanical Recovery Equipment Development, Test and Evaluation

Oil/Water Separator Test and Evaluation

Initial mechanical recovery technology assessments identified the need for small, lightweight oil/water separators that could be deployed aboard oil recovery vessels-of-opportunity. Coast Guard R&D, in cooperation with the Marine Spill Response Corporation, Naval Facilities Engineering Service Center, Navy Supervisor of Salvage, PCCI, Inc., Environmental Testing Services and Amoco, Inc., initiated a program to test and evaluate several lightweight, compact, easily transportable oil/water separators. Initial tests were conducted at the Amoco Refinery in Norfolk, Virginia. In 1992, each system was tested in a variety of conditions encountered in oil spill response operations to determine performance based on oil type, sea motion (figure 6),

mousse formation, and the presence of debris. The use of emulsion breakers with the separators was also investigated. A second round of tests was conducted in 1994 and the results were transmitted to Coast Guard Headquarters. Although none of the systems tested met all of the target requirements, the tests provided valuable input to developers on necessary refinements to their systems.

Figure 6. Oil/water separator being tested on a rocking platform to simulate sea motion.

Testing of Temporary Storage Systems

Once oil has been recovered from the water, it must be temporarily stored and transported to shore for disposal. Barges are often suitable for this if available, but are often slow to arrive on-scene. The Coast Guard required an easily-transported, durable system that could be towed behind a Coast Guard buoy tender for use with the VOSS oil recovery system. Fortunately, two such systems, the Canflex "Sea Slug" oil storage bladder (figure 7) and the Lancer oil recovery barge, were developed by private industry for this purpose. Coast Guard R&D initiated a test program to evaluate the effectiveness of both systems. The Lancer barge was tested in the OHMSETT test tank in calm water and wave conditions to determine its durability and ability to allow oil to separate from water while at sea. In cooperation with the Canadian Coast Guard, tests were performed on the Canflex oil storage bladder to determine the effectiveness of the oil offloading system, test its effectiveness in allowing oil/water separation, and determine ease of cleaning. Both systems proved reliable and are now in-service in the Coast Guard and the private sector.

Figure 7. Evaluating the Canflex "Sea Slug" for ease of deployment.

Assessment and Development of Fast Water Mechanical Recovery Technology

Recovering oil in fast current situations presents a unique problem in that conventional oil booms will not contain oil at current speeds above 0.75 knots. However, up to 60 percent of spills occurring in the U.S. can be subject to fast water conditions because of river and tidal currents. This made improving fast water oil spill recovery technology a high priority for the Coast Guard R&D program. An extensive technology assessment was conducted of existing systems and methods for recovering oil in fast water to identify promising equipment and strategies. Recommendations were made for technology development, testing and field demonstrations of methods and equipment that showed promise in currents from 1 to 6 knots.

This led to the extensive testing of two specific systems, the NOFI Vee-Sweep and the NOFI 600S Oilboom in the OHMSETT test tank. The NOFI Vee-Sweep was later tested at sea along with the Coast Guard VOSS. These tests showed that the NOFI systems were capable of containing oil at tow speeds up to 1.5 knots, which could significantly improve oil containment and recovery effectiveness in fast water situations.

In addition to equipment testing, training materials were developed to acquaint Coast Guard spills response personnel with fast water oil recovery equipment, methods and safety considerations, including a fast water recovery operations field guide and a training video.

<u>Alternative Oil Spill Countermeasures</u>

Testing and Evaluation of Fire-resistant Booms

To effectively burn oil from the surface of the water, the oil must be concentrated to a thickness of 2 mm or more. This is generally accomplished by containing the oil in a fire-resistant boom. Several boom designs were developed in the 1980s, but were found to deteriorate rapidly under the heat and mechanical stress encountered in burning at sea. Development efforts in the 1990s focused on improving these designs to make fire-resistant booms more durable. Coast Guard

R&D supported this development by sponsoring a rigorous fire-resistant boom test and evaluation program.

Fire-resistant boom test and evaluation (T&E) presented a significant challenge in that there were no test facilities in the U.S. and no protocols for measuring the performance of fire-resistant booms. Accordingly, Coast Guard R&D set about establishing an in-situ burn test and evaluation facility at its Marine Fire & Safety Test Detachment Facility on Little Sand Island in Mobile, AL. The initial facility consisted of a 50 ft. by 50 ft. open tank and oil handling system to allow static testing of fire-resistant boom. The facility was also used to sample burn emissions and refine emissions sampling technologies that would later be used in the full-scale, at-sea burn conducted off Newfoundland. As testing proceeded, the facility was enhanced to provide for more exact measurements of heat flux and the ability to simulate wave motion in the tank. Concurrently, Coast Guard researchers worked with the American Society of Testing and Materials F-20 Subcommittee to develop a draft test protocol for testing fire-resistant booms. This draft standard served as the framework for boom performance tests.

Actual testing of fire-resistant booms began before these facilities were available. In 1996, a series of tests were conducted at the OHMSETT test tank using six commercially available fire-resistant boom designs to check their oil retention and sea-keeping ability. No actual fire tests were conducted as the OHMSETT facility was not capable of supporting such tests. Four of the booms were found to have oil retention and sea-keeping characteristics comparable to those of state-of-the-art fire-resistant booms. In 1998, seven commercially-available booms were tested for fire-resistance and durability at the Coast Guard facility in Mobile, including two advanced water-cooled designs (figure 8). Four of the seven booms survived the test and were sent to OHMSETT for rigorous oil retention and sea-keeping tests to determine performance degradation following exposure to heat and flame. The tests indicated that the booms could contain oil in currents up to one knot and in various wave conditions after being exposed to multiple burns. These tests verified the performance expectations for the fire-resistant booms and increased the level of confidence that they could be successfully employed over an extended period of time in at-sea in-situ burn operations.

Full-Scale at Sea Test and Evaluation of In-Situ Burning – the NOBE Experiment

Despite the successful employment of in-situ burning in the EXXON VALDEZ spill, and the development of techniques and equipment in the laboratory and at shore-side test facilities, there were still questions on the operational feasibility of large-scale, extended in-situ burn operations at sea, and the impact of burn emissions and residual oil on the environment. Accordingly, Coast Guard R&D, in cooperation with a multi-agency U.S. and Canadian research group, also supported and participated in the Newfoundland Offshore Burn Experiment (NOBE) conducted off St. Johns Newfoundland in 1993 (figure 9). This experiment was designed to meticulously sample and analyze emissions from in-situ burning so that the threat to the environment and downwind populations could be clarified. The test results clearly showed that emissions generated from a typical in-situ burn operation are unlikely to pose significant environmental or human health risks. The tests also demonstrated again the operational feasibility of the countermeasure.

Figure 8. Fire-resistant boom being tested at the Coast Guard Fire & Safety Test Detachment in Mobile, AL.

Figure 9. Newfoundland Offshore Burn Experiment (NOBE) conducted in 1993.

Refinement of Operational Tactics for In-Situ Burning – the Galveston ISB Exercises

Having supported the development of fire-resistant boom technology and contributed to defining the environmental impacts of in-situ burning, the next important step in developing and gaining acceptance of the countermeasure was to refine in-situ burn operational tactics. To accomplish this, Coast Guard R&D collaborated with the Texas General Land Office, Marine Spill Response Corporation, and National Response Corporation in conducting full-scale, at-sea exercises simulating in-situ burn operations. The exercises were designed to test various tactics including vessels operating independently with fire-resistant booms, and vessels operating in coordination

whereby some vessels would act as collection vessels, and other vessels would be burn the oil in the fire-resistant boom once it was delivered to them by the oil collection vessels. The coordinated vessel approach proved to be more efficient during these exercises. In addition, it was learned that 6 – 10 hours was required for in-situ burn task force mobilization. These exercises further refined in-situ burn operational doctrine and fostered confidence in the viability of the countermeasure.

Developing Decision Support and Training Tools for In-Situ Burning

In addition to testing the technology and refining operational doctrine, Coast Guard R&D realized the importance of providing guidance to responders to clarify the conditions under which in-situ burning can be used, and the importance of compiling the knowledge acquired on in-situ burning so that it could be used to support on-scene decision making and training. To better define the "window-of-opportunity" for in-situ burning, Coast Guard R&D commissioned two studies to determine the impacts of weathering on the flammability of various oil types. To provide training and guidance on in-situ burn operations, an in-situ burn operations manual was developed to allow responders to determine if and how in-situ burning can be used in a certain scenario. It contains operational procedures, decision aids, and checklists that provide quick access to critical information to conduct the operations in an efficient and safe manner. A companion training video has also been produced.

Major Benefits for Spilled Oil Cleanup and Alternative Countermeasures

- The NSF Equipment Upgrade Study provided technical input to modernize the National Strike Force's inventory of equipment to provide a nationwide first-response capability for a large spill. This will allow NSFCC's first-responders to quickly remove oil from undamaged tanks and prevent further spillage if the structural integrity and stability of the vessel is threatened. It will also provide a first-line mechanical recovery capability for offshore spills when the Responsible Party declines or is unable to initiate a response effort.

- The VOSS technology assessment and the VOSS test and evaluation program provided valuable information to support development of a VOSS system for use on existing Coast Guard buoy tenders and integration into the new WLM buoy tender design. Because of this, the Coast Guard now has a viable first-response mechanical recovery capability at the port level.

- Sponsoring test and evaluation of oil spill recovery systems at OHMSETT and at sea provided incentive to private industry to advance the technology for oil mechanical recovery. Notable advances were made in fast water oil containment booms, oil/water separation systems and oil temporary storage devices. Several new commercially available systems are now available for purchase by the Coast Guard and OSROs.

- The Fast Water Oil Recovery Technology Assessment consolidated the strategy and techniques for responding to spills in fast water such that oil recovery in current speeds up to three knots is now considered feasible. The Fast Water Field Guide and Training

Video provided training tools to familiarize spill response personnel with these strategies and techniques. Prior to this, recovery in fast water environments was seldom attempted. Now fast water recovery is considered feasible and safe at moderate current speeds, and may increase the amount of oil that can be recovered following a major incident.

- Several projects within the Countermeasures and Cleanup focus area provided ongoing support for the OHMSETT test tank in Leonardo, NJ. This facility, operated by Minerals Management Service, is a valuable national and international R&D and training asset and must be maintained for further advances in oil spill response technology.

- The fire-resistant boom tests established standard testing protocol for determining the performance and durability of fire-resistant boom. They demonstrated the acceptable performance of state-of-the-art fire resistant booms in meeting fire endurance and sea-keeping criteria for extended in-situ burning operations at sea. This builds confidence in ISB as an oil spill countermeasure and provides further incentive to fire-resistant boom developers and manufacturers to refine and market their systems. Since the early 1990s, several new systems have been commercially marketed, and fire resistant boom is now pre-staged at several locations around the country.

- The NOBE ISB experiment and the Galveston ISB exercises provided further knowledge on the effectiveness and impacts of ISB, and refined operational tactics and increased confidence in the use of the countermeasure in the spill response community. This in turn increases the probability that in-situ burning will be used in a major spill situation. ISB is now considered a viable option, and is being considered as a countermeasure of choice in a number of spill scenarios.

- ISB decision support and training tools provide for the ongoing training of Coast Guard personnel in in-situ burn operational doctrine. This is particularly important due to the infrequent occurrence of spills that would warrant its use.

Infrastructure Development, University Grants and Outreach Initiatives

In addition to undertaking specific research and technology development projects, a significant portion of the Coast Guard R&D effort and funding was devoted to restoring the Nation's ability to aggressively conduct oil spill R&D. Specific initiatives included refurbishing and building facilities for the test and evaluation of techniques and equipment, promoting oil spill research in the academic sector through an aggressive grants program, and increasing awareness of R&D projects and accomplishments within the spill response community and with the general public.

<u>Test Facility Refurbishment and Construction.</u>

An important component of conducting a viable and sustainable oil spill R&D program in the United States is ensuring that that there is adequate infrastructure for testing the feasibility and effectiveness of new methods and technologies for responding to oil spills. This requires that certain shore-side facilities be available because of environmental restrictions on conducting oil spills for experimental purposes at sea and the difficulty in controlling and monitoring key

parameters during at sea tests. In the 1970s, this requirement was recognized and addressed when EPA and the Coast Guard collaborated in the construction of the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) at the Naval Weapons Depot in Leonardo, NJ. In subsequent years OHMSETT became a focal point for numerous interagency oil spill response technology development projects.

In the late 1980s, with the downturn in oil spill R&D activity, EPA decided to close the facility as a cost cutting measure and turn the property back over to the U.S. Navy. This was accomplished just weeks before the EXXON VALDEZ spill. Recognizing the imminent need for the facility to support renewed R&D efforts, Coast Guard R&D collaborated with Minerals Management Service and other agencies to refurbish and reopen the facility. Subsequently, the Coast Guard R&D program provided a major portion of the funding to support test and evaluation efforts at the facility (figure 10).

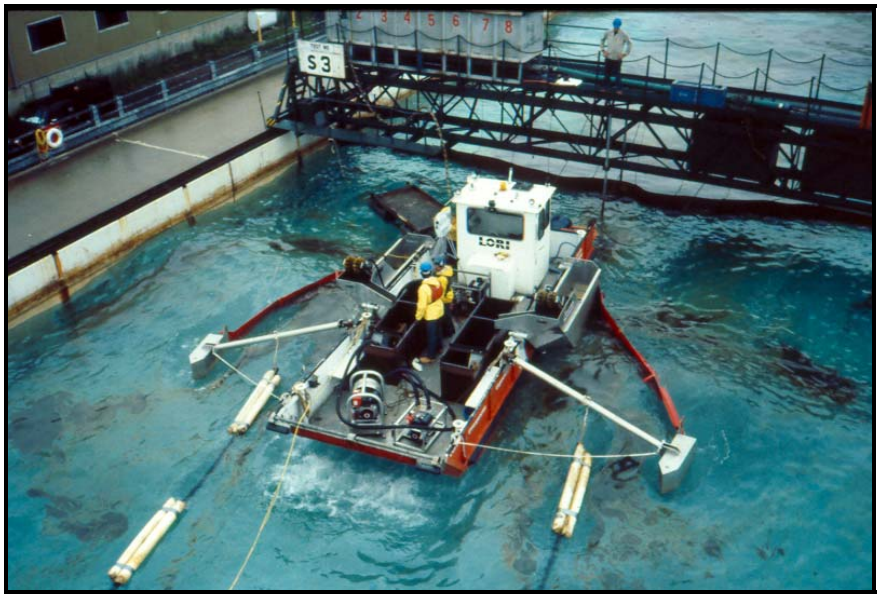

Figure 10. Coast Guard supported tests of the LORI Skimmer at OHMSETT.

A key requirement for further development and testing of in-situ burn technology was a facility where oil could be safely ignited and burned under controlled conditions. In the mid-1980s, in-situ burn tests were conducted at OHMSETT. However, stricter air quality regulations in New Jersey prevented continuation of oil burns at the facility. Coast Guard R&D was able to promptly fill this requirement by constructing a rudimentary in-situ burn test tank at its Marine Fire & Safety Test Facility in Mobile, AL in 1991. In-situ burn tests were conducted in this tank to learn more about the air quality implications of ISB and refine the experimental procedures and instrumentation that would later be used in the Newfoundland Offshore Burn Experiment (NOBE). In 1995, the facility was enlarged and outfitted with a wave generator for performance and endurance testing of fire-resistant booms. Construction of the Mobile ISB test facility was critical to the success of the ISB development effort in the 1990s.

University Grants Program

During the 1970s and 1980s, the Coast Guard had funded several oil spill technology research projects at major universities around the country. By the late 1980s, very few university researchers and their students were focusing on oil spill technology topics. To reinvigorate activity in the university community, as prescribed by OPA 90 and Congressional mandate, Coast Guard R&D initiated a University Grants Program.

The first grant initiative was establishment of the South Florida Oil Spill Research Center at the University of Miami. This initiative was prescribed by the Coast Guard FY92 Appropriations Bill and directed Coast Guard R&D to provide grant funding for a Federally Funded Oil Spill Research and Development Center in South Florida. A coordinated research program was established for the South Florida Oil Spill Research Center. It was tailored to the needs of the research programs ongoing at the University of Miami, selected to be the research lead for the grant so many of the results are not applicable outside of this area. The research program included projects in ocean circulation and spill trajectory prediction, development of an oil spill information management system, oil spill risk assessment and model development, and the development of fast water oil spill containment concepts and boom designs.

OPA 90 also called for a Nationwide Grant's Program to universities and non-profit institutions. The format of the program called for ten Federal Agencies participating in the Interagency Committee for Oil Spill Response to contribute $750,000 dollars to the program for a total of $7,500,000. This funding was to be provided over two years. However, the other Federal Agencies did not provide the funding for this effort. The reluctance came from the fact that Congress appropriated no additional funds for the grant's program and these agencies were reluctant to reallocate funds from other areas. Consequently, the Coast Guard became the primary agency providing funding and thereby fulfilling the OPA 90 mandate. The general administration of the grant program was passed to the Volpe National Transportation Systems Center. Coast Guard R&D provided technical expertise in proposal review and closely monitored the results of the program. Specific research projects were conducted on the following topics.

- Advanced Oil Spill Containment Concepts and Boom Designs
- Development of a PC-Based Shipboard Piloting Expert System
- Source Identification of Spills Based on Isotopic Composition of Weathered Oil
- Analysis of the Impact of Human Factors in Oil Spill Prevention
- Development of Oil Spill Response Simulation and Decision Support Systems
- Effects of Crude Oil and Dispersed Oil on Marine Organisms
- Rupture Analysis for Oil Tankers in a Side Collision
- Behavior Analysis and Removal of Low API Gravity Oils and Orimulsions

Of the two grants programs, the nationwide program was deemed more successful as it allowed participation by multiple universities, better targeting of the research topics, and more detailed and comprehensive reporting of the research results. A well-controlled and targeted university grants program provides an excellent means of sustaining basic research in oil spill technology R&D.

Port Demonstration Projects

OPA 90 called for the Coast Guard to carry out demonstration projects in four port areas (New York/New Jersey, New Orleans, Los Angeles, and Great Lakes) which would bring together and apply information and technology obtained from the R&D program in a systematic and integrated fashion to reduce the risk of acute and chronic oil discharges in port environments. The first OPA Port Demo was held in New Orleans during December of 1994, and the second was held at the Merchant Marine Academy in New York during October of 1995. These demos focused on the development and demonstration of research conducted over the past five years by the Coast Guard R&D Center, other government agencies, and industry. No funding was identified for the LA/LB and Great Lakes Port Demos for FY96 or FY97 and thus they were not conducted. Beyond the base funding for these port demonstrations, Coast Guard R&D devoted a substantial amount of time and effort in the organization, logistics and public outreach activities required to satisfy the OPA 90 Port Demo mandate.

Major Benefits for Infrastructure Development, University Grants and Outreach Initiatives

- Refurbishment and reopening of the OHMSETT T&E Facility restored a key component of the national oil spill R&D program. Continued progress in oil spill countermeasures and cleanup technology would have been severely hampered without this facility. The facility is still viable although the level of equipment test and evaluation has declined in recent years with the downturn in Federal oil spill R&D funding. But some of the funding support has been provided by CG and private industry training.

- Construction of an ISB T&E capability at the Marine Fire & Safety Test Facility in Mobile, AL, was critical to the success of the Newfoundland Offshore Burn Experiment and further development of fire-resistant boom technology. Because of the operational and environmental data gathered in Newfoundland and at Mobile, ISB is now considered a viable countermeasure for many coastal oil spill scenarios.

- The University Research Grant Program stimulated renewed interest in basic oil spill research and technology development in the academic community.

- The Port Demonstration projects raised public awareness of the Federal Oil Spill R&D Program and the need for continuing oil spill R&D.

Potential Long-Term Impact of Coast Guard Oil Spill R&D Accomplishments

Figure 11 provides a graphic summary of the various Coast Guard R&D accomplishments over the past decade discussed in detail in the previous sections. Longer term economic and environmental benefits derived from these accomplishments can be realized in three specific ways. First of all, advances in oil spill prevention and response technology can improve the *effectiveness of regulatory measures* in preventing spills to begin with. Second, the advances in oil spill response technology can improve *response effectiveness* by increasing the amount of oil that is contained, recovered or otherwise removed from the environment preventing economic

and environmental damages. Third, advances in oil spill response technology can improve *response efficiency* by lowering the cost of containing, recovering or otherwise removing a given volume of oil from the environment. Obviously, the goal of the Coast Guard's R&D efforts is to realize gains in all three areas.

Quantifying the potential long-term impact of the Coast Guard R&D Program in the 1990s is a difficult task for two reasons. First of all, the oil spill technological advances of the post-EXXON VALDEZ era were often attained through the collaboration of several government agencies and industry and cannot be ascribed to the Coast Guard program alone. Secondly, the long-term economic return on the R&D investment in spill prevention and response is somewhat predicated on the number and nature of spills experienced over the next decade.

The approach taken here in attempting to quantify this return on investment is to make some conservative assumptions on the impact of achievements in various focus areas on oil spill response effectiveness and efficiency, and apply these improvements to spill scenarios experienced over the past decade, both in a general sense based on spill number and volume, and also specifically to the EXXON VALDEZ spill. The result is a number of technology specific "potential impact" scenarios as well as a general 10-year potential impact prospectus that provides "representative quantitative estimates" of the actual cost savings that may be realized.

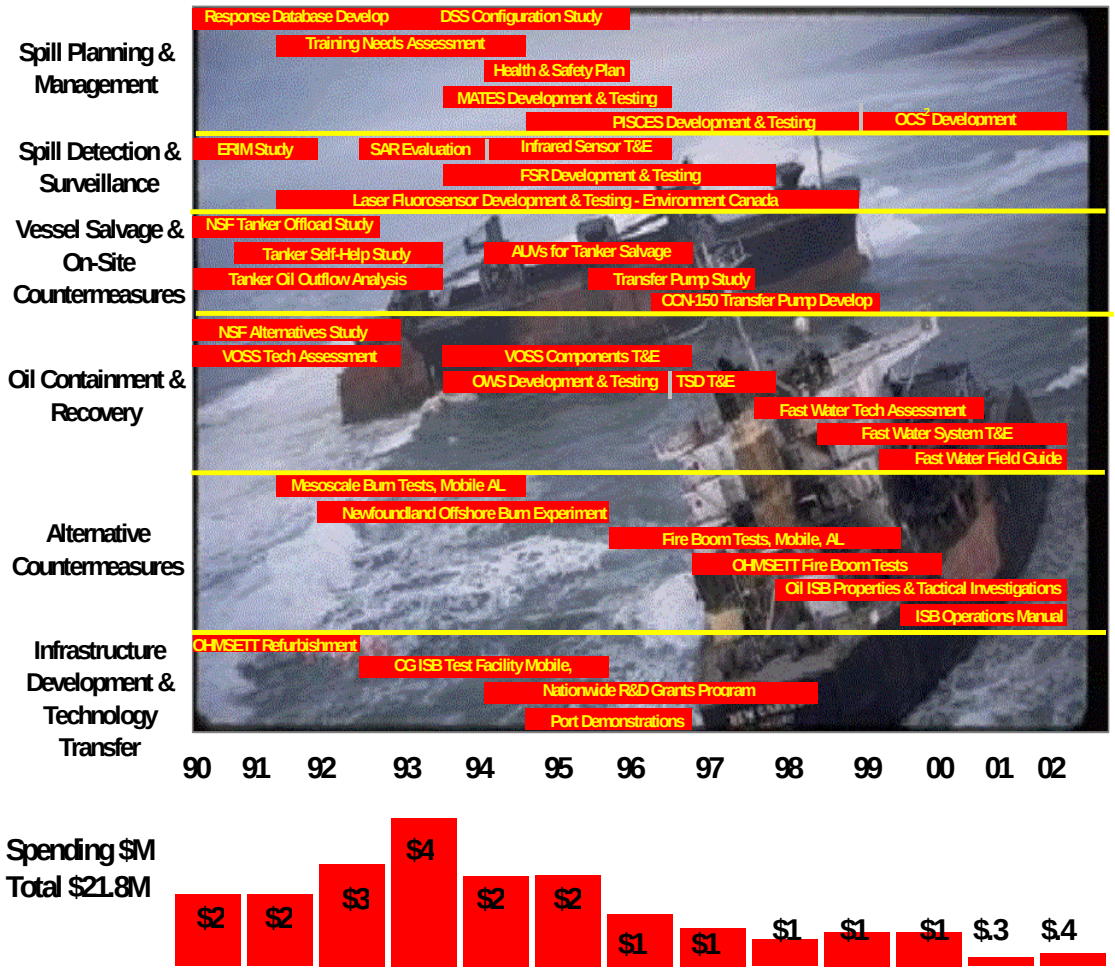

Figure 11. Coast Guard R&D Accomplishments during the post-EXXON VALDEZ Era (1990 – 2001).

Potential Impact Scenario for Double Hulls and Improved Salvage Capabilities on Major Tanker Spills

Coast Guard R&D provided technical support to the development of double hull regulations for tankers and barges as required by OPA 90. Double hulls on tankers have two main spill-prevention effects –

- Reducing the probability of spillage with impact (i.e., grounding, collision, or allision); and
- Reducing outflow in the largest spills or worst case discharges (over 1 million gallons) by up to 50 percent when hull penetration occurs with impact.

To illustrate the potential impact, consider that in 2002 the chances of an EXXON VALDEZ-type grounding are lower than in 1989. If a hard grounding were to occur, the amount of oil outflow would likely be only *half* as much if the tanker was double-hulled – *i.e.*, only 5.5 million gallons of spillage (see figure 12). Increased salvage capabilities may reduce the amount of spillage even further. ***This could have significantly reduced the response, natural resource damage and economic costs of the spill (which were approximately $4 billion), perhaps saving up to $2 billion for a single catastrophic tanker spill.***

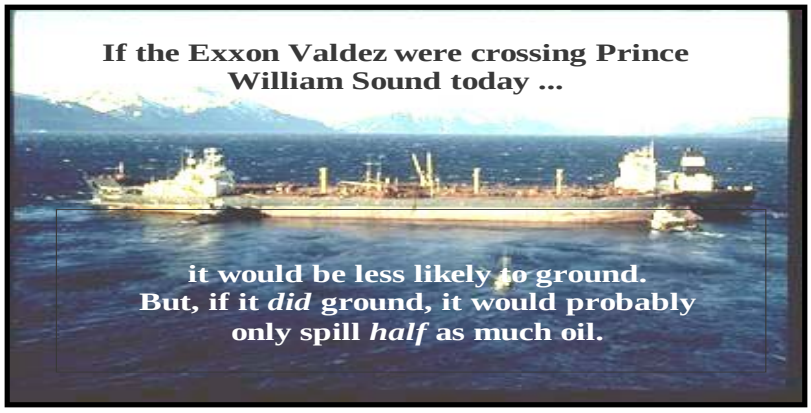

Figure 12. The Exxon Valdez Spill today.

Potential Impact of Fast Water Containment and Recovery

During the ten-year period 1992 – 2001, 25.3 percent of all oil spills of at least 100 gallons from both facilities and vessels into navigable water occurred in fast-current water bodies (exceeding one knot). This spillage accounted for 29.3 percent of the oil spilled into navigable water during this time period. Based on spill volumes for the period 1992-2001 and the average cost of mechanical recovery of oil on a per gallon basis, the savings associated with a 10 percent and 20 percent increase in removal effectiveness for fast water spills can be estimated. These values can easily be reached with the use of new techniques introduced and the use of the field guide and training aids produced. ***With a 10 percent mechanical recovery increase for these fast-current spills, a response and damage cost savings of approximately $560 million over the next ten years could be realized if a similar pattern of spillage occurs as during the last 10 years. With 20 percent recovery increase, a savings of $1 billion dollars might be realized in ten years (see figure 13).***

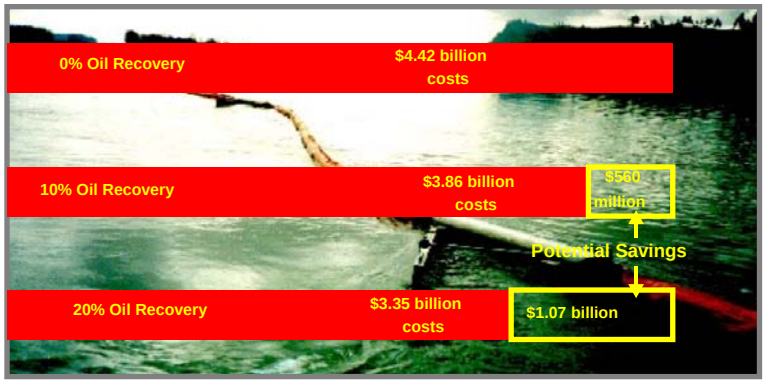

Figure 13. Potential Savings With Enhanced Oil Recovery in Fast-Current Waters.

Potential Impact of In-Situ Burning

The development of in-situ burning technology and the implementation of an ISB capability nationwide have significantly increased the possibility of removing larger quantities of oil from major spills. In several previous studies, attempts have been made to identify past spills where in-situ burning could have been used and estimate the amount of oil that could have been removed if ISB technology had been available (as reported in the USCG CAPS Study, (USCG, 1999); Kucklick and Aurand 1997; and Etkin and Tebeau 2003*). It has been estimated that if* ***in-situ burning had been used with a removal effectiveness of 80 percent on 28 significant post-Exxon Valdez U.S. oil spills*** (as identified in the USCG OSPPR Study (USCG, 2001)) for which the conditions were deemed appropriate for burning***, $755 million in response costs, environmental damages, and socioeconomic damages might have been saved. With the more effective in-situ burning response capability, for an EXXON-VALDEZ type major tanker spill, it is estimated that total response costs and damages might be reduced by $1.4 billion in comparison to the 1989 spill.***

Total Potential Cost Savings over a Ten-Year Period

In addition to estimating the cost-savings associated with individual focus area achievements, it is possible to estimate projected cost savings over a ten-year period by applying today's technology capabilities to the spills that occurred over the past decade. In doing so, it is assumed that the current capability would allow an overall recovery/removal effectiveness of 20 percent, versus 10 percent with the technology that was available in the 1980s. The 10 percent effectiveness for the pre-EXXON VALDEZ era is based on the 1990 Congressional Office of Technology Assessment Report entitled "Coping with an Oiled Sea" (OTA, 1990). As reported in the USCG OSPPR Study (USCG, 2001), the current (1990s) recovery effectiveness is generally considered to be at least 20 percent under favorable environmental conditions. This has been supported by oil recovery volumes in several recent spills as listed below.

Spill	Location/Date	% Oil Recovered
Unocal Pipeline Spill,	Morro Bay, CA, August 1992	39
Colonial Pipeline Spill	Potomac River, VA, March 1993	86
T/B BOUCHARD 155	Tampa bay, FL, August, 1993	45
T/B MORRIS J. BERMAN	Spill, San Juan, PR, January 1994	96
T/B BUFFALO 292,	Houston Ship Channel, TX, March 1996	44
T/B BUFFALO 286,	Houston Ship Channel, TX, May 1996	48
Colonial Pipeline Spill	Reedy River, SC, June 1996	91
T/V JULIE N.	Fore River, ME, September 1996	78
T/B CTCO	Mississippi River, LA, June 1998	50

By applying these 10 percent and 20 percent values to spills that occurred in the past decade, a representative 10-year cost savings can be computed as depicted below in table 1 and figure 14.

Table 1. Impacts of Enhanced Oil Spill Response on Total Estimated Oil Spill Damages.

Impacts of Enhanced Oil Spill Response on Total Estimated Oil Spill Damages (Spills of 100 Gallons and Larger)							
Year	**Number Spills**	**Gallons Spilled**	**Estimated Damages Based on Recovery[1] ($ million)**				
			0% Recovery	**10% Recovery**	**SAVINGS 10% Recovery**	**20% Recovery**	**SAVINGS 20% Recovery**
1992	708	1,585,955	$1,048	$943	$106	$840	$208
1993	618	2,060,422	$1,473	$1,316	$157	$1,164	$309
1994	662	3,945,487	$2,063	$1,850	$213	$1,646	$417
1995	505	1,899,525	$1,487	$1,326	$160	$1,167	$320
1996	521	3,146,931	$1,588	$1,413	$174	$1,260	$327
1997	395	1,019,809	$749	$673	$77	$597	$153
1998	436	798,832	$499	$447	$51	$398	$101
1999	367	1,315,204	$934	$834	$100	$737	$197
2000	353	838,044	$625	$559	$66	$494	$131
2001	253	501,045	$353	$315	$38	$280	$73
TOTAL	**4,818**	**17,111,254**	**$10,819**	**$9,676**	**$1,142**	**$8,583**	**$2,236**

[1]Damage costs include response costs, natural resource damages, and socioeconomic damages as modeled in Etkin and Tebeau (2003), based on oil type and spill size as in Etkin *et al.* (2002, 2003) with oil fate modeled based on Applied Sciences Associates' SIMAP (French-McCay *et al.*, 2002). Mechanical recovery assumed, with recovery percentage as noted.

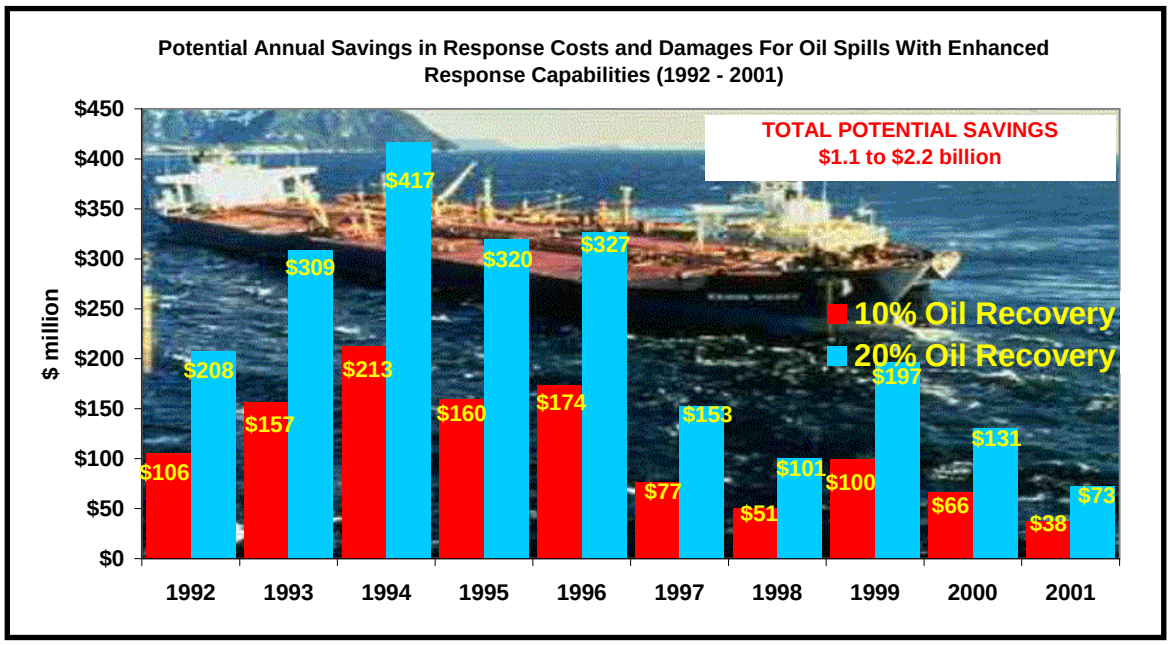

Figure 14. Potential Annual Savings in Response Costs and Damages for Oil Spills With Enhanced Response Capabilities.

Overall Assessment of the Coast Guard R&D Program in the 1990s

In closing, the Coast Guard R&D Program in the post-EXXON VALDEZ era was highly successful, both in meeting the expectations called out in OPA 90 and the Interagency Oil Spill Research and Technology Development Plan, and providing substantive technology advances that are likely to produce real cost savings in the future. For the several millions of dollars invested in the program, a return of up to 1 to 2 billion dollars may be realized subject to the number and nature of spills in the next decade. The program has been highly efficient, monitoring and capitalizing on the efforts of other agencies and industry wherever possible through active partnering. It has reinforced the Coast Guard's leadership position in oil spill R&D and encouraged oil spill technology development efforts by academia and industry. The challenge for the future lies in sustaining the program during periods when the threat of oil pollution is less visible in the national agenda and to maintain momentum and preserve oil spill technical expertise within Coast Guard R&D.

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APPENDIX A

U. S. Coast Guard Oil Spill Response Research & Development Program

Comprehensive Bibliography, 1991 - 2001

Description and Purpose

The 1990s were a significant decade for Coast Guard R&D because of the intensive oil spill research and technology development effort prompted by the *EXXON VALDEZ* oil spill in Alaska and the passage of OPA 90. The purpose of this bibliography is to provide a comprehensive listing of these reports for easy reference by both Coast Guard personnel, as well as other researchers in government, academia and industry.

This bibliography provides a collection of concise abstracts of all formal published reports and informal unpublished reports generated by the Coast Guard Oil Spill R&D Program during the period 1991 – 2001. It also contains a collection of abstracts from papers that dealt with R&D efforts initiated or supported by Coast Guard R&D presented at the International Oil Spill Conferences (IOSC) and the Arctic and Marine Oilspill Program (AMOP) Technical Seminars. The Coast Guard R&D reports can be obtained directly from the National Technical Information Service using the NTIS accession numbers provided. The informal unpublished can be obtained from the Coast Guard R&D Center. The IOSC and AMOP papers are published in the conference proceedings available from the IOSC sponsors and Environment Canada, respectively.

Coast Guard R&D Center Reports

Oil Recovery Systems for Coast Guard Coastal Buoy Tenders, Volume I-Technical Report
Author: Engineering Computer Optecnomics, Inc.
USCG R&D Oil Spill Response Report CG-D-04-91 (NTIS # ADA235890)

Available oil spill recovery systems were investigated for their applicability to be deployed from existing and proposed USCG buoy tenders. These systems included containment boom and skimming devices. Storage for the recovered fluid and possible separation of oil and water from the recovered fluids were investigated. It was found that the limited low speed maneuvering capability of the buoy tenders restricted the overall efficiency of the recovery process and the selection of the recovery systems. Suggestions for deployment are provided as well as recommendations for further investigations.

National Strike Force (NSF) Oil Spill Response Equipment Upgrade
Author: MAR, Inc.
USCG R&D Oil Spill Response Report CG-D-06-91 (NTIS # ADA242434)

Current options for upgrading oil spill response equipment for the Coast Guard's National Strike Force (NSF) were investigated. The specific systems and equipment addressed included

oil/water separation systems, temporary storage devices, skimmers and pumps. In addition, a concept for an alternative design for the NSF's skimming barrier retrieval system has been proposed. A survey of oil spill response equipment was conducted to identify candidate replacement equipment, and evaluation criteria were developed and applied in the screening of prospective equipment. This study is the first of a two-phase program designed to evaluate replacement equipment for the NSF.

Feasibility Study of Several Alternatives for Spilled Oil Recovery by the United States Coast Guard
Author: MAR, Inc.
USCG R&D Oil Spill Response Report CG-D-09-91

The objective of this report is to provide a systematic evaluation of four different, but supportive approaches to providing spilled oil mechanical recovery capabilities to both the coastal and high seas environment. A detailed evaluation of mechanical oil recovery systems currently available on the world market has been conducted, and a representative profile has been developed. Evaluation criteria have been developed as a means for comparing the advantages and limitations of these four concepts of operations for the mechanical recovery of oil, and a detailed discussion of this has been provided.

Investigation of Self-Help Oil Spill Response Techniques and Equipment
Author: W.I. Enderlin, J.P. Downing, C.W. Enderlin, W.S. Pope and T.F. Sanquist
USCG R&D Oil Spill Response Report CG-D-21-92 (NTIS # ADA 260881)

This document describes a study conducted of 45 self-help response techniques and equipment for oceangoing tankers and inland tank barges to assess their potential effectiveness. The results were considered by the Coast Guard to determine whether response requirements can be better met with shore-based equipment or vessel carried equipment. Based on the findings it was recommended that research pertaining to onboard self-help countermeasures focus on pumping with onboard containment category concepts. Other recommendations include further developing the model used in this study, combining the simulation models used in the study into one global model, and making a more in-depth investigation of the environmental data**.**

Innovative Inspection Techniques
Author: M. J. Goodwin and E. F. McClave
USCG R&D Oil Spill Response Report CG-D-06-93 (NTIS # ADA265418)

The study is a technology assessment of innovative vessel inspection techniques that could be used by Coast Guard marine inspectors. The study consists of an assessment of current CG marine inspection techniques for commercial vessels followed by an assessment of techniques used by other government agencies and industry to inspect large structures. Both sets of techniques are compared and recommendations made on how CG inspection techniques could be improved.

The study found that visual inspections, the current method used for ship inspections, is the most effective. Improvements in tank lighting for visual inspection or the use of night vision devices

show the greatest potential for inspection improvement at a reasonable cost. Better access to tank structures is also needed. It was also recommended that the Coast Guard consider requiring built-in access provisions for new tankers to reduce the risk of structural problems being missed during inspections.

Technical Survey and Evaluation of Underwater Sensors and Remotely Operated Vehicles
Author: B. G. DeRoos, G. Wilson, F. Lyon and W.S. Pope
USCG R&D Oil Spill Response Report CG-D-21-93 (NTIS # ADA274716)

This study is a technology assessment of Remotely Operated Vehicles (ROVs) and associated sensor systems that can be used to carry out vessel damage surveys. The report contains an analysis of CG vessel damage assessment mission requirements followed by a technical overview of underwater vehicles and sensor technologies that are currently available. Evaluations are provided as to how well each vehicle system would be able to meet the operational and environmental needs for sensor delivery, and how well sensors would be able to meet specific inspection requirements. The study found that a hull-crawling ROV with free-swimming capability would most adequately meet the overall damaged vessel inspection requirements. A conceptual system is proposed that integrates vehicle, sensors and navigation system. Recommendations for further system R&D are provided which include testing sensors in a laboratory environment, developing a vehicle test bed, analyzing sensor performance in an oil/water environment, and further monitoring of future systems and sensors as they become available.

Evaluation of Synthetic Aperture Radar for Oil-Spill Response
Author: G. Hover, G. Mastin, R. Axline, and J. Bradley
USCG R&D Oil Spill Response Report CG-D-02-94 (NTIS # ADA278796)

This report provides a detailed evaluation of synthetic aperture radar (SAR) as a potential technology improvement over the Coast Guard's existing side-looking airborne radar (SLAR) for oil-spill surveillance applications based on an experiment. Upon completion of the experiment, the potential utility of SAR as a replacement for SLAR in oil-spill applications was assessed during two data analysis workshops. Also, a cost-benefit analysis between the existing Coast Guard SLAR and a conceptual SAR design tailored to Coast Guard requirements was performed.

Ohmsett Test of NOFI Vee-Sweep and NOFI 600S Oilboom
Author: Michael J. Goodwin
USCG R&D Oil Spill Response Report CG-D-04-94 (NTIS # ADA 279525)

A NOFI Vee-Sweep and a NOFI 600S Oilboom were tested at the Ohmsett test basin to determine if the skimming could be performed at speeds higher than the current VOSS limit of 0.75 knots. Tests included critical tow speed tests, oil loss speed tests, wave conformance tests and oil loss rate tests. The results of the tests are discussed in the report.

Evaluation of Night Capable Sensors for the Detection of Oil on Water
Author: G.L. Hover and J.V. Plourde
USCG R&D Oil Spill Response Report CG-D-09-94 (NTIS # ADA281728)

This report documents a USCG Research and Development Center evaluation of several existing night-capable sensors for their utility in providing a first-response oil spill remote sensing capability to USCG marine pollution units, in support of the USCG marine environmental protection program. This report provides a primarily qualitative analysis and interpretation of the imagery obtained during the sensor test.

Ohmsett Tests of LORI LSC-2 Skimming Systems
Author: MAR, Inc.
USCG R&D Oil Spill Response Report CG-D-17-94 (NTIS # ADA294352)

The LORI LSC-2 side collector skimming unit was tested at the Ohmsett test facility to evaluate the effectiveness of the LORI brush system at recovering floating oil. The skimming vessel was towed at five different forward velocities from 1.5 to 3.5 knots, both in calm water and in waves. Three test oils were used including a light diesel fuel, medium refined oil and a heavy blend of refined oil. The results and conclusions are discussed in this report, including oil recovery rate, oil recovery efficiency and throughput efficiency.

Survey of Robotic Tankship Inspection Technology
Author: J. M. Alzheimer
USCG R&D Oil Spill Response Report CG-D-21-94 (NTIS # ADA 285871)

This study provides a survey and assessment of promising robotic technologies that can be used for the inspection of merchant vessel internal tank structures. The study includes development of general performance requirements for a remote robotic inspection system and an industry survey of remote inspection technology applicable to tank ship inspections. The incentives for using robotic devices are related to the potentials for more thorough inspections, reduced costs, and improved operator safety.

No existing robotic systems were identified during the industry survey that met the general performance requirements. While some progress is being made in this area, none of the currently available systems would fulfill more than a rather small subset of the performance requirements. Based on current requirements and foreseeable capabilities of robotic systems in the future, concepts for the development of a CG system are discussed along with the possible benefits of such a system.

Design, Construction, Test and Evaluation of a Frequency Scanning Radiometer for Measuring Oil Slick Thickness
Author: G.L Hover, T.J. Murphy, E.R. Brown, G.G. Hogan and O. McMahon
USCG R&D Oil Spill Response Report CG-D-29-94 (NTIS # ADA290040)

The results of past experiments using passive single frequency microwave radiometry to detect oil slicks and to estimate oil layer thickness showed that microwave radiometry could detect oil

and estimate oil thickness; however, because of the single sampling point, estimates of oil thickness became ambiguous. This final report starts with a complete technical description of the theory of radiometry as applied to the oil-slick thickness measurement problem. The advantages of using a frequency scanning radiometer to measure over a wide band of frequencies instead of measuring the radiometric brightness temperature with a fixed-frequency instrument are then discussed.

The Detection of Oil Slicks at Night with Airborne Infrared Imagers
Author: G.M. Daniels and G.L. Hover
USCG R&D Oil Spill Response Report CG-D-30-94 (NTIS # ADA289731)

This study compared the performance of Infrared imagers and Gimbal-mounted thermal imagers with hand-held imagers operating in the 3-5 micron region for nighttime detection of oil slicks on the ocean. The comparison was primarily theoretical with semi-quantitative support from an un-calibrated database of infrared images taken with various sensors. It was found that the 8-12 micron instruments produced images with better-oil contrast at night. It is recommended that the use of 8-12 micron imagers be continued for oil slick searches at night and the potential of new nighttime imaging devices be assessed.

Condensed USCG Oil Spill Response Health and Safety Plans
Author: Kevin J. Beltis
USCG R&D Oil Spill Response Report CG-D-15-95 (NTIS # ADA299133)

This report contains a ready-to-use set of safety and Health Plans (SHP) by the U.S. Coast Guard (USCG) in response to a release of oil or other petroleum product. This document is designed to be separable in the field to assist the Site Safety and Health Officer in preparing the necessary documentation in the shortest possible time. This should allow spill response personnel to access the site in a more timely fashion to mitigate the release and to help minimize any subsequent environmental damage.

Evaluation of Infrared Sensors for Oil Spill Operations
Author: G.L. Hover and J.V. Plourde
USCG R&D Oil Spill Response Report CG-D-18-95 (NTIS # ADA302656)

During November 1994, the USCG conducted a field evaluation of several commercially available portable infrared (IR) sensors for their ability to detect oil on water at night. Analysis of the image data confirmed that all of the sensors were capable of detecting oil slicks at night under favorable environmental conditions. Atmospheric moisture adversely affected the performance of the IR sensors to varying degrees. This and other aspects of oil slick observation are discussed in this report. Recommendations concerning the design and operation of portable IR sensors are provided for oil pollution monitoring and response applications.

Oil Spill Risk Assessment Model and Ranking of Ports for Oil Spill Vulnerability
Author: P. K. Raj and C. K. Turner
USCG R&D Oil Spill Response Report CG-D-35-95 (NTIS # ADA302991)

This report describes the development of an oil spill risk assessment methodology that can be used by Coast Guard Marine Safety Offices in preparing port contingency plans. The model provides a more rigorous approach to identify the type, size and frequency of occurrence for spills in a given port area. The model takes into consideration the specifics of the water body in the port, vessel traffic levels, current or projected oil transport volume, size distribution of vessels carrying oil, environmental conditions and channel characteristics. The model uses risk assessment factors developed in the Port Needs Study taking into account the accident rate reduction associated with vessel traffic systems. The output of the model is a histogram of frequency of accidents vs. potential spill volume. This allows comparison of spill risk in various ports. The oil spill risk for a number of ports is calculated and presented.

Robotic-Remote Operated Sensing Device for U.S. Coast Guard
Author: Christopher Alberts, Alan Guisewite, William Kaufman, and Melvin Siegel
USCG R&D Oil Spill Response Report CG-D-41-95 (NTIS # ADA 302929)

This report describes a research program to evaluate if any state-of-the-art robotics technology is applicable to hazardous-response robot for the Coast Guard. The major goal of this project is to produce a conceptual design of a robotic system capable of reducing risks to the health and safety of strike team personnel. The requirements of strike teams with respect to robotics technology are summarized in this document. The results of the literature search and a conceptual design of a hazardous response robotic system are also included.

Evaluation of Innovative Vessel Inspection Techniques (Phase II, Advanced Technology)
Author: M. J. Goodwin and K. Hansen
USCG R&D Oil Spill Response Report CG-D-42-95 (NTIS # ADA302624)

This report provides the results of a study to evaluate advanced technologies for use by Coast Guard marine inspectors by providing better information and making inspections more efficient. Technology categories addressed included: remotely controlled lights, video systems, climbing inspectors, fiber-optic video scopes, robotic manipulators, robotic climbers and walkers, acoustic and microwave imaging, thermography, and polarized light techniques. Candidate systems were identified based on manufacturer's literature and ranked based on criteria determined to be important in the inspection process. Certain systems were selected for field testing aboard ship and at shore sites. The results of the field tests are described. Video systems and the use of climbing inspectors were found to be the most promising technologies/techniques.

Improving the Performance of Oil Spill Containment Booms in Waves Part I – Literature Review, Part II – Physical Model Study: Procedure and Results
Author: Robert L. Van Dyck
USCG R&D Oil Spill Response Report CG-D-43-95 NTIS # ADA304305)

This study to improve boom performance in waves is intended to complement the ongoing oil spill research at the Ohmsett facility and within the Marine Spill Response Corporation. Based on analysis of the results that are provided in detail in this report, highly flexible booms with buoyancy/weight ratio of at least 10 and sufficient freeboard are recommended for open sea operation with a catenary tow at about 0.5 knots.

Ohmsett Tests of the Lancer Inflatable Barge
Author: M. Goodwin, D. S. DeVitis, S. L. Cuneff, D. L. Baker, R. L. Custer and S. McHugh
USCG R&D Oil Spill Response Report CG-D-04-96 (NTIS # ADA308014)

This report describes test and evaluation of the Lancer Oil Recovery Barge at the Ohmsett test basin. The tests measured the effectiveness of oil-water separation and decanting of water from the device. Tests were performed for two oil viscosities (0,954 and 2800 cSt) and in both calm water and two wave heights. The effectiveness of the internal liner for the barge was also tested.

The tests showed that the Lancer Barge performs well as an oil recovery barge with the oil separating quickly even when the barge is being towed. Wave motion affects the process with barge pitch being the most important factor. The decanting tube is effective in removing water from the bottom of the barge. The liner was found to be deficient developing a number of leaks during the tests.

Ohmsett Tests of: The CANFLEX "Sea Slug" Temporary Storage Device and the DOAS Flotation Collar
Author" Michael Goodwin and Roland L. Custer
USCG R&D Oil Spill Response Report CG-D-05-96 (NTIS # ADA308226)

This report describes an initial series of tests of the CANFLEX "Sea Slug" temporary storage device and the DESMI Offload Adapter System (DOAS). The tests were primarily to determine the effectiveness of offloading techniques with the DOAS, and determine the time required for oil and water to separate within the "Sea Slug." A third area of interest was determination of cleaning techniques for the "Sea Slug." It was concluded that an additional method of offloading should be investigated. This consisted of a pump lowered to the bottom mid-length along the "Sea Slug."

Oil/Water Separator Test and Evaluation
Author: Michele A. Murdoch, Kenneth R. Bitting, and Atle Nordvik
USCG R&D Oil Spill Response Report CG-D-06-96 (NTIS # ADA308186)

Four oil/water separators were tested to evaluate the performance of oil/water separators under a variety of conditions that replicated operating conditions expected during an offshore oil spill

recovery operation. Separation performance was documented, as well as observations on separator operability, reliability, maintenance requirements, safety and transportability. Complete test results and analysis, recommendations, test methods and parameters are provided in this report.

Test Tank Evaluation of a Frequency-Scanning, Microwave Radiometer to Estimate Oil Thickness and Physical Properties
Author: T.J. Murphy, O.B. McMahon and G.L. Hover
USCG R&D Oil Spill Response Report CG-D-18-96 (NTIS # ADA320082)

This report describes the testing of a 26-40 GHz Frequency Scanning Radiometer (FSR) to evaluate the instruments ability to detect and measure the thickness of oil films on water. The results indicate that the FSR was able to reliably measure oil thickness under calm conditions and, in some cases, under mild wave conditions. Future hardware development and further laboratory testing are also discussed.

At-Sea Evaluation of the Coast Guard VOSS, NOFI-V and FIOCS Oil Recovery Systems
Author: Kedric C. Eisenberg, Jon F. Etxegoien, and Deborah A. Furey
USCG R&D Oil Spill Response Report CG-D-19-96 (NTIS # ADA319794)

At-sea evaluations of the USCG Vessel of Opportunity Skimming System (VOSS) were conducted to determine its seaworthiness, handling and towing characteristics. A 225 ft offshore supply vessel was used to evaluate the VOSS, the NOFI-V Sweep and the FIOCS systems during trials. The results, including the deployment, operation and safety concerns of the systems, are discussed in the report.

U.S. Coast Guard 1994 Oil Pollution Research Grants, Parts I and II
Author: Various university and laboratory investigators
USCG R&D Oil Spill Response Report CG-D-27-96 (NTIS # ADA325735 (Part I) and ADA325734 (Part II))

These volumes contain the individual project reports for efforts undertaken as part of the OPA 90 Nationwide Grant's program to universities and non-profit institutions. Specific research projects were conducted on the following topics.

- A Hydrodynamic Model of Oil Containment by a Boom: Phase I
- Development of a Rapid Current Containment Boom: Phase I
- Source Identification of Oil Based on the Isotropic Composition of Individuals Components in Weathered Oil Samples
- Preventing Oil Spills by Evaluating, Monitoring, and Managing Port and Waterway Risk
- Effects of the Water Accommodated Fraction of Crude Oil and Dispersed Oil on the Early Life Stages of Two Marine Species
- Influence of Dispersants on Petroleum Bio-availability Within a Marine Food Chain
- Petroleum PC-Based Shipboard Piloting Expert System (SPES)
- Decision Support Technology for Oil Spill Response Configuration Planning

- Oil Spill Prevention Through the Improved Management of Human Organization Errors in the Operations of Tankers and Barges

Feasibility of Using Composite Materials to Reduce the Weight of the CCN-150 Transfer Pump
Author: H.K. Telegadas
USCG R&D Oil Spill Response Report CG-D-10-97 (NTIS # ADA327727)

The objective of this study was to determine the feasibility of using composite materials to reduce the weight of the National Strike Force cargo transfer pumps. Tests showed that the performance of the pump was not degraded with the composite parts. The use of the composite material reduces the weight of the stainless steel pump by 28%. This report offers three options for future pump development: perform additional testing to refine the current composite suction bell and pump bowl, fabricate additional parts of composite to reduce weight further, and design an all new joint Navy/Coast Guard transfer pump that would minimize weight and optimize strength advantages of composites.

Development of Composite Components for the CCN-150-5C Transfer Pump
Author: H.K. Telegadas and George F. Wilhelmi
USCG R&D Oil Spill Response Report CG-D-11-97 (NTIS # ADA327731)

The objective of this study was to determine the feasibility of using composite materials to reduce the weight of the National Strike Force cargo transfer pumps, focusing on the CCN-150 transfer pump. Tests showed that the performance of the pump was not degraded with the composite parts. The use of the composite material reduces the weight of the stainless steel pump by 28 percent. This report offers three options for future pump development: perform additional testing to refine the current composite suction bell and pump bowl, fabricate additional parts of composite to reduce weight further, and design an all new joint Navy/Coast Guard transfer pump that would minimize weight and optimize strength advantages of composites.

Development of a Seawater Hydraulic Transfer Pump, Phase I - Feasibility Study
Author: John Kunsemiller
USCG R&D Oil Spill Response Report CG-D-12-97 (ADA336841)

The Naval Facilities Engineering Service Center completed a Phase I feasibility study to determine whether or not a seawater hydraulic design for the CCN-150 transfer pump system would reduce weight, making the system easier for the USCG Strike Teams to deploy. This study includes a review of commercially available seawater hydraulic system hardware applicable to this conversion and development of a seawater hydraulic transfer pump system design concept.

Development of a Seawater Hydraulic Transfer Pump, Phase II - Demonstration
Author: John Kunsemiller
USCG R&D Oil Spill Response Report CG-D-13-97 (ADA339281)

This report describes the results of a demonstration of the CCN-150 oil transfer pump. A previous study (Phase I) determined that an open circuit seawater hydraulic system configuration of the transfer pump system with a lightweight seawater hydraulic power source has the potential to provide a 3,000 lb. savings in weight over the present hydraulic system. The Phase II tests showed that the seawater hydraulic design for the CCN-150 transfer pump is practical using commercial components.

U.S. Coast Guard 1995 Oil Pollution Research Grants, Parts I and II
Author: Various university and laboratory investigators
USCG R&D Oil Spill Response Report CG-D-22-97 (NTIS # ADA330201 (Part I) and ADA330202 (Part II))

These volumes contain the individual project reports for efforts undertaken as part of the OPA 90 Nationwide Grant's program to universities and non-profit institutions. Specific research projects were conducted on the following topics.

- Rupture Analysis of Oil Tankers in a Side Collision: Theory of Bow Cutting Through Decks
- Rupture Analysis of Oil Tankers in a Side Collision: Global Structural Model of Bow Indentation into Ship Side
- Rupture Analysis of Oil Tankers in a Side Collision: Hard Point Fracture of Shell Plating
- Numerical Modeling of Oil Containment by a Boom/Barrier System: Phase II
- Development of a Rapid Current Containment Boom: Phase II
- Micro- and Meso-Scale Methods for Predicting the Behavior of Low- API Gravity Oils (LAPIO) Spilled on Water
- Source Identification of Oil Spills Based on the Isotopic Composition of Individual Components in Weathered Oil Samples
- Human Reliability and Error Prevention in Tankbarge Transfer Operations

Test and Evaluation of Oil/Water Separators: IntrSeptor 250 and FRAMO Skimmer Separator
Author: M. Fickel and G. Bretz
USCG R&D Oil Spill Response Report CG-D-23-97 (NTIS # ADA330969)

This reports presents the results of testing of two Oil/Water Separator (OWS) systems: Intr-Septor 250 and FRAMO "Skimmer Separator." Each unit was subjected to a comprehensive sequence of tests that included the processing of various percentages of oil and water, and oil/water emulsion in free water (with and without emulsion breaker). The systems were also evaluated for ability to handle entrained debris. Although the systems were successful in separating oil from water under some conditions, other input conditions that might be encountered in a marine spill proved more problematic. The most significant deficiency was the inability to operate effectively reliably through wide variations in the percentage of waste oil and emulsion composition, and the inability to handle debris.

Investigation of a Multi-Sensor Method to Map Oil Spill Thickness
Author: G.L. Hover, R.E. Shemo and J.T. Parr
USCG R&D Oil Spill Response Report CG-D-09-98 (NTIS # ADA343664)

Presently, maritime oil spill response and pollution deterrence forces have no reliable means of mapping oil slick thickness and volume from the air. This report describes a technology demonstration and preliminary evaluation of a multi-sensor method that might provide such a capability. This document provides an analysis of the data collected and recommendations relating to any future development and operational implementation of the multi-sensor concept. This report concludes that substantial development of the FSR sensor and significant system integration work would be required to implement an operationally practical instrument.

Test and Evaluation of Six Fire Resistant Booms at Ohmsett
Author: David DeVitis, Susan Cunneff and James Nash
USCG R&D Oil Spill Response Report CG-D-12-98 (NTIS # ADA344642)

This report describes the testing, results and evaluation of six oil booms produced by five manufacturers. The booms were tested for first loss tow speed, oil loss rate, and critical tow speed. Four of the booms performed within speed and rate loss ranges that have been measured for commercial non-fire booms. One boom was found to be superior in critical tow speed. A prototype boom, with a unique paddle-wheel operating principle, was the sixth boom included in the study, and was found to need further development.

Evaluating a Protocol for Testing a Fire Resistant Oil Spill Containment Boom
Author: Kenneth R. Bitting
USCG R&D Oil Spill Response Report CG-D-07-99 (NTIS # ADA364692)

A series of experiments was conducted to evaluate a protocol for testing the ability of fire-resistant booms to withstand both fire and waves. The ASTM F-20 Committee has developed a draft standard; however the draft provides general guidelines and does not specify the details of the test procedure. The draft ASTM F-20 test protocol was evaluated using five typical fire-resistant oil spill containment booms, and the results of this evaluation are presented. The strengths and weaknesses of the protocol are discussed, along with areas for possible improvement.

Second Phase Evaluation of Protocol for Testing a Fire Resistant Oil Spill Containment Boom
Author: Michael A. Walz
USCG R&D Oil Spill Response Report CG-D-15-99 (NTIS # ADA367977)

A second series of fire tests utilizing the American Standard for Testing Material (ASTM) F-20 draft, Standard Guide for In-Situ Burning of Oil Spills on Water: Fire-Resistant Containment Boom as a guideline, were conducted in a wave tank at the USCG Fire and Safety Test Detachment. The results of the second test series are presented in this report, and the strengths and weaknesses of the protocol are discussed, along with the areas for possible improvement.

Past In-Situ Burning Possibilities
Author: Gary Yoshioka, Eva Wong, Beverly Grossman, Wendy Drake, Bob Urban, and Tom Hudon
USCG R&D Oil Spill Response Report CG-D-17-99 (NTIS # ADA368258)

This study evaluated the feasibility of conducting in-situ burning (ISB) using current technology on post 1967 major oil spills over 10,000 barrels in North America and over 50,000 barrels in South America and Europe. The results of the analysis show that, although there is growing interest in ISB for use on large volume oil spills, there are constraints to the widespread use of the technique. However, considering the potential effectiveness of ISB, the results are encouraging given the fact that constraints such as spill location, expected weather, and oil type are likely to be well known prior to undertaking a response, and can be accounted for.

Control of Oil Spills in High Speed Currents, A Technology Assessment
Author: Thomas Coe and Brian Gurr
USCG R&D Oil Spill Response Report CG-D-18-99 (NTIS # ADA369279)

This report is a technology assessment conducted to analyze the threat of oil spills in fast currents. Technologies and methods for response were evaluated and promising equipment and strategies were identified. Recommendations are made to pursue those methods, equipment and training that show the most promise for improved oil spill response capabilities in currents from 1 to 6 knots. In addition, regulations, guidelines and training requirements for the USCG and oil spill response industry were reviewed to determine adequacy for fast water response. Improvements are suggested in this report to make these practices more useful.

Predicting the Behavior of Orimulsion Spilled On Water, Volume I and II
Author: Scott A. Stout, Ph.D.
USCG R&D Oil Spill Response Report CG-D-24-99 (NTIS # ADA371851 (Vol. I) and ADA371844 (Vol. II)

Orimulsion, an alternative fuel for power generation, is a bitumen-in-water emulsion of approximately 70 percent natural bitumen and 30 percent fresh water. Previous work has determined Orimulsion may largely float, remain suspended, or settle depending on the spill conditions. The relative importance of different spill conditions (e.g., salinity, temperature, energy, Orimulsion concentration, particulate load, and particulate type) on oil spill behavior are investigated. The most important environmental parameters identified were determined to be the receiving water salinity, receiving water energy, and presence/absence of suspended mineral matter. The gross behavior of Orimulsion under different combinations of these parameters is predicted to provide the best available guidance to contingency planners and spill responders.

Test and Evaluation of Four Fire-Resistant Booms at Ohmsett
Author: David DeVitis, Kathleen Nolan, and William Schmidt
USCG R&D Oil Spill Response Report CG-D-25-99 (NTIS # ADA371800)

This report displays the results of the burn testing of seven commercial fire booms at the USCG Fire and Safety Test Detachment, in accordance with the proposed protocol, ASTM F-20. The results of this test report are consistent with the evaluation of fire booms previously tested at OHMSETT, but also show a slight increase in performance. The results and information from the study will be used by the Coast Guard to develop policies and procedures for the In-Situ Burning of oil during a spill.

Effects of Weathering on the Flammability of Oils
Author: Robert K. Jones
USCG R&D Oil Spill Response Report CG-D-04-00 (NTIS # ADA376001)

This report describes the development of a numerical weathering model that simulates the weathering and consequent changes in flammability of crude oils and fuel oils. The time required for a representative group of flammable oils to weather to a non-flammable state under various spill conditions was also estimated. The effects of the level of mixing caused by environmental factors were closely examined.

In-Situ Burn Investigation: Exercise #1, Galveston, Texas
Author: Theodore E. Camlin
USCG R&D Oil Spill Response Report CG-D-18-00 (NTIS # ADA384650)

The USCG Research and Development Center, with assistance from other organizations, has developed a multi-year project that is designed to evaluate the feasibility of conducting In-Situ Burning operations within an offshore Galveston, Texas, environment. It involves three field exercises, which are progressive in nature, in order to investigate thoroughly the critical aspects of a safe, efficient and effective offshore ISB response. This report documents the data, findings, conclusions, and recommendations derived from the first of these three ISB field exercises, which focused on the trial implementation of three presently recognized ISB Operational Procedures.

Unpublished Coast Guard R&D Center Reports

(White Papers and Workshop Proceedings)

U.S. Coast Guard Oil Spill Remote Sensing Workshop
Author/Editor: Environmental Research Institute of Michigan
28-29 January 1991, CG R&D Center, Groton, CT.

This workshop was convened to survey capabilities and identify near-term achievable remote sensing sensors and systems to improve Coast Guard capabilities in oil spill surveillance. The report contains the minutes of the workshop, copies of papers and graphics provided by speakers and the attendee list.

Discussion Notes: Workshop on Tanker Self-Help Countermeasures Systems, April 9-10, 1992, Toronto, Canada
Author: S.L. Ross Environmental Research Ltd for Environment Canada
April, 1992

The objective of the workshop was to assess a variety of concepts that could be used either to limit the spillage from a tanker accident or to use the tanker in some manner to assist in responding to the spill. The workshop was attended by U.S. and Canadian government officials, vessel owners and operators, shipping federations, and private maritime consultants. The agenda was comprised of three main components: presentations to a plenary session of two independent studies on tanker self-help countermeasures, evaluation of a specified list of countermeasure techniques by three working groups; and presentation and discussion of working group findings in a final plenary session. This report summarizes the main points of discussion of the workshop. Particular note is made of areas identified by participants as deserving of further investigation and or research.

United States Coast Guard Surveillance Requirements Document
Author: R. A. Lambert and J. T. Bortell, Environmental Research Institute of Michigan
Coast Guard R&D Center, 13 April 1992

The report summarizes the results of the Coast Guard wide Surveillance System Requirements Study (SuRS). The first portion of the study identified and assessed needs on a program-by-program basis. The communication, maintenance and logistics, and platform needs were considered along with sensor performance requirements. The second portion of the study assessed how well the present technologies would meet these needs.

Decision-Making Training Alternatives for Marine Spill Response Command Post Personnel
Authors: S. Siegel, J Harrald, M. Grabowski and T. Hammell
September 1993 (Report # MSI/CAORF 60-9051-01A)

This report documents an investigation by the Coast Guard R&D Center and the Computer Aided Operations Research Facility (CAORF) at Kings Point to identify ways to enhance oil spill multi-agency response decision-making. The approach involved first identifying the decision-making tasks that would be encountered by spill responders in the Port of New York in the event of a significant spill. These tasks, along with information collected from other Port of New York personnel, were systematically analyzed in order to develop a preliminary set of training objectives for the multi-agency, spill response command post. These training objectives were then further analyzed to identify the most promising training media for achieving these objectives.

Feasibility Study of an Ocean Simulating In-Situ Burning Test Tank System
Author: Lawrence A. Schultz and Peter V. Minnick
USCG R&D Oil Spill Report for Contract DTCG39-93-C-EOO799, January 1994

The purpose of this study is to assess the feasibility of constructing an ocean simulating oil burn test tank system at the Coast Guard Fire and Safety Test Facility in Mobile, AL. Starting with the present capability, incremental increases in capability and associated costs are examined. The results of the study reveal that a new in-situ burn tank test facility having various levels of capability greater than that provided by the existing in-situ burn test plan can be provided at a cost ranging from about $350,000 to $1.7 million. The design and cost information presented in the report allows for the evaluation of many additional cases.

Pollution Incident Simulation Control and Evaluation System (PISCES): Technical Assessment Report
Author: Naval Air Warfare Center, Orlando, FL
May 1994

The Pollution Incident Simulation Control and Evaluation System (PISCES) is envisioned as a computer-based system that embodies a systematic approach to the development, implementation and evaluation of spill response exercises within the National Preparedness for Response Exercise Program (PREP). PISCES is intended to support two specific functions. First, the PISCES exercise and simulation control functions will support the design of the spill scenario during the exercise planning stage, and control the sequence of events during the exercise itself. Secondly, PISCES will support the exercise team in the collection of objective performance data during the exercise and the display of the performance data during post-exercise debriefings.

This document provides a conceptual overview of the project. It identifies the objectives and top level requirements for the system, develops preliminary design considerations, and sets forth the overall system development plan.

Preliminary Technical Description for Oil Spill Preparedness Debriefing System Device
Author: Naval Air Warfare Center, Orlando, FL

The Pollution Incident Simulation Control and Evaluation System (PISCES) is envisioned as a computer-based system that embodies a systematic approach to the development, implementation and evaluation of spill response exercises within the National Preparedness for Response Exercise Program (PREP). The system contains two major computer software configuration items (CSCIs): the Exercise/Control System (ESCS) and the Computer-Based Debriefing System. The purpose of this document is to provide a preliminary description of the Computer-Based Debriefing System CSCI.

Spill Response System Configuration Study – Final Report
Author: R. V. Desimone and J. M. Agosta, Stamford Research Institute
October 1994 (Contract DTRS-57-89-D-0091)

This report documents an effort to develop a prototype Decision Support System to assist USCG planners in determining the appropriate types, quantities, and locations of oil spill response equipment and personnel to minimize the impact of possible spills at a number of locations. The tool is also designed to highlight in highlighting specific resource shortfalls. The system was developed using a rapid prototyping approach and comprises advanced artificial intelligence planning technology together with color map display capabilities, and models for spill trajectory forecasting and response plan evaluation with the aid of commercial software. The system also keeps track of decisions made by the user and notifies the users when they contradict one another.

Decision Support Technology for Oil-Spill Response Configuration Planning – Final Report
Author: R. V. Desimone, Stamford Research Institute
December 1995 (Contract DTRS-57-94-Y-00081)

This report documents follow-on development efforts to incorporate additional AI tools into the Spill Response Configuration System (SRCS) developed by SRI. The advanced technology includes he incorporation of dynamic re-planning techniques into SRCS for modifying response plans to changing scenarios. These techniques permit the user to explore the consequences of user-specified changes in response scenarios on response plans and predicted damage to the environment.

Specification for the Pollution Incident Simulation Control and Evaluation System (PISCES)
Author: Naval Air Warfare Center, Orlando, FL
July 1995

This document provides hardware and software specifications for the Pollution Incident Simulation Control and Evaluation System (PISCES). PISCES is an oil spill preparedness exercise support tool designed to: (1) simulate the interaction of the oil spill response team with the pollution incident dynamics; (2) provide a means of collecting and processing data, and documenting critical events related to the effectiveness of the spill response effort; and (3) automatically generate a debrief based on an objective assessment of the response team's performance. Hardware and software requirements and system configuration are discussed.

Evaluation of MAR_TAD System Requirements – Final Report
(Using the OSARMS System to Validate and Identify Refinements to MAR_TAD Requirements)
Author: Arthur D. Little, Inc.
August 1996

This report documents an effort to develop a preliminary set of functional requirements for a Coast Guard Multi-Agency Response Tactical Action Display (MAR-TAD) System to facilitate management and display of response related information at spill response Command Posts. The approach adopted is to select the Magnavox OSARMS System, an industry computer-based oil spill response information management system as a representative prototype, and evaluate the system with respect to Coast Guard functional requirements. Specific project tasks included conducting a structured evaluation of the OSARMS system at MSO New Orleans to refine the MAT_TAD functional requirements for future USCG system implementation, and also developing a set of "Recommended Guidelines" for the private sector to follow when developing and procuring computer based oil spill response information management systems. The report provides the results of the demonstration, as well as specific recommendations for future development.

Close-Out of Pollution Incident Simulation and Evaluation System Project
Author: Marc B. Mandler, Technical Director, USCG Research and Development Center
USCG R&D Memorandum, June 24, 2002

The USCG R&D Center has completed development of the Pollution Incident Simulation and Evaluation System (PISCES) to the National Strike Force Coordination Center (NSDCC). NSFCC uses PISCES within the Exercise Planning, Conduct and Debriefing Phases of its PREP exercises. PISCES is also being used by TRACEN-Yorktown to enhance its Port Ops, Contingency Planning, and OSC Crisis Management Training Programs. Finally, PISCES is also being considered for use as an exercise support tool for high capacity passenger vehicle casualty exercises. This PISCES project has also stimulated the establishment of a commercial PC-based maritime response tool within the private sector.

Close-Out of On-Scene Command and Control Concept Demonstration System
Author: Marc B. Mandler, Technical Director, USCG Research and Development Center
USCG R&D Memorandum, July 25, 2002

This task provides a computer based-capability which could eventually be loaded upon CGSWIII, to assist Coast Guard personnel in the NIIMS ICS-based management, of both day-to-day and Unified Command response operations. Many organizations worked together to define and develop OSC^2, a maritime response information management tool. The OSC^2 Concept Demonstration System has been successfully used by several Marine Safety Offices and the AST during a number of exercises and actual response operations. This project has provided the USCG with considerable insight into design and operations of this maritime response information tool, and has also provided a definition of the benefits and costs that are associated with a CGSWIII-compatible system to assist in the NIIMS ICS management of emergency response operations.

Conference and Journal Papers Reporting the Results of the Coast Guard Oil Spill R&D Program,1991 – 2001

International Oil Spill Conference Proceedings, 1991 - 2001

Coast Guard Research and Development for the 1990's
Authors: Donald S. Jensen and Peter A. Tebeau
1991 Oil Spill Conference Proceedings, page 661

Based on various workshops and technology assessments, the Research and Development (R&D) Center has developed a five-year program to identify oil spill response technology, needs and the R&D efforts that would support those needs. The elements of this program are described here in detail, including plans for cooperative efforts with other agencies, other countries, and industry.

Burning of Oil Spills
Authors: D.D. Evans, G.W. Mulholland, J.R. Lawson, E.J. Tennyson, P.A. Tebeau, M. F. Fingas, and J.R. Gould
1991 Oil Spill Conference Proceedings, page 677

The Center for Fire Research is conducting research related to safety in offshore drilling and oil spill pollution, focusing on examining the phenomena associated with crude oil combustion and the impact of using burning as a spill response method. This paper describes the project that was undertaken to measure the effects of oil spill burning in laboratory and field tests.

Oil Spill Sorbents: Testing Protocol and Certification Listing Program
Authors: David Cooper and Ingvil Gausemel
1993 Oil Spill Conference Proceedings, page 549

This paper describes a program that would see the development of a certification and listing program in addition to a national standard for the testing of sorbent materials. The paper also details the test methods used to categorize sorbents according to their operating characteristics, including oil spills on water, oil spills on land, and industrial use.

Mesoscale Experiments Help To Evaluate In-Situ Burning of Oil Spills
Authors: David D. Evans, William D. Walton, Howard R. Baum, Kathy A. Notarianni, Edward J. Tennyson, and Peter A. Tebeau
1993 Oil Spill Conference Proceedings, page 755

This report describes the mesoscale and laboratory experiments conducted to measure the burning characteristics of crude oil fires. The report discusses the advantages of burning spilled oil over other cleanup countermeasures, and also the public safety concern of the content and extent of the smoke plume from the fires.

A Graphics-Based Oil Spill Tracking and Coastal Impact Model for Contingency Planning
Authors: Phani K. Raj and Ivan Lissauer
1993 Oil Spill Conference Proceedings, page 817

The USCG has initiated an effort to develop a software system, called the Spill Response Information System (SRIS), to provide port areas, spill simulation models and several port-specific databases for contingency planning to respond to oil and hazardous material releases in the water. The oil spill trajectory model, one of the simulation models included in the SRIS, is detailed in this poster presentation. The principal purpose of this model is to evaluate potential oil impact areas under a variety of assumptions about spill locations, quantities, tidal phases, weather and seasons, to provide a basis for optimally locating response personnel and equipment.

National Contingency Plan Product Schedule Data Base
Authors: John Putukian and Robert R. Hiltabrand
1993 Oil Spill Conference Proceedings, page 824

During oil spills there are often proposals by the technical community and industry to use chemical agents to help in oil spill cleanups. Federal Clean Water Act regulations require that any chemical agents that the federal on-scene coordinator (FOSC) wants to use for oil cleanup be listed on the U.S. Environmental Protection Agency National Contingency Plan Product Schedule. This paper provides a brief, easy-to-use list of information that the FOSC needs to make the determination to use a specific chemical agent.

U.S. Coast Guard National Spill Response Resource Inventory
Author: David M. Giraitis
1993 Oil Spill Conference Proceedings, page 838

The Oil Pollution Act of 1990 (OPA) mandated the establishment of a National Strike Force Coordination Center whose duties included compiling and maintaining a comprehensive list of spill removal resources, personnel and equipment that would be available worldwide and to Federal and state agencies and to the public. The list was named the Response Resource Inventory (RRI). This report describes the RRI in detail, including its purpose, contents, and the methods of obtaining and entering data.

Evolution of the U.S. Coast Guard's Oil Identification System
Authors: Martha S. Hendrick and Thomas R. Reilly
1993 Oil Spill Conference Proceedings, page 873

This paper describes the Oil Identification System (OIS), designed by the U.S. Coast Guard in its task to develop procedures and techniques to be employed in identifying oil and hazardous substances by the 1972 Federal Water Pollution Control Act. The OIS's development, implementation and strategies are discussed in further detail.

Trace Metal Analysis For Fingerprinting Oil Spill Samples
Authors: James P. Spotts, Thomas Reilly, Kristy Plourde, and Martha Hendrick
1993 Oil Spill Conference Proceedings, page 881

This report describes the four organic analytical techniques used by the Coast Guard Central Oil Identification Laboratory to fingerprint oil spill samples. The methods, results and conclusions of gas chromatography, fluorescence spectroscopy, Fourier transform infrared spectroscopy and high-performance liquid chromatography techniques are discussed.

Effectively Managing Level of Effort in Oil Spill Cleanup: Resolving the "How Clean is Clean" Issue
Authors: Peter A. Tebeau
1995 International Oil Spill Conference Proceedings, page 663

Successful oil spill response requires effectively managing the level of effort devoted to response operations, which includes choosing appropriate technologies and implementing them to achieve optimal environmental benefit, while controlling costs. At the end of the response, effective management requires resolving the "how clean is clean" issue to ensure a smooth termination of the response effort. Various approaches to making these management decisions are reviewed, based on experience in the Exxon Valdez, American Trader, and Morris J. Berman spills. The advantages and constraints of these approaches are summarized, along with suggestions about how the process might be facilitated.

Oil Thickness Detection Using Wideband Radiometry
Authors: O.B. McMahon, E.R. Brown, G.D. Daniels, G.L. Hover, T.J. Murphy
1995 International Oil Spill Conference Proceedings, page 15

A major problem in the cleanup of oil spills on large bodies of water is determining the oil thickness distribution since much of the oil can be contained in a small fraction of the spill area. Knowledge of the location of the thick patches allows one to use cleanup resources more efficiently. To address this problem, we have designed, built and tested a millimeter-wave, frequency-scanning radiometer for remotely determining the thickness of oil films. This paper discusses the experimental design and results.

Full Scale Oil Containment Boom Testing At Sea
Authors: Atle Nordvik, Ken Bitting, Paul Hankins, Larry Hannon, Robert Urban
1995 International Oil Spill Conference Proceedings, page 31

The Marine Spill Response Corporation, U.S. Coast Guard, U.S. Navy and Minerals Management Service conducted a joint test of oil containment booms in Lower New York Bay and the Atlantic Ocean. These tests allowed the collection of quantitative data on boom performance, including tow forces, skirt draft, and boom freeboard, as a function of tow speed and environmental forces due to currents, wind and waves. The test methods, results and conclusions are described in this paper.

The Newfoundland Offshore Burn Experiment – NOBE
Authors: Mervin F. Fingas, Greg Halley, Francine Ackerman, Robert Nelson et. al
1995 International Oil Spill Conference Proceedings, page 123

This paper discusses in detail the methods, quantitative analytical data, results and conclusions of a major offshore burn experiment conducted by a group of 25 agencies from Canada and the United States near Newfoundland, Canada. The experiment involved the measurement of emissions to the air, levels of oil and related compounds in the water, and operational parameters relevant to in-situ burning. Data were collected and analyzed to generate information on over 2000 parameters.

Coast Guard VOSS/NOFI/FIOCS/SEA SLUG At-Sea Evaluation
Authors: D.A. Furey, K.C. Eisenberg, J.F. Etxegoien
1995 International Oil Spill Conference Proceedings, page 884

This report describes the at-sea evaluations of the Coast Guard Vessel of Opportunity Skimming System (CGVOSS), the Norweigan NOFI VEE Sweep and the Fully Integrated Oil Collection System (FIOCS) oil recovery systems, conducted to determine their sea-worthiness and handling and towing characteristics. Dynamic data were collected for information on the stability and performance of each system. Test methods, results and conclusions are given in this paper.

Orimulsion Research and Testing and Open Water Containment and Recovery Trials
Authors: Donald R. Deis, Nelson Garcia Tavel, Carlos Villoria, et al.
1997 International Oil Spill Conference Proceedings, page 459

The permitting process for the introduction of Orimulsion fuel into the international energy market has required extensive research and testing on its chemical composition, physical properties, behavior in water, environmental toxicity and containment and recovery after a spill. This paper provides a review and summary of the scientific information available regarding the fate of an Orimulsion spill.

The Environmental Behavior of Orimulsion Spilled on Water
Authors: Stanley A. Ostazeski, Scott C. Macomber, Lyle G. Roberts and Allen D. Uhler
1997 International Oil Spill Conference Proceedings, page 469

For some electric utility companies Orimulsion has been successfully marketed as a cost-effective alternative to traditional heavy fuels used as feedstock for the generation of electric power. Battelle Ocean Sciences has investigated the fate and behavior of Orimulsion spilled in water using a tiered approach that has included laboratory physical and chemical characterization studies as well as meso-scale (flume) studies conducted with both fresh water and seawater. The methods, results and conclusions are discussed further in this report.

Response Resource Inventory
Authors: Robert A. Van Zandt and Jorice Williams
1997 International Oil Spill Conference Proceedings, page 909

Recent revisions to the Oil Spill Removal Organization (OSRO) have mandated the use of the Response Resource Inventory (RRI) by OSRO applicants. This report describes how data are obtained from the OSRO classifications, and how plan holders can access and use the RRI as a tool to conduct their own analysis of an OSRO's capacity to meet their specific planning requirements.

OSIMS: Oil Spill Information Management System
Authors: Christos Dougligeris, John Collins, R. Blanco, J. Jacobs, and Bart Baca
1997 International Oil Spill Conference Proceedings, page 982

The oil spill information management system (OSIMS) is an integrated information management tool providing a graphical interface to a database of spill-related data and models. OSIMS combines the utility of a geographic information system (GIS) with the intelligence of a decision support system, and provides worldwide access through the World Wide Web. OSIMS is described in further detail in this paper.

Developing a Technological Tool for Managing Complex Environmental Incidents
Authors: Steve Wischmann, Lorne Thomas, Jim Gynther
1999 International Oil Spill Conference Proceedings.

This paper will discuss the United States Coast Guard's response to the need for technological solutions to the incident management challenges posed by oil spills and hazardous material releases. Additionally, this paper will examine some of the difficulties presented by technology itself; that is to say, technological tools come with both implicit and explicit ramifications that must be understood and overcome in order to fully harness the potential contained within such capabilities**.**

Gulf Coast Oil Spill Plans: Remediation and Restoration Adequacy
Authors: Christos Douligeris, Peter A. Tebeau, Bart J. Baca
1999 International Oil Spill Conference Proceedings.

This paper describes the results of a research effort commissioned by the U.S. Corps of Engineers to study the role of the oil spill contingency planning process in addressing two key elements of spill response: remediation and restoration. The analysis focuses on the role of contingency planning in optimizing the success of these two processes, and specifically how key shoreline remediation and restoration decisions are addressed and implemented in the Gulf Coast region.

Emissions From Mesoscale In-Situ Oil (Diesel) Fires From the Mobil 1998 Experiments
Authors: Mervin F. Fingas, Zhendi Wang, Pat Lambert, Francine Ackerman, Ken Li, Robert Hiltabrand, et al.
2001 International Oil Spill Conference Proceedings, page 539

A series of mesoscale burns were conducted in 1998 to assess fire-resistant booms, twelve of these were used to study emissions from diesel oil burns. Extensive sampling and monitoring were conducted to determine the emissions at nine downwind ground stations, one upwind ground station, and at six side stations. Particulates were measured using high-volume samplers and real-time particulate analyzers. Particulate samples in air were taken and analyzed for polycyclic aromatic hydrocarbons (PAHs). Over 100 compounds were identified and quantified; most concentrations were too low to be considered a health risk. It was concluded that small burns of this size (burn area about 25m 2) are too small to pose a health hazard. This paper discusses the tests performed, the results and the conclusions.

Studies of Emissions From Oil Fires
Authors: Mervin Fingas, Patrick Lambert, Ken Li, et al.
2001 International Oil Spill Conference Proceedings, Volume 1, page 539

Over 45 mesoscale burns were conducted to study various aspects of diesel and crude oil burning in-situ. Extensive sampling and monitoring of these burns were conducted at downwind stations, upwind stations and in the smoke plume. Emission data from the 45 experimental burns were used to develop prediction equations for over 150 specific compounds or emission categories. The details, results and conclusions of the experiments are discussed further in this paper.

Fastwater Techniques and Equipment Evaluation
Author: Kurt A. Hansen
2001 International Oil Spill Conference Proceedings, Volume 2, page 1347

The U.S. Coast Guard Research and Development Center has been evaluating the state-of-the-art containment and cleanup of oil in currents over 1 knot since 1997. An assessment of techniques and equipment was performed that has led to a series of field demonstrations in various locations. Tests on other potential fastwater systems have also taken place. The results of the equipment evaluations are presented in this report, along with a brief description of the format for a fastwater field guide that is being prepared. The result will be an increase in the capability of both the USCG and commercial firms to respond to spills in fast water.

Flexible, Submergence Plane Oil Containment Systems
Authors: M. Robinson Swift, Patrick Dugan, Peter Nourse, et al.
2001 International Oil Spill Conference Proceedings, Volume 2, page 1355

Flexible, floating submergence plane barriers were developed for intercepting and containing oil spills under fast water conditions. The barriers retain oil by allowing the flow to drive incident oil down an inclined bow to a gap opening where the oil enters and is trapped in a protected containment volume. In this paper, the development of flexible systems, which make use of submergence plane technology, is described.

Emissions From Mesoscale In-Situ Oil (Diesel) Fires: Emissions From the Mobile 1998 Experiments
Authors: Mervin F. Fingas, Zhenid Wang, Pat Lambert, Francine Ackerman, et al.
2001 International Oil Spill Conference Proceedings, Volume 2, page 1471

A series of mesoscale burns were conducted in 1998 to assess and evaluate six fire-resistant booms, twelve of these were used to study emissions from diesel oil burns. Extensive sampling and monitoring were conducted to determine the emissions at nine side stations. This report provides the data from the 1998 trials using diesel fuels, including the methods and results of the air, water and fuel monitoring and sampling.

Arctic and Marine Oilspill Program (AMOP) Technical Seminar Proceedings 1991 - 2001

Smoke Emission from Burning Crude Oil
Authors: D. Evans, W. Walton, H. Baum, G. Mullholland, J. Lawson, H. Koseki, A. Ghoniem
Proceedings of the Fourteenth Arctic and Marine Oil Spill Program Technical Seminar (1991), page 421

Research has shown that burning can be an effective means to remove oil from the surface of the water after a spill. Previous research has focused on laboratory studies of combustion products from oil pool fires less than 1 meter in diameter. This paper describes instrument packages developed to determine the amount of various combustion products emitted from large crude oil pool fires.

First results of Airborne Trials of a 64-Channel Laser Flourosensor for Oil Detection
Authors: R. Dick and M.F. Fingas
Proceedings of the Fifteenth Arctic and Marine Oil Spill Program Technical Seminar (1992), page 365

A new 64-channel air borne laser fluorosensor for oil detection has been assembled and tested. During the spring of 1992 a series of flights were made over various targets, comprising oil on water, on ice and on simulated beach material. Some of the 640-channel spectra data are

presented in this report, and the implications of the spectral responses for classification and identification of oil are reviewed, in the context of remote sensing of arctic and marine oil spills.

Oil Spill Sorbents: Testing Protocol and Certification Listing Program
Authors: David Cooper and Lisa Keller
Proceedings of the Fifteenth Arctic and Marine Oil Spill Program Technical Seminar (1992), page 479

A universally accepted standard method for testing oil spill sorbents is not currently employed by the majority of sorbent manufacturers. End-users are limited to manufacturers' and distributors' claims that may be perceived as being biased. Environment Canada has spearheaded a drive to develop an official Canadian standard for testing and certification of sorbents using Canadian General Standards Board as the certification body, and also plans to provide a system to maintain an unprejudiced method for testing oil spill sorbents. This standard and system are described in further detail in this paper.

In-Situ Burning of Oil Spills: Mesoscale Experiments
Authors: D.D. Evans, W.D. Walton, H.R. Baum, et al.
Proceedings of the Fifteenth Arctic and Marine Oil Spill Program Technical Seminar (1992), page 593

A series of 14 mesoscale fire experiments were performed to measure the burning characteristics of crude oil on salt water. Results of the measurements for burning rate and smoke emissions are compared to those from previous smaller scale burns. The test methods, results, conclusions and predictions are discussed in this paper.

NOFI Oil Vee-Sweep and Extension Boom Test and OHMSETT
Authors: Kenneth R. Bitting and James Vicedomine
Proceedings of the Sixteenth Arctic and Marine Oil Spill Program Technical Seminar (1993), page 393

The NOFI Vee-Sweep and a NOFI 600S oil diversion boom were tested for its first and gross oil loss speeds. The NOFI Vee-Sweep was also evaluated for wave conformance, oil thickness vs. tow speed, oil loss rate, and critical tow speed. The results and conclusions of these tests are described here in this paper.

Evaluating Oil/Water Separators
Authors: Michele A. Murdoch
Proceedings of the Sixteenth Arctic and Marine Oil Spill Program Technical Seminar (1993), Volume 1, page 435

The Naval Civil Engineering Laboratory recently completed tests of four commercially available oil/water separators. Each separator was tested against mixtures of salt water and crude oil, and mixtures of salt water and a water-in-oil emulsion. The impact on the addition of emulsion breakers and debris to the influent also were evaluated. This paper describes the test equipment,

plans and procedures used to conduct the tests. Recommendations for improved test procedures are included. Separator performance results from the tests are not discussed, however.

In-situ Burning of Oil Spills: Mesoscale Experiments and Analysis
Authors: William D. Walton, David D. Evans, Kevin B. McGrattan, et al.
Proceedings of the Sixteenth Arctic and Marine Oil Spill Program Technical Seminar (1993), Volume 2, page 679

A series of six mesoscale and one large laboratory fire experiments were performed to measure the burning characteristics of Louisiana crude oil in water in a pan. Results of the measurements for burning rate and smoke emissions are compared to those from previous burns of various scales in this report. Predictions of smoke plume trajectory and particulate deposition at ground level from the Large Eddy Simulation model developed as part of this research effort are also presented.

Recent Activities of the Emergencies Science Division's Remote Sensing Working Group
Authors: Carl E. Brown, Mathias Furhwirth, Patrick Lambert and Mervin F. Fingas
Proceedings of the Sixteenth Arctic and Marine Oil Spill Program Technical Seminar (1993), Volume 2, page 1073

The Emergencies Science Division of Environment Canada is working on several projects related to the remote sensing of oil in the marine environment. This paper presents preliminary results from one of these projects: the recent oil-on-water airborne remote sensing field trials involving the Laser Environmental Airborne Fluorosensor, the Laser Acoustic Oil Thickness Measurement Sensor, and various other sensors from international agencies.

Smoke Measurement Using a Helicopter Transported Sampling Package
Authors: William D. Walton, Jay McElroy, William H. Twilley and Robert R. Hiltabrand
Proceedings of the Seventeenth Arctic and Marine Oil Spill Program Technical Seminar (1994), Volume 1, page 735

A first generation smoke sampling package, designed to be deployed on a helicopter winch cable, has been developed. The package contains three sampling pumps that are operated via radio control from the helicopter. The background, configuration, burn procedures and other details of the package are explained in this report.

The Newfoundland Offshore Burn Experiment – NOBE Experimental Design and Overview
Authors: Merv F. Fingas, Greg Halley, Francine Ackerman, et al.
Proceedings of the Seventeenth Arctic and Marine Oil Spill Program Technical Seminar (194), Volume 2, page 1053

A group of over 25 agencies from Canada and the United States conducted a major offshore burn near Newfoundland, Canada. Two lots of oil, about 50 tons each, were released into fire-proof boom. Each burn lasted over an hour and was monitored for emissions and physical parameters. Over 200 sensors or samplers were employed to yield data on over 2000 parameters or

substances. The experiment resulted in extensive analytical data as well as significant operational data, some of which are presented in this paper.

The Newfoundland Offshore Burn Experiment – NOBE Preliminary Results of Emissions Measurement
Authors: Merv F. Fingas, Francine Ackerman, Ken Li, Patrick Lambert, et al.
Proceedings of the Seventeenth Arctic and Marine Oil Spill Program Technical Seminar (1994), Volume 2, page 1099

A group of over 25 agencies from Canada and the United States conducted a major offshore burn near Newfoundland, Canada. Two lots of oil, about 50 tons each, were released into fire-proof boom. Each burn lasted over an hour and was monitored for emissions and physical parameters. Over 200 sensors or samplers were employed to yield data on over 2000 parameters or substances. The quantitative analytical data and preliminary results of the experiment are discussed in this paper.

May 1993 Oil Spill Sensor Test Program: Correlation to Laser Fluoresensor Data With Chemical Analysis
Authors: Carl E. Brown, Zhendi Wang, Mathias Fruhwirth and Mervin F. Fingas
Proceedings of the Seventeenth Arctic and Marine Oil Spill Program Technical Seminar (1994), Volume 2, page 1239

Selected results of the May 1993 airborne oil spill sensor test program are presented. The test program provided an opportunity for international oil spill response agencies to collect an extensive data set in a controlled test. This paper presents an analysis of the data obtained by Laser Environmental Airborne Fluorosensor and correlations with detailed chemical analysis of oil samples collected in the extensive ground truthing program.

Surface Drifter Deployment in Experimental Oil Spill
Authors: Robert P. LaBelle, James M. Price, Walter Johnson and Charles F. Marshall
Proceedings of the Eighteenth Arctic and Marine Oil Spill Program Technical Seminar (1995), Volume 1, page 493

During at-sea field experiments in the North Sea several surface and near-surface (1 m) drifters were deployed in controlled releases of oil. Although the main purpose of the field work was to calibrate laboratory test methods of dispersant effectiveness against sea trials, this release of several control (untreated) slicks provided a good opportunity to test oil-following capabilities of two types of surface drifters. Preliminary comparisons between drifter movements and slick trajectories are presented. Results are discussed in the context of an ongoing research effort to evaluate under what ocean and oil conditions the surface drifters may mimic oil spill movement.

Enhancing the Encounter Rate of a Prototype Weir Skimmer
Author: Mark. J. Delozier
Proceedings of the Eighteenth Arctic and Marine Oil Spill Program Technical Seminar (1995), Volume 2, page 661

New techniques for maximizing oil encounter rates proved critical in demonstrating the adequacy of a high-volume mechanical skimmer. The Graham Rec skimmer, developed for initial oil response in Prince William Sound, was tested at sea under a range of conditions in January 1995 and received regulatory agency approval. Two methods for adjusting the weir lip relative to the water's surface were central in demonstrating that the skimmer's overall estimated oil recovery rate was adequate to meet regulatory response planning standards. The results of the tests and information on the Graham Rec skimmer are detailed in this paper.

Flow Around an Oil Boom System
Authors: Kau-Fui Vincent Wong, Ph.D., P.E. and Michael Witmer
Proceedings of the Eighteenth Arctic and Marine Oil Spill Program Technical Seminar (1995), Volume 2, page 671

The objective of this report is to investigate the flow around a system of booms combined with other shapes, with the ultimate aim of increasing the effectiveness of the system in trapping oil. Three sets of parallel booms were tested with different shapes in the present work. The shapes investigated here include a "small" elliptical shape, a "large" elliptical shape, and a teardrop shape. The results and conclusions of the tests are given here in this paper.

The Newfoundland Offshore Burn Experiment: Further Results of Emissions Measurement
Authors: Merv Fingas, Francine Ackerman, Patrick Lambert, Ken Li, et al.
Proceedings of the Eighteenth Arctic and Marine Oil Spill Program Technical Seminar (1995), Volume 2, page 671

Analysis of samples and data from the NOBE experiment continue due to the extensive nature of experimental data. Details and results of combustion gases, volatile organic compounds, airborne particulate material and metals are given in this paper.

Smoke Measurement Using an Advanced Helicopter Transported Sampling Package with Radio Telemetry
Authors: William D. Walton, William H. Twilley, Anthony D. Putorti and Robert R. Hiltabrand
Proceedings of the Eighteenth Arctic and Marine Oil Spill Program Technical Seminar (1995), Volume 2, page 1053

A second-generation smoke sampling package, designed to be deployed on a helicopter winch cable, has been developed and tested. Improvements in the second-generation package include real-time sampling for carbon dioxide with an infrared gas analyzer and volatile organic compounds with a photoionization detector, among others. The design of the package, operational experience and measurements taken during the diesel fuel test fires are presented here in this paper.

Comparison of Simulated and Observed Surface Currents Used in Oil-Spill Model
Authors: Robert P. LaBelle, Charles F. Marshall and Pearn P. Niiler
Proceedings of the Nineteenth Arctic and Marine Oil Spill Program Technical Seminar (1996), Volume 1, page 847

Oil spill trajectory models are increasingly being used for both real-time spill response and longer term contingency planning and risk assessment. This paper compares the Oil Spill Risk Assessment (OSRA) model runs surface currents generated by a numerical ocean circulation model with model runs using Lagrangian drifter data as a supplement to the numerical surface current field.

Progress Toward the Development of Micro- and Meso-Scale Methods for Predicting the Behavior of Low-API Gravity Oils (LAPIO) Spilled on Water
Authors: Stanley A. Ostazeski, Gregory S. Durell and Allen D. Uhler
Proceedings of the Nineteenth Arctic and Marine Oil Spill Program Technical Seminar (1996), Volume 1, page 1

This presentation reports on the status of the on-going research program involving the behavior of low-API gravity oils (LAPIO), because these products potentially behave quite differently when spilled on water. Research has been working toward the development of test methods for predicting the environmental behavior of LAPIO fuel spilled on water, and this paper details this research.

Weathering Properties and the Predicted Behavior At Sea of a LAPIO Oil (Weathered No. 6 Fuel Oil)
Authors: Stanley A. Ostazeski, Per S. Daling, Scott C. Macomber, et al.
Proceedings of the Nineteenth Arctic and Marine Oil Spill Program Technical Seminar (1996), Volume 1, page 137

Due to their relatively low costs and high BTU-values, Residual Group V fuel oils (low API fuels or LAPIOs) have been increasingly to power electric utilities. This in turn has lead to an increase in the marine transport of these products and therefore the associated increased risk of marine spills. This paper describes a detailed study of the weathering properties and the predicted behavior at sea of a No. 6 fuel oil.

Emissions From Mesoscale In-Situ Oil (Diesel Fires: The Mobile 1994 Experiments
Authors: Merv Fingas, Francine Ackerman, Patrick Lambert, et al.
Proceedings of the Nineteenth Arctic and Marine Oil Spill Program Technical Seminar (1996), Volume 2, page 907

A series of three mesoscale burns was conducted in 1994 to study various aspects of diesel oil burning in-situ. Extensive sampling and monitoring of these burns was conducted to determine the emissions. Details of the experiments, the results and conclusions are detailed in this paper.

Upgrading the Laser Environmental Airborne Fluoresensor to Provide a Real-Time Response to Oil Spill Emergencies
Authors: Carl E. Brown, Mathias Fruhwirth, and Robert Nelson and Mervin F. Fingas
Proceedings of the Nineteenth Arctic and Marine Oil Spill Program Technical Seminar (1996), Volume 2, page 907

The Laser Environmental Airborne Fluorosensor (LEAF) has recently undergone a series of upgrades to its computer hardware and software components. These changes have improved the LEAF's functionality as a real-time tool in response to oil spill emergencies. This paper discusses the inaugural operational test of the new LEAF system.

Development of Exercise Design, Development and Implementation Protocol in the Utilization of Simulators for Response Management Training
Author: J.H. Giesen
Proceedings of the Twentieth Arctic and Marine Oil Spill Program Technical Seminar (1997), Volume 1, page 275

United States federal legislation was passed which authorized the funding for development and operation of marine oil spill management simulator systems to be made available at several institutions. The USCG is interested in investigating the potential of such regional facilities to assist in providing a distinctive type of support to the nation-wide Preparedness for Response Exercise Program. This paper addresses protocol development and provides discussion on integration of Naval Air Warfare Center Training Systems Division guidelines into any training conducted within the spill response community.

Oil Containment Test of Fire Booms
Authors: Kenneth R. Bitting and Phillip M. Coyne
Proceedings of the Twentieth Arctic and Marine Oil Spill Program Technical Seminar (1997), Volume 2, page 735

The U.S. Coast Guard R&D Center and the U.S. Department of Interior Minerals Management Service conducted tests on currently available fire booms to provide performance characteristics for use by planners in developing response plans for the in-situ burning of marine oil spills. This paper reports the results of the oil loss tests of five fire booms as measured using actual oil in waves and currents at the test facility.

An Evaluation of Propane as a Fuel for Testing Fire-resistant Oil Spill Containment Booms
Authors: William D. Walton, William H. Twilley and Joseph V. Mullin
Proceedings of the Twentieth Arctic and Marine Oil Spill Program Technical Seminar (1997), Volume 2, page 755

A series of experiments has been conducted to measure and compare the thermal exposure to a fire-resistant boom from liquid hydrocarbon fuel and propane fires during an in-situ burn using fire-resistant booms. The experimental design, results and conclusions are presented in this paper.

Laser Fluorosensor Overflights of The Santa Barbara Oil Seeps
Authors: Carl E. Brown, Robert D. Nelson, Mervin F. Fingas and Joseph V. Mullin
Proceedings of the Twentieth Arctic and Marine Oil Spill Program Technical Seminar (1997), Volume 2, page 1043

The Emergencies Science Division of Environment Canada recently participated in a series of remote sensing flights over the naturally occurring oil seeps off Santa Barbara, California. During these flights the Laser Environment Airborne Fluorosensor was operated to test its ability to detect oil in an actual marine environment. This paper presents details of the overflights and post-flight analysis of the fluorescence data using the Pearson correlation coefficient.

The On Scene Command and Control System (OSC^2): An Integrated Incident Command System (ICS) Forms-Database Management System and Oil Spill Trajectory and Fates Model
Authors: Eric Anderson, Chris Galagan, Eoin Howlett, and Donald Jensen
Proceedings of the Twenty-first Arctic and Marine Oil Spill Program Technical Seminar (1998), Volume 1, page 449

This paper describes the OSC^2 system that is being used by the Atlantic Strike Team for PREP government-led area exercise use in an evaluation program. The paper includes OSC^2 development history, configuration and system goals.

Instrumentation and Techniques for Monitoring the Air Emissions During In-Situ Oil/Fuel Burning Operations
Authors: P. Lambert, F. Ackerman, M. Fingas, et al.
Proceedings of the Twenty-first Arctic and Marine Oil Spill Program Technical Seminar (1998), Volume 2, page 529

An evaluation of two models of portable real-time aerosol monitors under specific field conditions was conducted, in conjunction with the USCG sponsored 1997 mesoscale fire boom trials in Mobile, Alabama. Two experiments were carried out, and the experimental designs, results and conclusions are presented in this paper.

Particulate and Carbon Dioxide Emissions From Diesel Fires: The Mobile 1997 Experiments
Authors: Merv Fingas, Pat Lambert, Francine Ackerman, et al.
Proceedings of the Twenty-first Arctic and Marine Oil Spill Program Technical Seminar (1998), Volume 2, page 569

A series of 12 mesoscale burns were conducted in 1997 to assess fire-resistant booms and to study various aspects of in-situ burning of diesel oil. Extensive sampling and monitoring of these burns were conducted to determine the emissions. This paper reports on the measurements of particulates and carbon dioxide at the burns, as well as the test procedures, results and conclusions.

Mid-scale Tests of In-Situ Burning in a new Wave Tank at Prudhoe Bay, AK
Authors: I. Buist, J. McCourt, J. Mullin, N. Glover, C. Hutton and J. McHale
Proceedings of the Twenty-first Arctic and Marine Oil Spill Program Technical Seminar (1998), Volume 2, page 599

A series of research burns was carried out in 1997 in Prudhoe Bay, Arkansas, in a new wave tank purpose-built for in-situ burning studies, to evaluate the effects of oil type, emulsification, temperature and waves on in-situ burning. The test procedures, results and conclusions are presented in this paper.

Evaluating a Protocol for Testing Fire-Resistant Oil-Spill Containment Boom
Authors: William D. Walton, William H. Twilley, et al.
Proceedings of the Twenty-first Arctic and Marine Oil Spill Program Technical Seminar (1998), Volume 2, page 651

Most response plans for in-situ burning of oil at sea call for the use of a fire-resistant boom to contain the oil during a burn. Presently, there is no standard method for the user of fire-resistant boom to evaluate the anticipated performance of different booms. A draft test protocol, based on the guidelines in the ASTM F-20's Standard Guide for In-situ Burning of Oil Spills on Water: Fire-Resistant Containment Boom, was evaluated using five typical fire-resistant oil-spill containment booms. The results of this evaluation are presented, along with the strengths and weaknesses of the protocol.

Oil-Spill Remote Sensors: New Tools That Provide Solutions to Old Problems
Authors: Carl E. Brown, Mervin F. Fingas, and Ron H. Goodman
Proceedings of the Twenty-first Arctic and Marine Oil Spill Program Technical Seminar (1998), Volume 2, page 783

At the present time, the most commonly employed sensor is an infrared camera or combination infrared/ultraviolet system. This sensor class can detect oil under a variety of conditions, discriminate oil from some backgrounds and has the lowest cost of any sensor. Other remote sensors used for oil-spill slick detection and monitoring are reviewed, and new technologies are also highlighted in this paper.

Development and Testing of an Inexpensive Remote Sensing Package
Authors: H.M. Brown, R.H. Goodman, Alex B. Markov and Henry Hudema
Proceedings of the Twenty-first Arctic and Marine Oil Spill Program Technical Seminar (1998), Volume 2, page 795

A new remote sensing system has been developed to assist surveillance personnel in locating and determining the extent of an oil spill. The development of the system is described in this paper, together with test results from an oil spill in a wave basin and from aircraft flights during the 1997 North Sea dispersant trials.

Putting the Scanning Laser Environmental Airborne Fluorosensor Through Its Paces: Initial Test Results:
Authors: Carl E. Brown, Mervin F. Fingas, Joseph V. Mullin, Robert Dick, and Claudine Groud
Proceedings of the Twenty-first Arctic and Marine Oil Spill Program Technical Seminar (1998), Volume 2, page 811

The Scanning Laser Environmental Airborne Fluorosensor (SLEAF) has been designed to detect and map oil and related petroleum products in complex marine and shoreline environments where other nonspecific sensors (e.g. infrared, visible spectral cameras etc.) experience difficulty. The construction of the SLEAF system has recently been completed and underwent a systematic verification of system functionality. A complete description of the system and its development are described in this paper.

Predicting the Spill Behavior of Orimulsion Using Design of Experiment Principles
Authors: S.A. Stout, P.J. Barrett and L.G. Roberts
Proceedings of the Twenty-second Arctic and Marine Oil Spill Program Technical Seminar (1998), Volume 1, page 15

Design of Experiment, a discipline that incorporates statistics into the process of experimentation, was used to design and evaluate the results of 43 controlled benchtop spill experiments in order to determine the direct and interactive effects of the receiving water's salinity, temperature, energy, bitumen concentration and load and type of suspended mineral on the fate of spilled Orimulsion. The methods, results and conclusions of the evaluation are provided here in this paper.

Second Phase Evaluation of a Protocol for Testing Fire-Resistant Oil Spill Containment Boom
Authors: William D. Walton, William H. Twilley, Nelson P. Bryner, et al.
Proceedings of the Twenty-second Arctic and Marine Oil Spill Program Technical Seminar (1999), Volume 2, page 447

A second series of fire tests utilizing the ASTM F-20 draft, Standard Guide for In-Situ Burning of Oil Spills On Water: Fire-Resistant Containment Boom, as a guideline were conducted in a wave tank at the USCG Fire and Safety Test Detachment in Mobile, Alabama. The results of the second series evaluation are presented and compared to the first. The strengths and weaknesses of the protocol are discussed along with areas for possible improvement.

Studies of Emissions from Oil Fires
Authors: Merv Fingas, Francine Ackerman, Patrick Lambert, et al.
Proceedings of the Twenty-second Arctic and Marine Oil Spill Program Technical Seminar (1999), Volume 2, page 467

More than 35 mesoscale burns were conducted to study various aspects of diesel and crude oil burning in-situ. Extensive sampling and monitoring of these burns was conducted at downwind

stations, upwind stations, and in the smoke plume using a remote-controlled helicopter. The measurements, calculations, results and conclusions of the burns are presented in this paper.

Re-Engineering of a Stainless Steel Fire Boom for use in Conjunction with Conventional Fire Booms
Authors: I. Buist, S. Potter, J. McCourt, et al.
Proceedings of the Twenty-second Arctic and Marine Oil Spill Program Technical Seminar (1999) Volume 2, page 545

Many existing refractory fabric fire booms will deteriorate quickly in use and may require frequent replacement in a large-scale burn operation. These problems can be minimized, or even eliminated, by using a highly durable and a fire-resistant material in the pocket of the boom where the highest heat and stress loads exist. In this project an existing large, stainless steel boom was designed, constructed and tested to reduce its size, weight and cost. The test procedures, results and final design are presented in this paper.

Emissions From Mesoscale In-Situ Oil (Diesel) Fires: Gases, PAHs and VOCs from the Mobile 1997 Experiments
Authors: Merv Fingas, Zhendi Wang, Pat Lambert, Francine Ackerman, et al.
Proceedings of the Twenty-second Arctic and Marine Oil Spill Program Technical Seminar (1999) Volume 2, page 567

A series of twelve mesoscale burns were conducted in 1997 to assess fire-resistant booms and to study various aspects of diesel oil burning in-situ. Extensive sampling and monitoring of these burns were conducted to determine the emissions of combustion gases, PAHs, VOCs and burn residue. The evaluation procedures, results and conclusions are discussed in this paper.

Development of an Integrated Forms Management and GIS Application for Spill Response
Authors: C.W. Galagan, E.M. Howlett and E.L. Anderson
Proceedings of the Twenty-second Arctic and Marine Oil Spill Program Technical Seminar (1999), Volume 2, page 767

The On Scene Command and Control system is a prototype ICS forms management, GIS, and oil-spill model system that has been developed for the USCG. Improvements planned focus on making the system easier to use within the time constraints of spill drills and real time response. A detailed review of the system's development and future improvements are provided in this report.

Equipment Evaluation of Fast Water Oil Recovery Equipment
Author: Kurt. A Hansen
Proceedings of the Twenty-third Arctic and Marine Oil Spill Program Technical Seminar (2000), Volume 1, page 367

The USCG R&D Center has been evaluating the state-of-the-art of containment and cleanup of oil in currents in order to improve response capabilities. An assessment of current fast-water techniques identified potential equipment and led to a series of field demonstrations that included

skimmers and boom handling equipment. Tests on potential fast water skimmers also occurred. The results of these tests and the development of additional fast water systems are included in this paper.

A Flexible Submergence Plane Barrier for Fast Current Applications
Authors: M.R. Swift, B. Celikkol, and S.E. Root III
Proceedings of the Twenty-third Arctic and Marine Oil Spill Program Technical Seminar (2000), Volume 1, page 401

A flexible, floating submergence plane barrier was developed for intercepting and containing oil spills under fast current conditions. The system is intended to replace conventional oil boom at speeds great enough to cause standard oil booms to fail through leakage. A prototype was constructed and tested. The results of these tests, as well as developmental and logistics issues of the system, are presented in this report.

Second Phase Evaluation of Fore Resistant Booms: Containment of Performance
Author: Kurt. A. Hansen
Proceedings of the Twenty-third Arctic and Marine Oil Spill Program Technical Seminar (2000), Volume 1, page 429

The USCG R&D Center has been investigating the use of in-situ burning as an alternate oil spill response tool. As part of this effort, tests of four fire resistant booms were conducted to determine the ability to collect and contain oil. The objective of the tests was to measure the containment performance of the fire booms after they had been subjected to fire. Test protocol, results and conclusions are described in further detail in this paper.

Emissions from Mesoscale In-Situ (Diesel) Fires: Emissions from the Mobile 1998 Experiments
Authors: Merv Fingas, Zhendi Wang, Pat Lambert, Francine Ackerman, et al.
Proceedings of the Twenty-third Arctic and Marine Oil Spill Program Technical Seminar (2000), Volume 2, page 857

A series of mesoscale burns were conducted to assess fire-resistant booms, with 12 of these burns used to study emissions from diesel oil burns. Extensive sampling and monitoring for combustion gases, PAHs, and VOCs, were conducted to determine the emissions at nine downwind ground stations, one upwind ground station and at six side stations. The results and conclusions of the tests are presented in this paper.

Development of a Fast-Water Field Guide
Author: Kurt A. Hansen
Proceedings of the Twenty-fourth Arctic and Marine Oil Spill Program Technical Seminar (2001), page 237

About 58 percent of all of the oil spilled between 1992 and 1997 in the U.S. occurred on waterways with currents that routinely exceed one knot. A field guide has been developed that

can be used for training and responding to fast-water spills. The background, organization, and use of this field guide are described in this document.

Evaluation of Fast-Water Oil Recovery Equipment
Authors: Kurt A. Hansen, Dave DeVitis, Stewart Ellis, Steve Potter and Thomas Coe
Proceedings of the Twenty-fourth Arctic and Marine Oil Spill Program Technical Seminar (2001), page 251

About 70 percent of the oil transported on U.S. waterways between 1992 and 1997 were on waterways with currents that routinely exceed one knot. The USCG R&D Center has been evaluating the state-of-the-art of containment and cleanup of oil in fast water currents. Five sets of tests were performed to collect data and the results are presented in this paper. The evaluations included a prototype rope mop system, sheet absorbents, flow diverters, modifications to the U.S. Coast Guard's High Speed Skimmer and measurement of towing forces on diversion booms.

In-Situ Burn Operational Procedures Development Exercise
Authors: K. Bitting, J. Gynther, M. Drieu, A. Tideman, and R. Martin
Proceedings of the Twenty-fourth Arctic and Marine Oil Spill Program Technical Seminar (2001), page 695

This paper contains a discussion of the conduct and results of three at-sea oil spill exercises developed and carried out by the USCG, Texas General Land Office and National Response Corporation. The exercises tested and evaluated several techniques for carrying out in-situ burning operations at-sea. Actual response vessels, water-cooled fire boom, helicopters and helitorch were used and appropriate data were recorded. The results of these exercises are being used to create planning and training tools to make in-situ burning a viable spill response tool.

Studies of Emissions From Oil Fires
Authors: Merv Fingas, Patrick Lambert, Zhendi Wang, et al.
Proceedings of the Twenty-fourth Arctic and Marine Oil Spill Program Technical Seminar (2001), page 767

A series of 45 mesoscale burns were conducted to assess various aspects of diesel and crude oil burning in-situ. Extensive sampling and monitoring for combustion gases, PAHs, and VOCs, were conducted to determine the emissions at downwind stations, upwind stations and in the smoke plume. The emissions data from the experimental burns were used to develop prediction equations for over 150 specific compounds or emission categories. These are used to calculate safe distances and levels of concern for various burn sizes that would typically be contained in a boom. The results and conclusions of the tests are presented in this paper.