Regional Sustainability Solutions (RSS) FY07

Project 3.7: Hawaii Region-Undersea Munitions Response Assessment

Final Preliminary Systems Requirements Report

March 6, 2009

Distribution Statement "A" applies
Approved for public release; distribution is unlimited.

Contract No. W74V8H-04-D-0005
Task No. 0501
Project 3.7
CDRL No. A004

Prepared by
National Defense Center for Energy and Environment (NDCEE)

Submitted by
Concurrent Technologies Corporation
100 CTC Drive
Johnstown, PA 15904

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE March 6, 2009	3. REPORT TYPE AND DATES COVERED Final (9/29/07 through 9/29/09)

TITLE AND SUBTITLE
Preliminary Systems Requirements Report
Project 3.7: Hawaii Region-Undersea Munitions Response Assessment

4. FUNDING NUMBERS
Contract: W74V8H-04-D-0005
Task: 0501

5. AUTHOR(S)
James Seliga, Brian Yallaly, Shannon Lloyd

6. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Defense Center for Energy and Environment
Operated by Concurrent Technologies Corporation
100 *CTC* Drive
Johnstown, PA 15904

7. PERFORMING ORGANIZATION REPORT NUMBER

8. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
NDCEE Program Office (Office of the Assistant Secretary of the Army for Installations and Environment)
1235 South Clark Street, Suite 307
Arlington, VA 22202-3263
Program Manager: Tom Guinivan, NDCEE Program Manager, 410-436-5910

9. SPONSORING/MONITORING AGENCY REPORT NUMBER
NDCEE-CR-2008-079

10 SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution A - Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The ability of the United States Department of Defense (DoD) to protect human health and environment during its operations is key to sustaining DoD"s mission capability. This report identifies seven potential technologies to address undersea munitions and compares these technologies to established evaluation criteria. Based on this comparison, one technology was selected for further evaluation under this project.

14. SUBJECT TERMS
Undersea munitions, UXO, ROV, munitions recovery, assessment, technology search

15. NUMBER OF PAGES
36

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	None

TABLE OF CONTENTS

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

AFRL	Air Force Research Laboratory
AOE	Automated Ordnance Excavator
ARA	Applied Research Associates, Inc.
BIP	Blow In Place
CDC	Controlled Detonation Chamber
CTC	Concurrent Technologies Corporation
DMM	Discarded Military Munitions
DoD	Department of Defense
DTIC	Defense Technical Information Center
EOD	Explosive Ordnance Disposal
ESOH	Environment, Safety and Occupational Health
ESTCP	Environmental Security Technology Certification Program
HPU	Hydraulic Power Unit
I&E	Installations and Environment
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization of Standardization
MEC	Munitions and Explosives of Concern
MECV	Mobile Explosion Containment Vessels
MM	Military Munitions
MURS	Magnetic UXO Recovery System
NDCEE	National Defense Center for Energy and Environment
O&M	Operational and Maintenance
OASA	Office of the Assistant Secretary of the Army
ODASA	Office of the Deputy Assistant Secretary of the Army
ORS	Ordnance Recovery System
PEC	Planteco Environmental Consultants
POC	Point of Contact
ROUMRS	Remote Operated Underwater Munitions Recovery System
ROV	Remotely Operated Vehicle
SAIC	Science Applications International Corporation
SDC	Static Detonation Chambers
SERDP	Strategic Environmental Research and Development Program
TNT	Trinitrotoluene
UOR	Underwater Ordnance Recovery, Inc.
UXO	Unexploded Ordnance

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the following individuals and their facility support personnel who provided information used in the preparation of this report:

Mr. Hany Zaghloul	Office of the Assistant Secretary of the Army for Installations and Environment (OASA(I&E) ESOH)
Mr. J.C. King	Office of the Deputy Assistant Secretary of the Army (Environment, Safety and Occupational Health) (ODASA[ESOH])
Mr. Geoff Carton	ODASA(ESOH)
Mr. Larry Karl	Oceaneering
Mr. John Coughlin	ARA Inc.
Mr. Harley Heaton	UXB International, Inc.
Mr. Phil Hammond	UXB International, Inc.
Mr. James Barton	Underwater Ordnance Recovery, Inc.
Dr. Jim McDonald	Science Applications International Corporation (SAIC)
Dr. Walter O‟Neill	Planteco Environmental Consultants (PEC)
Dr. Valentine A. Nzengung	PEC

EXECUTIVE SUMMARY

The ability of the United States Department of Defense (DoD) to protect human health and the environment during its operations is key to sustaining DoD"s mission capability. DoD"s past use of the sea to dispose of excess, unserviceable, or obsolete military munitions, a practice stopped in 1970, has raised concerns about the potential adverse impact to human health and the environment. While other efforts have concentrated on the ability to delineate these potential effects, the DoD will benefit from technologies that can address such undersea munitions if a response is determined necessary. Response actions reviewed range from *in situ* treatment through removal. Indeed certain sea disposed munitions may pose a hazard (explosive, chemical agent, hazardous materials) to human health or the environment.

Through National Defense Center for Energy and Environment (NDCEE)[1] Task 501, Project 3.7, the Army seeks to identify and evaluate currently available technologies that are capable of addressing undersea munitions in the vicinity of the Hawaiian Islands. This Preliminary Systems Requirements Report documents the first two phases of this assessment. First, potential technologies were identified. Then, the attributes of these technologies were evaluated against key criteria, leading to the selection of one technology for further evaluation.

As part of a technology search, the NDCEE identified the following seven technologies that may be viable alternatives for addressing undersea munitions.

- Remotely Operated Underwater Munitions Recovery System (ROUMRS), Oceaneering/Applied Research Associates (ARA) Inc.
- Munition Recovery System, UXB International, Inc.
- Ordnance Recovery System (ORS), Underwater Ordnance Recovery (UOR), Inc.
- Magnetic UXO Recovery System (MURS), ESTCP Project MM-0732/Air Force Research Laboratory(AFRL)/NDCEE
- Efficient Shallow Underwater UXO Retrieval, ESTCP Project MM-0606/SAIC
- In-Situ Treatment, Planteco Environmental Consultants (PEC)
- Microbial Mat, PEC

The Army established four main criteria to determine which technology showed the most promise for this application. The four criteria are the technology"s ability to meet safety and environmental requirements, operational capabilities, stage of development, and cost. Based on these criteria, the ROUMRS technology was selected for further evaluation under this project. The ROUMRS technology met all of the established criteria, including being the most economically feasible technology.

[1] The NDCEE is operated by Concurrent Technologies Corporation (*CTC*).

1.0 INTRODUCTION

A key component to sustaining the United States Department of Defense"s (DoD"s) mission capability is the ability of the to protect human health and the environment during operations. Concerns about potential adverse impact to human health and the environment have been raised about DoD"s past use of the sea to dispose of excess, unserviceable or obsolete military munitions (MM), a practice stopped in 1970. While other efforts have concentrated on the ability to delineate those potential effects, the DoD will benefit from technologies that can address such undersea munitions if a response, such as treatment or removal, is determined necessary. Certain sea disposed munitions may pose a hazard (explosive, chemical agent, hazardous materials) to human health or the environment.

National Defense Center for Energy and Environment (NDCEE)[2] Task 501, Project 3.7 was initiated by the Army to identify and evaluate currently available technologies that are capable of addressing undersea munitions and select one technology for further evaluation in preparation for a potential future demonstration of the selected technology. The down-selection to one technology is based on a comparison of the various identified technologies" attributes relevant to a potential demonstration of the technology in the vicinity of the Hawaiian Islands. The methodologies used during the technology identification and comparison, as well as the selection of one technology for further evaluation are contained in this Preliminary Systems Requirements Report.

2.0 TECHNOLOGY IDENTIFICATION

A technology search was performed to identify the available response technologies for undersea munitions. The search included efforts completed by the NDCEE, Strategic Environmental Research and Development Program (SERDP), Environmental Security Technology Certification Program (ESTCP) and other DoD research projects; open internet sources; and stakeholder input. The following subscription databases for defense and scientific related research publications were also keyword searched.

- Defense Technical Information Center (DTIC)
- American Chemical Society Scientific & Technical Information Network Database Search Tool
- Thomas Scientific Dialog
- Institute of Electrical and Electronics Engineers (IEEE) database
- ProQuest
- Scirus

[2] The NDCEE is operated by Concurrent Technologies Corporation (*CTC*).

These sources were searched using combinations of the following keywords.

- Underwater unexploded ordnance (UXO) mitigation
- Underwater munitions and explosives of concern (MEC) (i.e., UXO and discarded military munitions (DMM)) mitigation
- Underwater munitions mitigation
- Underwater UXO remediation
- Underwater MEC remediation
- Underwater MM remediation
- Underwater UXO recovery
- Underwater MEC recovery
- Underwater MM recovery
- Underwater UXO removal
- Underwater MEC removal
- Underwater munitions removal
- Underwater UXO response
- Underwater MEC response
- Underwater munitions response
- Underwater UXO retrieval
- Underwater MEC retrieval
- Underwater munitions retrieval

The search resulted in the identification of the following seven potential undersea munitions response technologies (and respective vendors), which are presented in detail in Section 3.

- Remotely Operated Underwater Munitions Recovery System (ROUMRS), Oceaneering/Applied Research Associates (ARA) Inc.
- Munition Recovery System, UXB International, Inc.
- Ordnance Recovery System (ORS), Underwater Ordnance Recovery (UOR), Inc.
- Magnetic UXO Recovery System (MURS), ESTCP Project MM-0732/Air Force Research Laboratory (AFRL)/NDCEE
- Efficient Shallow Underwater UXO Retrieval, ESTCP Project MM-0606/Science Applications International Corporation (SAIC)
- In-Situ Treatment, Planteco Environmental Consultants (PEC)
- Microbial Mat, PEC

3.0 TECHNOLOGIES

The technology vendors were contacted to provide technology information for specific attributes within the following areas:

- Safety/Environmental Features. The ability of the technology to negate potential adverse human health and environmental effects associated with addressing underwater munitions.

- Operational Capabilities. The capabilities of the technology in relation to operating depth, munitions size, sea states, maintenance requirements, and operating time intervals.
- Equipment Specifications. The identification and description of specific technology equipment components, surface vessels, and support equipment.
- Personnel Requirements. The quantity and training level of personnel required to operate the technology.
- Costs. Technology cost including relocation to site, setup, operation, and maintenance.
- Mobility. The ability of the technology to be moved from site to site.
- Developmental Stage. The current stage of technology development and the time required to provide a system for demonstration.

The following sections detail the information collected from each technology vendor.

3.1 ROUMRS

ROUMRS is a package of technologies consisting of a remotely operated vehicle (ROV), adaptable attachments, specialized tools, and lifting packages. The ROUMRS system involves an ROV tailored for either large or small munitions removal. Munitions are remotely placed in a lift basket and floated to the surface. The munitions remain submerged in the basket to reduce the hazard to people, the hazardous fragment distance and the potential damage to equipment during transport. The basket is then towed by a commercially chartered vessel to a location where its munitions contents can be disposed by any number of standard methods. The ROUMRS system, manufactured by Oceaneering/ARA Inc., qualifies as made in America although some components (e.g., the video displays) may be foreign made.

Oceaneering is a provider of engineered services and products primarily to the offshore oil and gas industry, with a focus on deepwater applications. Oceaneering also serves the defense and aerospace industries. Oceaneering‟s capabilities include ROVs, mobile offshore production systems, built-to-order specialty subsea hardware, engineering and project management, subsea intervention and installation services, non-destructive testing and inspections, and manned diving.

Oceaneering
7001 Dorsey Road
Hanover, MD 21076
Point of Contact (POC): Larry Karl
(443) 459-3755
Email: karl@oceaneering.com
Website: www.oceaneering.com

ARA was established in 1994 with headquarters located in Fairfax, Virginia. ARA‟s Engineering and Sciences Division specializes in high hazard explosives and environmental remediation, the cleanup of munitions and explosives of concern (MEC) and the development of new technologies.

ARA Inc.
11211 Waples Mill Road
Suite 310
Fairfax, VA 22030
POC: John Coughlin
(443) 745-4163
Email: jcoughlin@arainc.net
Website: www.arainc.net

3.1.1 Safety/Environmental Features

Mitigation of Explosive Hazard

ROUMRS is designed to safely and remotely recover armed munitions. The ROUMRS system includes a sensor suite to characterize munitions by type, size, and condition (discarded, fuzed, fired), allowing a determination of the explosive hazard prior to any contact with a munition. The system has the ability to remotely place armed munitions in a lift basket and float them to the surface without contact by personnel. The munitions can then be transported to a disposal site. In addition, the system can be engineered to contain bulk energetic compounds.

Mitigation of Environmental Impact

ROUMRS mitigates the environmental impact of undersea munitions by removing the munitions from the environment. The sensor suite and cameras mounted on the ROV can be used to assess the condition of the munitions before removal. For those munitions deemed to be in damaged or in an enhanced state of decay, encapsulation or blow in place (BIP) options provide alternate methods to protect people and the environment.

Operator Safety

ROUMRS has inherent safety in remote operation. The system allows for remote characterization of munitions for removal. This system performs without diver support. Remote operation allows personnel to avoid explosive hazards and exposure to water temperatures and pressures.

3.1.2 Operational Capabilities

ROUMRS is designed to operate at depths up to 300 feet, but can be adapted to operate at up to 1,000 feet. This depth is currently limited by the lift baskets which would need to be modified to operate at greater depths. The system‟s munitions capacity is the manipulation and recovery of .50 cal to 155mm munitions. Lift baskets or straps are used to recover multiple items simultaneously or for items up to 2,000 pounds. A specialized system can be engineered to contain munitions constituents (e.g., propellants, explosive fillers, metal debris) to minimize release of such constituents from deteriorated (e.g., corroded) munitions during the recovery process. The system can operate at a sea state of three or less in water temperatures of 28 to 90 °F. The system is not engineered to operate in the surf zone. The ROV is equipped with high resolution sonar, cameras, depth altitude, and laser scaling for local munitions search, locate and documentation capabilities.

The ROV can in effect remain submerged for an extended period of time; 24 hours per day, seven day per week operation is typical for ROVs. The system, however, requires one hour of on-deck maintenance per 12 hours of operation with 160 hours between scheduled maintenance.

3.1.3 Equipment Specifications

ROUMRS underwater systems include the ROV with electric thrusters, two manipulators, high resolution sonar, zoom camera, wide camera, wrist camera, still camera, variable ballast, lighting, depth/altitude, laser scaling, hydraulic power unit (HPU)/manifold, multibeacon, and a recovery basket. Magnetometers and a chemical sensor suite are available. Pump, shovel and brush attachments are available for light removal of sand, dirt, or silts from on top of munitions. The ROV‟s six-function manipulators can lift 130 pounds using on-board thrusters. The ROV can place straps and lift bags to raise items of 2,000 pounds. The recovery containers consist of a composite-lined recovery basket with a compressed air lift bag system, a multibeacon/pinger, and strobe.

Surface systems include an umbilical docking and an umbilical overboard sheave. Surface auxiliary equipment includes a power distribution generator, transit cases, monitors, a controller, a compressor, cables, and lifting/recovery baskets. The system requires a 55- to 75-foot vessel of opportunity and crew. A 144-square foot air-conditioned dry space on the vessel is desirable for support equipment and personnel. Auxiliary small craft may be required to tow munitions to the shore or to an offshore disposal site.

The ROV uses a control station with video monitors and a recording suite contained on the surface vessel. An umbilical connects the control station to the ROV. Navigational equipment includes ultra short baseline navigation with video, sonar, and digital recordings. The system has the capability to document munitions recovery through the use of the ROV camera, sonar, and digital still systems, recorded and referenced for time and geo-referenced position.

3.1.4 Personnel Requirements

ROUMRS requires a crew of two people per 12 hours, plus the vessel crew. Some specialized training is required for ROV pilot proficiency. Identification of military munitions requires at least one member of the crew qualify as a UXO technician level III or higher.

3.1.5 Costs

Capital Cost: $800,000. This cost includes all equipment specified in Section 3.3.3, with the exception of the support vessel.

Relocation Cost (vendor to Hawaii): $100,000. This cost includes $95,000 for packing, mobilization (including unpacking and assembly on the support vessel), system testing, and demobilization after the demonstration and shipping cost of roughly $5,000 for a 20-foot International Organization for Standardization (ISO) container.

Operational and Maintenance (O&M): $900k to $1.2M per month. Cost estimates vary greatly with several variables. The costs presented for the ROUMRS system are associated with a complete system that removes a wide range of munitions, from bullets to one-ton air dropped bombs. The fact that ROUMRS is a complete system should be considered when comparing the cost of this technology to others that are not acting as a complete system. The operation cost includes the support vessel and crew, ROV and crew, and the crafts for transporting the lift baskets to a nearby shore or disposal site.

3.1.6 Relocation/Mobility

ROUMRS is a portable system that can be transported by ground, air, or sea in a standard 20 foot ISO shipping container. Shipping time to Hawaii is estimated to be two weeks, but faster delivery is possible at an additional cost.

3.1.7 Stage of Development

The development of the system is near completion. All components are commercially available; however, the system still has to be assembled. The system can be assembled and ready for demonstration within 10 months.

3.2 Munitions Recovery System

The Munitions Recovery System, manufactured by UXB, uses ROVs to place underwater munitions in a lift basket (a sealed "coffin" container can be developed for chemical munitions). Ropes, straps or lift bags are then attached to the basket to lift or float the munitions to the surface. The munitions are placed directly into an explosion-proof DYNASAFE container without breaching the water surface and are destroyed on-site. This system allows for remote operation, and transport and disposal of the munitions with no direct human contact. The technology diminishes explosive hazards and prevents the release of munitions constituents to the environment.

UXB has teamed with DYNASAFE to allow for transport and destruction of recovered conventional and chemical munitions. DYNASAFE produces explosion containment products and munitions destruction chambers. DYNASAFE‟s munitions destruction chambers can be placed on a sea platform, a barge or on shore. The recovery containers can be fed directly into the destruction chamber for complete destruction of the munitions and its container. More elaborate disposable containers are currently being developed, and can be ready for demonstration in 10 months.

UXB International, Inc. provides hazardous waste services for waste military munitions, both nationally and internationally. UXB labels itself as the first private U.S. waste military munitions disposal company. UXB has experience in land and underwater recovery of UXO. UXB also has experience in the transportation of UXO and the operation of destruction plants for UXO. Based in Virginia, UXB runs most of its underwater operations out of the United Kingdom.

UXB International, Inc.
2020 Kraft Dr. Suite 2100
Blacksburg, Virginia 24060
POC: Harley Heaton
(540) 443-3700
Email: harley@uxb.com
Website: www.uxb.com

DYNASAFE Germany GmbH, founded in 2002, designs and manufactures explosion containment and suppression chambers, transport vessels, and plants for munitions destruction. DYNASAFE‟s Static Detonation Chambers (SDC), a hot

detonation technology, are designed for the destruction of conventional and chemical munitions. DYNASAFE‟s Controlled Detonation Chambers (CDC), a cold detonation technology, are designed solely for the destruction of chemical munitions.

3.2.1 Safety/Environmental Features

Mitigation of Explosive Hazard

The UXB system is designed to recover armed munitions without direct contact by personnel. The system has the ability to remotely place armed munitions in a lift basket and float them to the surface without contact by personnel. Coffin containers can be developed to seal chemical munitions to prevent the release of harmful materiel. Once lifted to the surface, the munitions can be placed in an explosion-proof containment chamber for transport to an on-shore disposal facility, if necessary.

Mitigation of Environmental Impact

The UXB system mitigates the environmental impact of undersea munitions by removing the munitions from the environment. The ROV mounted camera allows a visual inspection to assess the condition of the munitions before removal. Once the munitions are deemed stable, the system remotely removes the munitions to the surface. A sealed coffin container can be developed for the recovery of suspected leaking munitions, including chemical munitions. An explosion-proof sealed containment chamber is used to contain the munitions for transport to the disposal site.

Operator Safety

This system allows for remote surface operation, explosion proof containment, transport, and disposal of the munitions with no direct human contact. Remote operation allows personnel to avoid explosive hazards and exposure to water temperatures and pressures. Training courses are required for all operators.

3.2.2 Operational Capabilities

The system operates at depths up to 500 feet and can address munitions up to 155mm. Sealed coffin containers can be developed to address leaking munitions, including chemical munitions. The system can operate at a sea state of three or less with no water temperature restrictions. UXB has the ability to computer integrate a multibeam technology, digital global positioning system, magnometer, side scans, echo depth sounding, a sub

bottom profiler, and geophysical samples to enable the generation of highly accurate charts for munition locations.

The ROV can remain continuously submerged indefinitely, pending regular inspections. Maintenance requirements are one-half shift per week, mostly for routine inspections.

3.2.3 Equipment Specifications

Underwater Systems include: the ROV, including the camera system, an inertial navigation system, and grapple arms; and containment units on the ocean floor (wire basket), hung off a wet well in the surface vessel or a barge.

The primary surface vessel required is an ocean-going, flat-bottom barge, typically 100 feet by 400 feet, equipped with a wet well put in or hung off to side. The surface vessel is required for deployment and operation of the ROV, storage and deployment of containment chambers, and overall site management. The ROV controls are located on the surface vessel with cables connected to the ROV. The surface vessel can also contain the DYNASAFE CDC for onsite destruction of the munitions. No other vessels are required with the possible exception of small safety and personnel transport vessels.

This technology uses a recovery basket to lift munitions to the surface either by ropes, straps or lift bags. A coffin container can be developed for chemical munitions. Once at the surface, munitions are placed in DYNASAFE Mobile Explosion Containment Vessels (MECV). MECVs are in operation worldwide for testing and transport of explosives and munitions including chemical munitions. MECVs are available and are rated between 1 and 25 kg trinitrotoluene (TNT) equivalent. Design and equipment are customized to the need of the specific application. The MECV can be mounted onto a variety of vehicle loading frames or directly on a trailer or low body vehicle. A number of options and attachments are also available. The system has the capability to document munitions recovery through the use of the ROV camera system.

3.2.4 Personnel Requirements

This technology requires four members of the control team in addition to any required crew for the barge. Two control members operate the ROV, and two run the DYNASAFE munition destruction system.

3.2.5 Costs

Capital Cost: The UXB system is based on an equipment lease. A long term lease would be required to allow USB to purchase the equipment necessary to assemble the system. If the complete UXB disposal system is required, an additional capital cost of $19.25M would be incurred for the DYNASAFE destruction system (Model SDC 1200 CM), a gas treatment system, and secondary containment structure. This cost is based on the assumption that the constructed units will be used by the customer for a relatively long period of time, encompassing several removal projects in the same or different areas. The client would essentially keep the DYNASAFE product after the project is completed.

Relocation Cost (vendor to HI): $405,000. This is the total for both the shipment of components to Hawaii ($285,000) and local shipment and mooring at site ($120,000).

Setup Cost: $227,000. This will include setup of all equipment.

Operational Cost: $961,000 per month. This includes $361,000 System O&M (lease) including personnel and $600,000 per month for surface vessel hire. As a separate option, UXB estimates the cost to purchase a used barge for use as a surface vessel is $450,000.

3.2.6 Relocation/Mobility

This portable system can be shipped by ground, air, or sea in a standard 20 foot ISO shipping container. Shipping time is estimated to be 30 days.

3.2.7 Stage of Development

The system is fully developed, has been demonstrated, and is commercially available. UXB has demonstrated their technology for the British Royal Navy, with the main purpose of removing German ground mines from World War II. The DYNASAFE containment and disposal systems are custom-built for each order, and are shipped from Sweden.

3.3 ORS

The ORS, manufactured by UOR, is based on a "crawler" type ROV with an attached conventional boom-mounted grapple, lowered to the seafloor from a surface vessel. The ROV has a drive chassis that balances the need for traction, stability, and maneuverability, with the sensitivity, consistency, and profile of the bottom terrain. The grapple is used to collect and place munitions in a recovery basket. The system is operated remotely from the surface using closed circuit cameras to guide the grapple. Once the munitions are placed in the basket, the

basket is floated to the surface and towed using a second surface support vessel. The technology was developed by the University of Georgia and UOR Inc. The system is designed to safely recover fully armed munitions. The system has the ability to recover munitions and tow them to a disposal location without contact by personnel. The towed munitions remain under the surface throughout the process to mitigate damage from unintentional detonation.

UOR was formed in 1999 by Mr. James Barton. Mr. Barton has worked with underwater UXO since 1975 and is retired from Naval Explosive Ordnance Disposal Mobile Unit Two, Norfolk, VA. Mr. Barton began his career in 1975 by joining Explosive Ordnance Disposal (EOD Mobile Unit One in Hawaii). Mr. Barton is a commercially certified professional diver, qualified in surface supplied air/mixed gas, and bell/saturation diving. Mr. Barton has provided advanced EOD underwater munitions response training to US Navy Fleet EOD assets worldwide, is a qualified Master Training Specialist, Curriculum Developer, and Small Arms Master Instructor, and achieved the rank of petty officer first class.

UOR
P.O. Box 14003
Norfolk, VA 23518
POC: James Barton
(757) 451-8545
Email: jamesbarton@uwuxo.com
Website: www.uwuxo.com/index.htm

3.3.1 Safety/Environmental Features

Mitigation of Explosive Hazard

ORS is designed to safely recover fully armed munitions. The system has the ability to recover munitions and tow them to a disposal location without contact by personnel. The towed munitions remain under the surface to mitigate damage from unintentional detonation. In addition, armed munitions can be "rendered safe" by using an abrasive water jet cutting "wand" to neutralize fuzes before the munition leaves the bottom.

Mitigation of Environmental Impact

ORS mitigates environmental impact of undersea munitions by removing them from the environment. ORS is designed to keep the munitions under the surface to mitigate the spread of material in case of unintentional detonation. Munitions (including chemical) in an advanced state of decay can be located, exposed, analyzed, recovered intact (via clam shell attachment), and transferred to a suitable overpack container via an Integrated Transfer Station for "contained" transport to a distant processing or disposal station. Structurally intact containers can be

penetrated, the contents removed, or simply “treated” with a neutralizing agent before being re-sealed, and or placed into a containment/transport device.

Operator Safety

This system allows for remote surface operation and transport of the munitions with no direct human contact. Remote operation allows personnel to avoid explosive hazards and exposure to water temperatures and pressures. A multi-layered safety approach includes training, standard operating procedures, and "Safe Exclusion Zone" determinations.

3.3.2 Operational Capabilities

ORS operates at depth of 250 feet or more, with 1,000 feet or more potentially possible. The system can address munitions of greater than 2,000 lbs, and up to 48 inches in diameter. Neutralizing agents, a "Clam Shell" manipulator, and underwater containment units can be used to address leaking munitions. The system can operate in water temperatures of 20 to 180°F. The ROV is equipped with a camera system with lighting elements, closed circuit video, with pan/tilt/zoom features for local munitions search and locate capabilities.

The ROV can remain continuously submerged indefinitely - 24 hours per day, seven day per week operation is typical for ROVs. The system requires four hours of routine maintenance per 40 hours of operation.

The ORS is a “crawler” type ROV, whose weight can be adjusted over a wide range. The affect currents have on the ROV is minimized by making it “bottom-heavy”. The physical impact a heavier ROV has on the sea floor is offset by selecting a drive chassis that balances the need for traction, stability, and maneuverability, with the sensitivity, consistency, and profile of the bottom terrain.

3.3.3 Equipment Specifications

The ORS is built around a seafloor based crawler type ROV, lowered into position on the bottom near the munitions to be recovered. A range of “grapples” can be mounted on the end of a 15 foot modified knuckle boom with a 360 degree swing, it can grasp and lift objects weighing in excess of 2,000 pounds and up to 48 inches in diameter close in, and objects weighing in excess of 500 pounds at the full 15 foot extension. Other subsystems include a dredge, sheers, abrasive water jet cutting wand, magnetometer, analytical instrumentation, etc., all of which may be used independently or in conjunction with the other subsystems.

Surface systems include a command module, launch and recovery station, ROV tether handling system, and various subsystem components. The command module is a climate controlled portable structure which houses the majority of "topside" electronics such as communications, telemetry, and user interface, along with subsystem read outs. The launch and recovery station is a free standing assembly capable of handling the weight and shape of the ORS ROV configuration desired. The ROV tether handling system is integrated into the structure of the launch and recovery station. The ROV tether contains fiber optics and electrical wiring to connect the ROV to the surface controls. Surface auxiliary equipment includes two diesel-powered generators, welding machine, and an electric auxiliary pump.

A surface vessel is needed to accommodate the command module, launch and recovery system, and ROV tether handling system, and to deploy the ROV and recovery basket. Surface vessel requirements include a dynamic positioning system with 32-ton capacity, and over 600 square feet of deck space. Other required small craft include two safety boats, a water taxi, and tow boats to transport the recovery basket to ashore or offshore disposal system.

The primary manipulator is a hydraulically operated, electrically powered "knuckle boom." Installed on the end are interchangeable "attachments", such as a grapple, basket, clamshell, etc., which are proportional in size to the items being targeted. The grapple has a 48 inch diameter capacity. Containment units vary depending upon the targets size, shape, fuze condition, physical condition, and type of filler material involved. In some cases a commercially available containment system can be adapted for use in containing and transporting the most hazardous underwater materials with little effort, where in other cases the containment unit must be manufactured and tailored to match both the characteristics of the target, and the handling capabilities of the ORS from scratch.

A closed circuit camera system from the underwater platform is monitored at the operator station. The camera system uses carefully selected lighting elements and closed circuit color and black and white video cameras which are positioned at strategic locations to act as the primary set of "eyes" for the operators. These cameras are enhanced with pan/tilt/zoom features, and image enhancing software. Special sonar units are used to operate in zero visibility conditions (also known as "blackwater" operations).

3.3.4 Personnel Requirements

The ORS requires a crew of five people plus the vessel crew. The ORS crew requires six months of "Systems Specific" training.

3.3.5 Costs

Capital Cost: $15 million basic system cost. An additional $5 million is required to design, fabricate, and integrate compatible accessories needed to meet site specific challenges (e.g., render safe, demilitarization of armed munitions using an abrasive water jet cutting system). The equipment will always remain the property of UOR. Once a client pays for a particular system to be built, the only additional "build" costs are the specific modifications to the configuration requested by the client. This may involve simply swapping out a "standard" attachment for something fabricated in-house for a specific target, or it could involve something more extensive based on the need. To reserve the equipment for the exclusive use of the organization who originally paid to have it built, as well as maintain it in a "ready to deploy" status (3-4 months normal, but "rapid response" capability is available), a two year lease is included with the initial contract. After that time expires, the lease can be extended for a fee, or the system is returned to UOR for use by other clients.

Relocation Cost (vendor to HI): Varies. Relocation costs are affected by how fast the system is needed, how remote the location, and of course the standard shipping rate for the trucks, ship, or aircraft, selected to relocate it.

Setup Cost: $162,000. Set up takes a 4 man crew 5 days to complete, and involves the use of a crane/operator, a 15 ton fork truck, a 3 ton fork truck, and welder, throughout the set up process.

Operational Cost: $1,855,000 per month. This total includes $720,000 for the system lease and operating personnel, $1,125,000 for surface vessel hire. The surface vessel estimate was based on surface vessel requirements provided by the vendor and researching prevailing rates for similar vessels. The estimate identified is $37,500/day for vessel hire and crew, and $10,000 for maintenance.

3.3.6 Relocation/Mobility

This portable system is palletized for shipping and can be shipped by a C-17 Cargo Jet. Upon arrival, the system components are loaded on flat bed trucks using a fifteen ton fork truck, for transport to the support vessel. The system is loaded onto the support vessel with a 30 ton crane and can be assembled and put into an operational status in six days.

3.3.7 Stage of Development

The system is fully developed, has been demonstrated, and is commercially available. A prototype of this technology was successfully

tested during sea trials in Key West, FL, in 2005. It was designed for continuous operations at depths in excess of 250 feet, and operational depths in excess of 1,000 feet may be possible. The prototype is configured to handle targets in excess of 2,000 pounds and up to 4 feet in diameter. The prototype successfully demonstrated the baseline system capabilities by picking up a pair of MK82 munitions‟ shapes off the sea floor and placing them in a recovery basket before floating them to the surface. UOR has placed further development “on hold” until a client retains their services.

The prototype system is ready for demonstration. Each system is built "on demand" for clients. The prototype system can be demonstrated with three months notice, depending on the specific site and application.

3.4 MURS

ESTCP Project MM-0732 is being performed by AFRL with portions subcontracted to NDCEE Task 475. AFRL has developed the automated ordnance excavator (AOE) system, a robotic excavator that permits an electromagnet retrofit. This ESTCP project is using the AOE and the existing relationship between Caterpillar and Walker Magnet to demonstrate the MURS. The electromagnet could be useful for shallow water, soil surface, and potentially subsurface UXO recovery. This task focuses on land-based UXO recovery. However, limited underwater (swimming pool) testing has been performed, with good results.

The ESTCP is a DoD program that promotes innovative, cost-effective environmental technologies through demonstration and validation at DoD sites.

AFRL is the Air Force's only organization wholly dedicated to leading the discovery, development, and integration of warfighting technologies for U.S. air, space and cyberspace forces.

The NDCEE was established in 1991, with the directive to serve as a national leadership organization to address high priority environmental, safety, and occupational health problems for the DoD, other government organizations, and the industrial community.

O.S. Walker was founded in 1896 and has become an industry leader in magnetic solutions for workholding, material handling, and separation.

ARFL
Materials & Manufacturing Directorate
Robotics Research and Development Group
104 Research Road
Tyndall AFB, FL 32403
POC: Bill Lewis

(850) 283-3725
Email: bill.lewis.ctr@tyndall.af.mil
Website: www.wpafb.af.mil/AFRL
Project Website: www.estcp.org/Technology/MM-0732-FS.cfm

NDCEE
Office of the Assistant Secretary of the Army for Installations and Environment
1235 South Clark Street, Suite 307
Arlington, VA 22202-3263
NDCEE Task 475 POC: Ronald "Josh" Bowers (*CTC*)
(814) 269-2621
Email: bowersr@ctc.com
Website: www.ndcee.ctc.com

O.S. Walker
Rockdale St.
Worcester, MA 01606
(508) 853-3232
Email: sales@walkermagnet.com
Website: www.walkermagnet.com

3.4.1 Safety/Environmental Features

Mitigation of Explosive Hazard

The system mitigates the explosive hazard by remotely recovering the UXO. The system can remove the munitions to the surface for transport to a disposal facility. However, the system does not have blast containment capabilities at this stage of development.

Mitigation of Environmental Impact

The system limits the environmental impact of the munitions constituents by remotely recovering the munition. However, there are no provisions for containing propellants or explosives when recovering severely degraded munitions.

Operator Safety

This system allows for remote surface operation. Remote operation allows personnel to avoid explosive hazards and exposure to water temperatures and pressures. Safety procedures were established in conjunction with the ESTCP demonstrations on land and in water.

3.4.2 Operational Capabilities

This technology is currently capable of operating in shallow water less than 20 feet. Increased depths may be limited by current drop due to the length of the electrical cables required for the electromagnet. The system is capable of recovering munitions up to 2,000 pounds. This system would not be recommended for leaking munitions due to the potential spread of environmental contamination. The system does not currently have local munitions search and locate capabilities.

The system is not affected by currents or water temperature. Current effects are only related to the capabilities of the surface vessel. Use of the appropriate surface vessel would mitigate current effects. Wave/swell effects on the surface vessel will cause the suspended magnet position to change with the surface vessel. This may cause problems when the magnet is close to the munitions resulting in the magnet impacting the munition with substantial force. The extent of the wave/swell effects is dependent on the configuration and capabilities of the surface vessel.

3.4.3 Equipment Specifications

Underwater systems include the electromagnet and connecting winch/crane cable and electrical cables. Surface systems include a crane/winch, power generator, and electromagnet controls. The winch cable supports the electromagnet and a power cable runs from the electromagnet to the surface controls. The surface vessel will consist of a barge or ship capable of supporting the crane/winch, magnet, generator, and cables. A second vessel or barge may be required for placement of the recovered munitions. Recovery containers are not currently used in the process. The technology is equipped with a camera system. This system would need to be adapted for underwater use.

3.4.4 Personnel Requirements

The technology crew consists of one operator plus the vessel crew. Operator training requirements have been established for the land based system.

3.4.5 Costs

All cost determinations are still in progress.

3.4.6 Relocation/Mobility

This portable system is capable of being shipped by truck, rail, or ship. The cost of shipping is minimized as only the electromagnet and controls would require transportation. The winch/crane, generator, and support

vessel can be hired locally. Transport times would be normal truck, rail, or ship transport times.

3.4.7 Stage of Development

This system has been demonstrated under ESTCP Project MM-0732, focusing mainly on land-based UXO removal. Some underwater testing has been performed, with good results. System specifications including the specifications for the required length of underwater electromagnet power cables will need to be determined. The system is not commercially available, but the electromagnet is commercially available. A system could be designed and developed for underwater recovery within 18 months; however this development is not included in the current scope of the ESTCP project.

3.5 Efficient Shallow Underwater UXO Retrieval

The Efficient Shallow Underwater UXO Retrieval technology, being developed by SAIC under ESTCP Project MM-0606, consists of a shroud structure lowered from a boat over the UXO to protect from initial detonation. A vacuum dredge will be used to remove overlying sediments to expose the target so that it can be visualized using lights and remotely operated cameras. Following identification and a safety evaluation, the target will be recovered using either an electromagnet system or a mechanical grapple operated from the deck.

The Environmental ESTCP is a DoD program that promotes innovative, cost-effective environmental technologies through demonstration and validation at DoD sites. SAIC, a systems, solutions and technical services company, offers a broad range of expertise in defense modernization efforts, intelligence, homeland security, logistics and product support, health and life sciences, space and earth sciences and global commercial services.

SAIC
120 Quade Drive
Cary, NC 27513
POC: Dr. Jim McDonald
(919) 653-0215 Ext. 102
Email: Jimmie.R.McDonald@saic.com
Website: www.saic.com
Project Website: www.estcp.org/Technology/MM-0606-FS.cfm

3.5.1 Safety/Environmental Features

Mitigation of Explosive Hazard

The system mitigates the explosive hazard by remotely recovering the UXO. The vacuum dredge and inspection using lights and remote cameras enables the operator to make a visual inspection to determine the condition prior to performing retrieval operations. The protective shroud placed over munition mitigates unintentional detonation blast effects. The munition can be lifted to the surface and placed on a barge for transport to a disposal site.

Mitigation of Environmental Impact

The system mitigates the environmental impact by removing the munitions from the environment. The vacuum dredge and inspection using lights and remote cameras enables the operator to make a visual inspection to determine the condition prior to performing retrieval operations. Intact munitions can be uncovered, lifted to the surface, and transported to a disposal facility. The vacuum dredge could potentially be used to recover propellant or bulk explosives released from degraded munitions.

Operator Safety

The system allows for remote visual inspection to determine the condition of the munitions prior to performing retrieval operations. This system performs without diver support. Remote operation allows personnel to avoid explosive hazards and exposure to water temperatures and pressures.

3.5.2 Operational Capabilities

The system is currently intended to operate in shallow water less than 20 feet. The munition capacity has not been determined. The system does not address leaking munitions. Operation time and maintenance schedules have not been determined. The system is intended for use in calm waters.

3.5.3 Equipment Specifications

Underwater systems include a deployable shroud, a vacuum dredge, and an electromagnet lowered by a crane or winch. Surface systems include a crane or winch to lower shroud and electromagnet. The winch cable supports the electromagnet and a power cable runs from the electromagnet to the surface controls. Surface auxiliary equipment includes a power generator and winch/crane/electromagnet controls. The required surface

vessel is a barge or ship capable of supporting shroud and electromagnet deployment. Underwater cameras are expected to document recovery.

3.5.4 Personnel Requirements

Personnel requirements have not been determined.

3.5.5 Costs

No costs have been determined.

3.5.6 Relocation/Mobility

The system has the potential to be portable. No transportation requirements have been determined.

3.5.7 Stage of Development

This technology is currently in development with a possible demonstration in Lake Erie mid-summer 2008. No follow-on development is currently planned.

3.6 *In-Situ* Treatment

3.6.1 Technology Vendor/Owner

The in-situ chemical treatment, developed by PEC, is designed to be injected into or placed around degrading weapons and release the treatment via slow-decaying polymer containers. The chemicals react with both the metal weapon casings and their contents, leaving only safe byproducts behind. These slow, yet consistent reactions alleviate the risk associated with the gradual release of chemical warfare materials.

PEC was founded in December 2000 by a group of experienced professionals in the environmental consulting industry. PEC provides green solutions and sustainable technologies, consulting, feasibility studies, turnkey innovative remediation, and engineered green remediation product applications. PEC provides services in remediation technologies, environmental permitting and compliance, environmental auditing and management services, laboratory and field sampling and analysis and sustainable technologies and products.

PEC
337 South Milledge Ave.
Athens, GA 30605
POC: Dr. Walter O'Niell

(706) 316-3525
Email: woniell@planteco.com
Website: www.planteco.com

3.6.2 Safety/Environmental Features

Mitigation of Explosive Hazard

This treatment is performed on munitions left in place, mitigating the explosive hazards by not requiring munitions movement or relocation. The chemicals react with both the metal weapon casings and their contents, reducing the explosive hazard over time as munition is decomposed.

Mitigation of Environmental Impact

This system mitigates the environmental impact by reacting with the munitions casing and contained materiel, rendering them harmless to the environment. The munitions do not have to be moved or disturbed. Constituents are treated in situ minimizing the potential for catastrophic failure of the munitions and release of their contents which could occur during recovery.

Operator Safety

At this time the in-situ treatment must be done by divers. This leads to risks due to exposure to the munitions and the sea conditions. ROV placement of the chemicals is being investigated by PEC, but such a system is not readily available.

3.6.3 Operational Capabilities

This technology is currently for shallow water use. The technology is applicable to leaking munitions. The operating time is limited to restrictions on divers. An ROV technology is possible, but has not been developed. No search and locate except for diver location of munitions. Sea state is restricted by diver limitations.

3.6.4 Equipment Specifications

The underwater system consists of divers. Surface systems consist of dive support equipment. The surface vessel consists of a standard dive vessel.

3.6.5 Personnel Requirements

One trained diver plus dive crew and vessel crew are required.

3.6.6 Costs

Cost information has not been obtained.

3.6.7 Relocation/Mobility

The system is portable with the only the PEC chemicals and chemical application equipment requiring shipment. All dive equipment and the dive vessel can be hired locally.

3.6.8 Stage of Development

The system is commercially available for use in groundwater and land applications. This technology is currently being used as an in situ bioremediation technology for perchlorate and explosive compounds in soils at Hawthorne Army Depot. The system is ready for demonstration, in shallow water or on land.

3.7 Microbial Mat

Microbial Mats, manufactured by PEC, is a non-toxic, algae-like material with a rapid growth rate due to the presence of bacteria. Once grown around a munition, the "mat" protects the outside environment by reacting with both the organic and inorganic materials (including metals). The mat uses a photosynthetic process to produce oxygen, which is in turn used by the bacteria to remain active indefinitely. Please refer to section 3.6 for information on PEC.

3.7.1 Technology Overview/Concept

Microbial Mats is a non-toxic, algae-like material with a rapid growth rate due to the presence of bacteria. Once grown around a munition, the "mat" protects the outside environment by reacting with both the organic and inorganic materials (including metals and munitions constituents). The mat uses a photosynthetic process to produce oxygen, which is in turn used by the bacteria to remain active indefinitely.

3.7.2 Safety/Environmental Features

Mitigation of Explosive Hazard

This treatment is performed on munitions left in place, mitigating the explosive hazards by not requiring munitions movement. The microbes react with both the metal weapon casings and their contents, rendering them harmless. Movement or relocation of munitions is not required. The treatment will reduce hazard, over time, as munitions are decomposed.

Mitigation of Environmental Impact

This system mitigates the environmental impact by reacting with the munitions casing and contained materiel, rendering them harmless to the environment. Munitions are left in place and do not have to be moved or disturbed. Constituents are treated in situ minimizing the potential for catastrophic failure of the munitions and release of their contents that could occur during recovery.

Operator Safety

At this time the mats must be put in place by divers. This leads to risks due to exposure to the munitions and the sea conditions. ROV placement of the mats is being looked into, but such a system is not readily available.

3.7.3 Operational Capabilities

This technology is only applicable to shallow depths (e.g., depth of light penetration) due to the required photosynthesis. The technology is applicable to leaking munitions. The operating time is limited to restrictions on divers. An ROV technology is possible, but has not been developed. No search and locate except for diver location of munitions. Sea state is restricted by diver limitations.

3.7.4 Equipment Specifications

Underwater systems consist of divers. Surface systems consist of dive support equipment. The surface vessel consists of a dive vessel.

3.7.5 Personnel Requirements

Multiple trained divers plus dive crew and vessel crew are required.

3.7.6 Costs

Cost information has not been obtained.

3.7.7 Relocation/Mobility

The system is portable with the only items requiring shipment being the mats. All dive equipment and the dive vessel can be hired locally.

3.7.8 Stage of Development

The system is not yet commercially available. The technology is currently being demonstrated to treat landfill leachate at Fort Hood for use in

groundwater and land applications. The system is ready for demonstration in shallow water or on land.

3.8 Summary of Technologies

Table 1 provides a summary of the information collected for each technology.

Table 1. Undersea Munitions Response Technology Summary

Technology	Safety/Environmental Features	Operational Capabilities	Equipment Specifications	Personnel	Costs	Relocation/Mobility	Developmental Stage
ROUMRS	Remote surface operation. Remote munitions characterization capabilities. Munitions remain under surface and are towed to disposal site.	Depth: 300 ft (adaptable to 1000 ft) 24/7 operation, 1 hr maintenance per 12 hrs operation. Munitions capacity: .50 cal to 155mm (can be modified to 2000lbs)	ROV, manipulators, sonar, camera system, laser scaling, multibeacon, recovery basket. Magnetometers and chemical sensor suite available. 55 to 75 foot surface vessel.	2 persons/12 hrs plus vessel crew.	Capital: $800k Relocation, setup, demobilization: $100K O&M: $900K-1.2M/month	Mobile system. Ship ground, rail, or sea in 20ft ISO container. Approximate 2 week transit time.	All commercially available components. Has not been assembled. Can be ready to demonstrate in 10 months.
Munition Recovery System, UXB	Remote surface operation. Munitions remain in containment units until disposal. Explosion-proof sealed containment chamber for munitions transport, and destruction.	Depth: 500 ft 24/7 operation: ½ shift per week maintenance. Munitions capacity not provided at this time. Munitions locating technologies.	ROV, camera system, and sealed containment system. Large surface vessel for controls and to house munition containment unit.	4 persons/8 hrs/3 shifts; 2 for ROV, 2 for DynaSafe (if required)	Capital: None (long term lease required). Relocation: $450k Setup: $227K O&M: $961K/month	Mobile system. Relocation method not provided at this time.	Technology demonstrated for the British Royal Navy. The containment system is commercially available.
Ordnance Recovery System, UOR	Remote surface operation. Munitions remain under surface and are towed to disposal site. Specialized containment options for leaking or chemical munitions.	Depth: Over 250 ft, (possibility of over 1000 ft). 24/7 operation: 4hrs maintenance per 40 hrs of operations. Munitions: >2000 lbs , up to 48" in dia.	Seafloor crawler ROV with grapple, surface controls, and camera system. Surface vessel w/32-ton lift capability and additional small craft support vessels.	5 man crew plus vessel and small craft crew	Capital: $15M basic system cost. $5M site specific equipment. Setup: $162K O&M: $1.855M/month	Mobile system. Palletized for shipping. C-17 transport or trucks.	Technology demonstrated in sea trials in Key West, FL in 2005 to remove two 500lb practice munitions from 30 ft depth. Demo ready in 4 months.
MURS ESTCP Project MM-0732	Remote surface operation.	Depth: Under 20 ft. Operation times and maintenance schedules are not available. Demonstrated with 2000 lb munitions.	Government owned AOE System, electromagnet, electrical cables, power generator, camera system, control system. Surface barge/vessel capable of supporting surface equipment.	One operator plus vessel crew.	Cost determinations are still in progress.	Mobile system. Requires shipment of AOE system, electromagnet and controls. Generator and support vessel hired on site.	System is not commercially available. This system was demonstrated on land-based UXO removal with limited underwater testing.
In-Situ Treatment, PEC	Performed by divers. Munitions not relocated. Results in on-site degradation and mitigation of explosive/environmental hazard.	Depth: Shallow water. Stable versus swells and wave action. Operation time and maintenance schedules have not been determined Munitions: Not limited by munitions size.	Dive equipment, dive vessel and in-situ treatment materials and equipment.	One diver plus dive support and vessel crew.	No information provided at this time	Mobile system. Requires shipment of in-situ material and equipment. Dive vessel hired on site.	Technology is commercially available for groundwater and land applications. Has not been used in undersea applications.
Efficient Shallow Underwater UXO Retrieval ESTCP Project MM-0606	Remote surface operation with protective shroud.	Depth: Under 20 ft.	Electromagnet, winch/crane, electrical cables, power generator, control system. Surface barge/vessel capable of supporting surface equipment.	One operator plus vessel crew.	Cost determinations are still in progress.	Mobile system. Requires shipment of electromagnet and controls. Winch/ crane, support vessel hired on site.	System is in development. Possible demonstration mid-summer „08. The system is operational at this time, and no further development currently planned after Fall ‟08.
Microbial Mat, PEC	Performed by divers. Munitions not relocated. Results in on-site degradation and mitigation of explosive/environmental hazard.	Depth: Shallow water. Stable versus swells and wave action. Munitions: Not limited by munitions size.	Dive equipment, dive vessel, and microbial mat material.	Multiple divers plus dive support and vessel crew.	No information provided at this time	Mobile system. Requires shipment of microbial mat equipment. Dive vessel hired on site.	Technology not commercially available. Technology demonstrated on groundwater and land applications. Has not been used in undersea applications.

4.0 TECHNOLOGY COMPARISON

Based on information provided from government technical stakeholders, four main criteria were established to determine which technology shows the most promise for this particular application. The major criteria used are the ability to meet safety and environmental requirements, operational capabilities, stage of development, and cost. The following sections detail the comparison of the identified technologies to each of these criteria.

4.1 Ability to Meet Safety and Environmental Requirements

The technology approach/concept must focus on negating potential adverse human health and environmental effects associated with addressing underwater munitions. The safety attributes of the systems were the first criteria to be examined during this project. Placing divers into the water for these systems may be considered one of the more risk-related activities. The PEC Microbial Mat and the PEC In-Situ treatment both required placing divers in the water to implement their processes. However, these technologies have the potential to mitigate safety and environmental risks from underwater munitions without having to move the munitions.

The use of magnets to retrieve munitions from the underwater environment may also have an effect on munition fuzes, however, the potential effect is unknown at this time. Regardless, this does present another potential risk to recovery of the munitions. The ESTCP MURS and the ESTCP Efficient Shallow Underwater UXO Retrieval both use or may use magnets in the retrieval of submerged munitions.

All technologies identified meet the response requirement, at various levels, to safely deal with explosive hazards and because sea-disposed munitions may be in varying conditions of deterioration, to limit the potential impact of any release of munitions constituents to the environment.

4.2 Operational Capabilities

The technology must have the ability to operate at depths ranging from 20 to 300 feet, at a sea state of three or less, and address munitions of at least 150 pounds (155 mm) in size. The depths that the systems can operate vary widely. The MURS, In-Situ Treatment, Efficient Shallow Underwater UXO Retrieval, and Microbial Mat all operate in depths less than 35 feet. The more robust ROUMRS, Munition Recovery System, and ORS systems can operate at 300 feet, 500 feet and greater than 250 feet, respectively. Therefore, these three technologies can likely meet the operational criteria.

4.3 Stage of Development

The system must be at a stage of development to allow for a demonstration within 16 months. The following technologies can likely be developed successfully, and have the potential for deployment within 16 months.

- ROUMRS, Oceaneering/ARA, Inc.
- Munition Recovery System, UXB
- ORS, UOR

4.4 Cost

No specific cost limitation was imposed by the government technical stakeholders; however, the technology costs can and should be compared to determine the most cost effective technology. The cost information collected for each technology to perform a one-month demonstration off the coast of Hawaii is as follows.

- ROUMRS, Oceaneering/ARA, Inc., $1.8-2.3 Million
- Munition Recovery System, UXB, $1.6 Million (long term lease required to cover capital cost of equipment)
- ORS, UOR, $22.0 Million
- MURS, ESTCP, cost determinations are still in progress.
- Efficient Shallow Underwater UXO Retrieval, ESTCP, cost determinations are still in progress.
- In-Situ Treatment, PEC, no information was provided.
- Microbial Mat, PEC, no information provided.

4.5 Summary of Technology Comparison

Table 2 provides a summary of each technology‟s ability to meet the four established criteria. Costs are based on one month of on-site service.

Table 2. Ability of Technologies to Meet Established Criteria

Technology	Safety/ Environmental	Operational Capabilities	Developmental Stage	Cost
ROUMRS (Oceaneering, ARA, Inc.)	✔	✔	✔	Capital: $800K Relocation and Setup: $100K O&M: 900K–1.2M /month
Munition Recovery System (UXB)	✔	✔	✔	Capital: None (long-term lease required) Relocation: $405K Setup: $227K O&M: $961K/month
ORS, UOR	✔	✔	✔	Capital Cost: $20.9M Relocation: Varies Setup: $162K O&M: $1,855M/month
MURS (ESTCP)	✔			Not Available
In-Situ Treatment (PEC)	✔			Not Provided
Efficient Shallow Underwater UXO Retrieval (ESTCP)	✔			Not Available
Microbial Mat (PEC)	✔			Not Provided

5.0 CONCLUSIONS AND RECOMMENDATIONS

Several criteria were used to down-select the technologies until the most promising technology could be determined. The second criterion, which was the ability of the technology to meet the required operational capabilities, eliminated four of the seven technologies, as seen in Table 2. None of these four technologies could be considered to handle munitions at depths considered too great for divers (up to 300 feet). The three remaining technologies after this filter were those offered by Oceaneering/ARA, UXB, and UOR.

Cost is the second distinguishing factor among the remaining three technologies. It was determined that the costs associated with the ORS was far greater than that of the ROUMRS or the UXB Munitions Recovery System. The cost for a one month demonstration of the UXB Munitions Recovery System was similar to the cost of the ROUMRS system; however, the UXB Munitions Recovery System requires a long term lease that would result in additional costs and commitments.

It should be noted that the UXB technology, when compared to the other technologies, has the added capability of disposal of the munitions on site when used in conjunction with the DYNASAFE unit. UXB uses its own capable ROV and lift baskets to bring weapons to the on-board munition destruction system. The munitions would never actually be exposed to surface conditions because they are fed to the DYNASAFE unit through the bottom of the barge. This represents a major advantage in the general safety of the local area. However the addition of the DYNASAFE unit results in a large increase in the capital cost and the customer would be expected to either keep the DYNASAFE unit, or use it for an extended period of time and for multiple UXO projects, with munitions numbering in the tens of thousands. This technology could be the best selection for long-term munition disposal tasks.

After careful consideration of the costs involved, it was determined that the ROUMRS technology is the most feasible alternative for a technology demonstration. Because the scope of this project will involve a single location and will address munition counts in the hundreds to thousands (not tens of thousands), it is not necessary to invest in the capital costs associated with longer-term technologies. It is therefore recommended that the ROUMRS system be selected for further evaluation under this task.

Following this Preliminary Systems Requirements Report, a Systems Requirements Report will be developed to provide a detailed discussion of the capabilities, operational requirements, and subsystem specifications for the chosen technology in relation to a demonstration of the technology. Following the Preliminary Systems Requirements Report, the project team will work with the technology vendor to prepare a Preliminary Design Document Report for the chosen technology. This report will provide a cost analysis for the implementation of the technology including capital, operational, set-up, transport, demobilization, and maintenance costs. The report will also include specifications for all equipment and subsystems, procedures for transport, setup, operation, demobilization and maintenance necessary to perform a demonstration of the technology.