LLNL-TR-747186

LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

Shallow Water Imaging Sonar System for Environmental Surveying Final Report CRADA No. TC-1130-95

L. C. Ng, H. Rosenbaum

March 2, 2018

Disclaimer

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Shallow Water Imaging Sonar System for Environmental Surveying

Final Report
CRADA No. TC-1130-95 LLNL--99001312

Date: May 1, 1998 Revision:

A. Parties

The project is a relationship between the Lawrence Livermore National Laboratory (LLNL) and CENTRA Technology, Inc.

University of California
Lawrence Livermore National Laboratory
7000 East Avenue, L-795
Livermore, CA 94550
Dr. Lawrence C. Ng 925-422-8741

CENTRA Technology, Inc.
19-C Crosby Drive, Suite 350
Bedford, MA 01730
Dr. Harold Rosenbaum, 617-275-4444

B. Project Scope

The scope of this research is to develop a shallow water sonar system designed to detect and map the location of objects such as hazardous wastes or discarded ordnance in coastal waters. The system will use high frequency wide-bandwidth imaging sonar, mounted on a moving platform towed behind a boat, to detect and identify objects on the sea bottom. Resolved images can be obtained even if the targets are buried in an overlayer of silt. Reference 1 (also attached) summarized the statement of work and the scope of collaboration.

The specific technical objective of this research was to develop and test a prototype system that is capable of: (1) scan at high speeds (up to 10m/s), even in shallow water (depth to ten meters), without motion blurring or loss of resolution; (2) produce images of the bottom structure that are detailed enough for unambiguous detection of objects as small as 15cm, even if they are buried up to 30cm deep in silt or sand. The critical technology involved uses an linear FM (LFM) or similar complex waveform, which has a high bandwidth for good range resolution, with a long pulse length for similar Dopper resolution. The lone duration signal deposits more energy on target than a narrorer pulse, which increases the signal-to-noise ratio and signal-to-clutter ratio. This in turn allows the use of cheap, lightweight, low power, piezoelectric transducers at the 30-500 kHz range.

The division of responsibilities and the assignment of tasks are as follows: The Andreyev Acoustics Institute (AAI) is responsible for the design, laboratory testing, construction of the prototype and field experiments; LLNL is responsible for the technical evaluation of the experimental results as well as providing technical direction where needed; the Defense Group Inc., or now the CENTRA Inc., is responsible for the project coordination and ensuring that the capabilities and design of the prototype meet market needs.

A two phase program, with a production decision at the end of phase one, was proposed. Phase one to last about 18 months, involved the design, production, and testing of a prototype system. Phase two, to last about 36 months, would involve initial production of systems in Russia for sale or use to provide survey services to the global market. Phase one was funded jointly by DOE and CENTRA, and phase two would be funded with venture capital. The CRADA covers only phase one.

The phase one project milestones were divided into nine consecutive stages and each stage lasted approximately two months. Interim report at the end of each stage was to be written by AAI and delivered to LLNL and CENTRA. The final report at the end of stage nine summarized the experimental performance of the prototype system.

C. Technical Accomplishments

As shown in References [2] to [10], technical reports summarizing the progress and findings at the end of each stage were delivered to LLNL and CENTRA on time and on schedule except for stage 8 where it was three months late because of the lack of availability of hardware components. Final report for stage 9 provided the final experimental evaluation of the sonar prototype. A short article detailing the interim progress of this work was published in the USIC Connection [11]. Here is a brief summary and conclusions of the final effort.

A sonar prototype (Fig. 1) was constructed, along with the necessary signal conditioning hardware, digital signal processor for received signal target extraction, and a PC based comprehensive 2D graphical display systems (Fig. 2). Fig. 3 shows the graphical displays of the sonar detection during a test trial on the left and numerical displays on the right showing detected object information such as depth, vertical and horizontal angles.

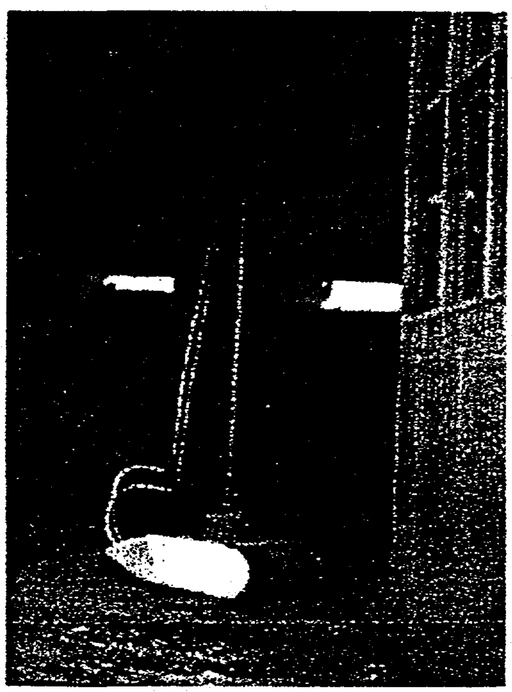

Fig. 1 Sonar Prototype during lab trial

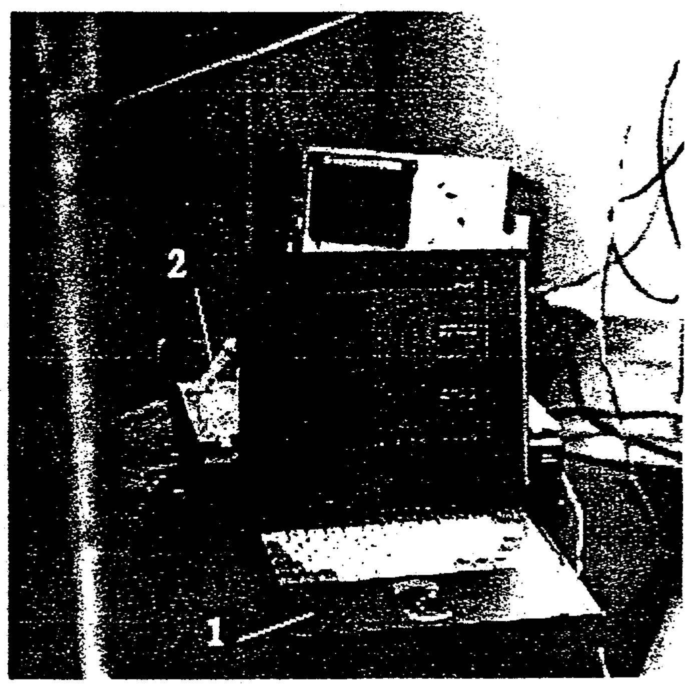

Fig. 2 PC based display

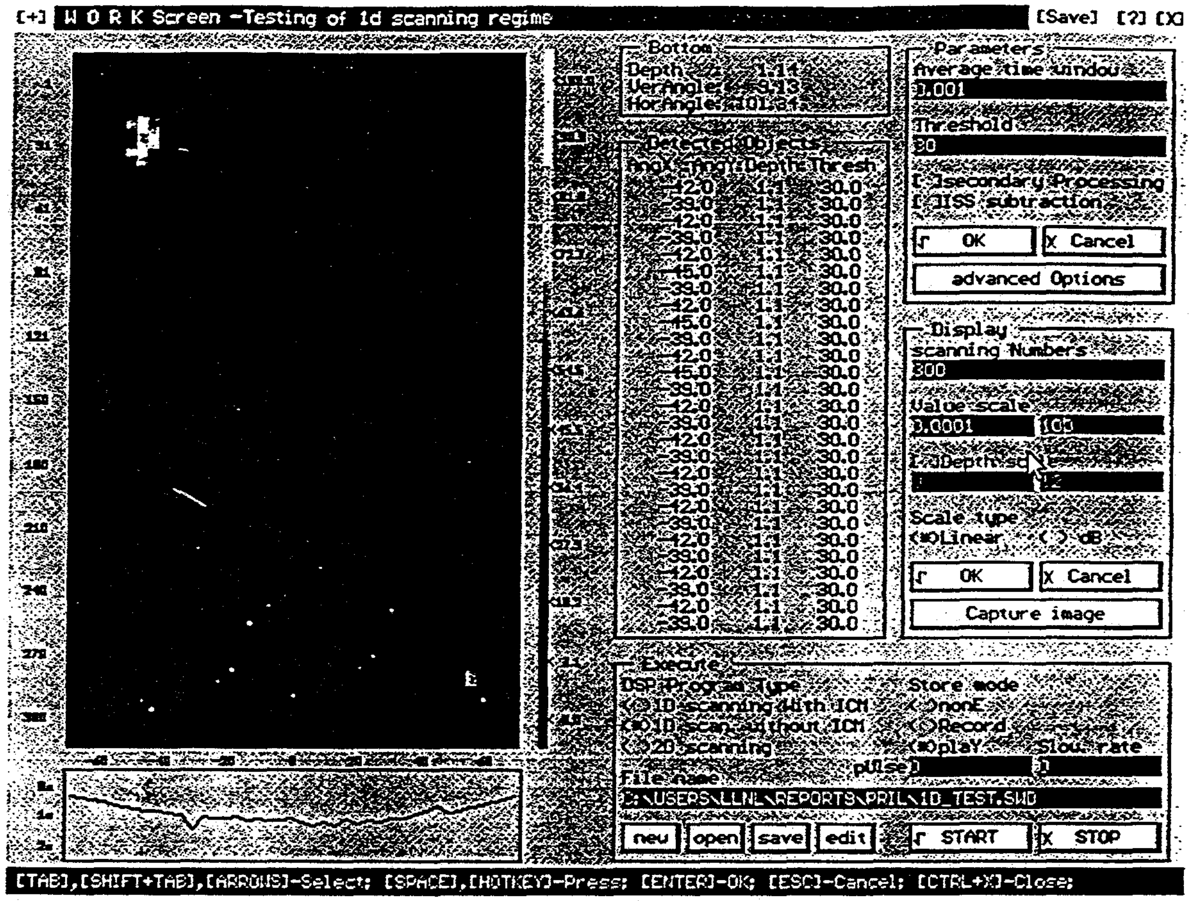

Fig3. PC based sonar graphical and numerical displays

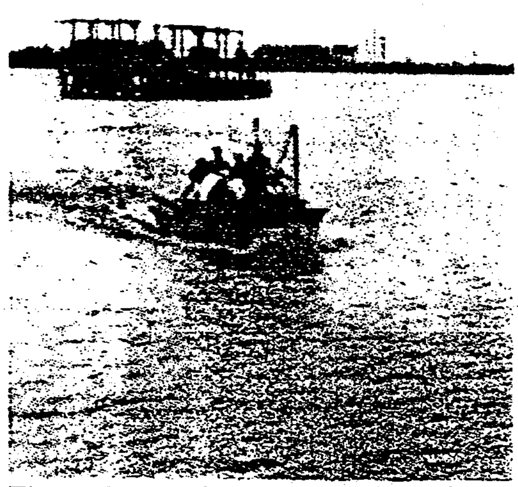

Fig. 4 View of boat during lake trials

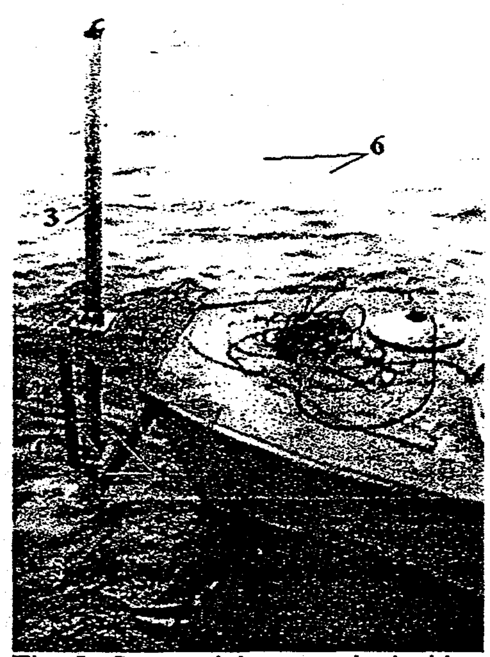

Fig. 5 Sonar trial test on dock side

Experimental testing of the sonar prototype was conducted on October 9 to 15, 1997 on the Ivankovskoe artificial lake on the Volga River. The lake is located at the North of the Moscow region. A small boat (length 7m, with a displacement of 5000kg) was used as sonar carrier (Figs. 4&5). Metallic bjects consisting of: (1) a salient disc, (2) a valve, (3) a sphere, and (4) two foam plastic reflectors (FPR) as shown in Fig. 6. These objects have an equivalent sonar cross section of about 5cm, 10cm, 15cm, 50cm and 1m. The last two came from the plastic reflector with two different sizes (a 15cm cube and a 10cm cube). Objects were placed at a water depth of about 8m. The boat was cruising at about 5m/s or about 4 mile per hour while scanning the lake bed to find the objects.

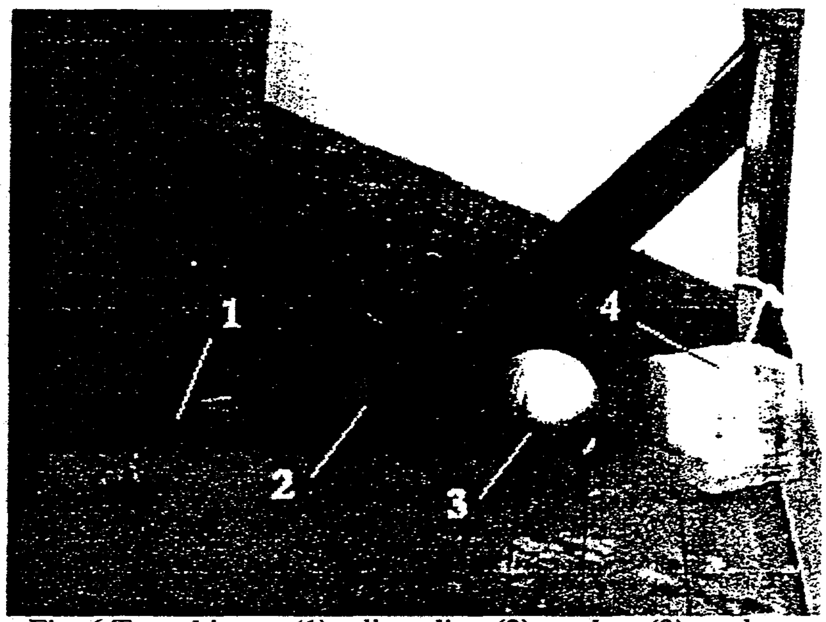

Fig. 6 Test objects : (1) salient disc, (2) a valve, (3) a sphere, and (4) two foam plastic reflectors (FPR)

Object detection was done in relatively deep water (8.5m), as well as in shallow (3m) lake environments. For deep regions the foam plastic reflectors (FPR) having equivalent radii of 1m and 0.5m and the valve were used. Distance between the FPRs was about 50m, the valve was placed in the middle point. Boat speed was about 5m/sec. There were 20 probing singal pulses per second. A view of the working screen of the sonar prototype (Fig. 7) for one of the test is shown in Fig. 7. Note that the two brightest areas on the screen correspond to the two FPRs. The bright area in the middle should be corresponding to the valve location.

Thus experimental data showed that an object with a one meter sonar cross section buried at water depth 8m or less and covered with silt less than 30cm can be detected in good weather conditions as well as in bad weather conditions with strong surface agitation while cruising at a speed of 5m/s.

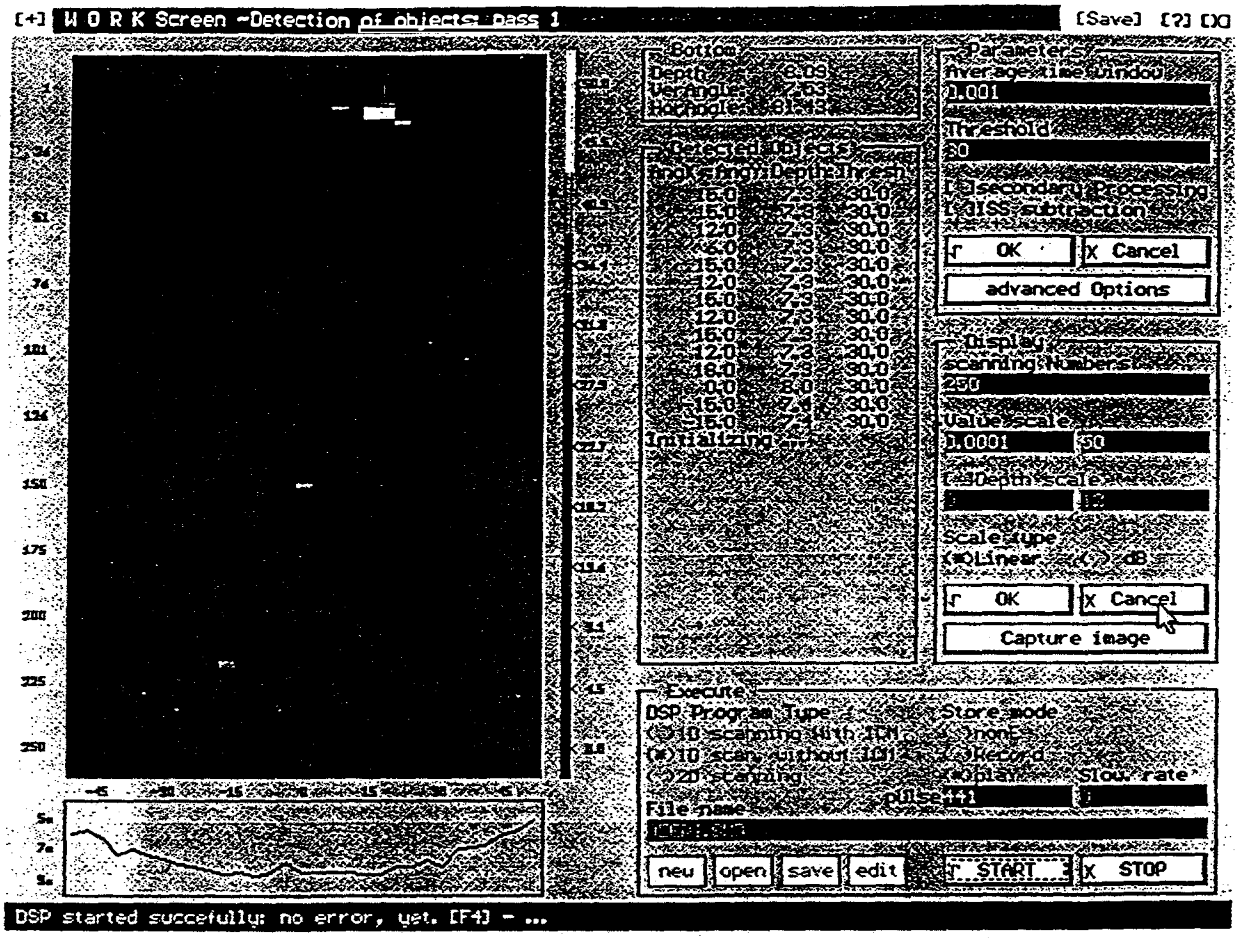

Fig. 7 A working screen during test showing detection of two FPRs (top and bottom) and a valve located at the middle.

In general smaller objects with a sonar cross section of less than 50cm were unable to detect with high probability because of multiple reflections from the rough lake bottom masked the signal location of the true buried objects. For example Fig. 8 shows 4 consecutive images for the 2D scanning. These figures indicate the complex bottom structure of multiple reflected signals. The figures also show that the sonar response is not repeated between consecutive processing periods, therefore the bottom structure was rather complex.

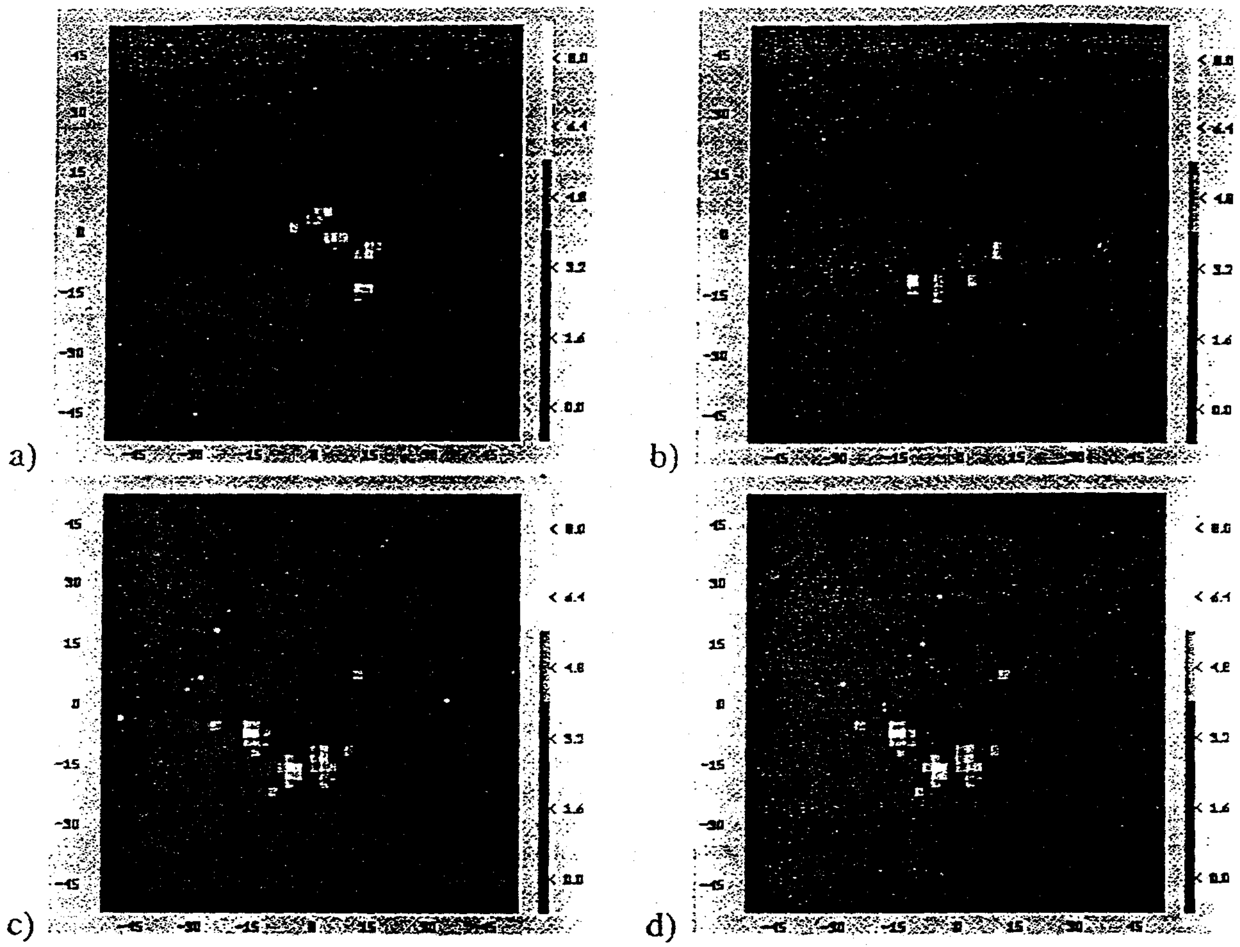

Fig. 8 Typical sonar returns from rough lake bottom during trials

The Andreyev Acoustics Institute had investigated several advanced signal processing alternatives to improve the performance. In particular, the Russian investigators had analyzed the improved performance using known adaptive beamforming techniques. The proposed noise suppression algorithms was studied and verified with the use of the raw data from array hydrophones recorded during the lake trials. Estimates based on the raw data demonstrated that the current sonar prototype hardware, with the implementation of advanced adaptive processing, should allow object detection in rough bottom environments for objects imbedded in 30cm of sediments and having a sonar cross section of 15cm or greater.

D. Expected Economic Impact

The commercial application of this system could be used for environmental surveying and cleanup of coastal areas by locating buried shallow water mine fields, unexploded ordnance, and other hazardous objects.

E. Partner Contribution

CENTRA hosted several meetings with the Russian development team, coordinated delivery and translation of materials from the Russian team to US participants, and conducted preliminary work to identify potential market needs. CENTRA has provided translation and travel coordination support for the Russian development team, and CENTRA personnel have met with Russian investigators in both its Boston and Moscow offices to facilitate the management and implementation of the project.

CENTRA has investigated potential market applications for the shallow water environmental surveying sonar (SWESS) for the detection, location, and classification of mines, other ordnance and explosive waste (OEW), and environmental wastes in shallow waters. There are three general potential market sectors: government agencies (defense, environmental), local authorities (environmental, restoration), and engineering companies. The SWESS system may have potential for use in the detection, location, and classification of mines in very shallow waters, perhaps even including wetlands areas. In each market sector, CENTRA has sought to identify and contact potential sponsors or customers for the SWESS system.

Potential Market Sectors

US government customers for OEW and MCM work include the Huntsville Advanced Technology Division and Waterways Experiment Station of the Army Corps of Engineers, the Coastal Systems Station of the Naval Surface Warfare Center (CSS NSWC), the Department of Defense Strategic Environmental Research and Development Program (SERDP), and the Army Environmental Center. CENTRA has contacted the above organizations to identify possible funding sources. Many of the OEW efforts are oriented towards the cleanup of Formerly Used Defense Sites (FUDS). In addition, various US Army Corps of Engineers District offices contract for support in surveying and cleaning up FUDS and other sites contaminated with OEW.

Over 50 FUDS are expected to need underwater OEW surveys, yet the technical capability to do this does not yet exist. For example, SERDP is funding ongoing efforts to develop the development and testing of underwater OEW survey systems, such as SWESS, for future use to cleanup FUDS. A multiple sensor Mobile Underwater Debris Survey System that has a design similar to SWESS is being developed and tested using SERDP funding. Some of these potential funding sources have ongoing test and demonstration programs where the SWESS could potentially be demonstrated for us to meet US needs.

There are also a number of Federally-funded organizations that could potentially provide funding for the final development and testing of the SWESS. For example, the Center of Excellence for Research in Ocean Sciences (CEROS) has funded the engineering development of shallow water surveillance technologies. The National Coastal Resources Research and Development Institute (NCRI) also funds the commercial application and evaluation of prototype technologies for environmental surveying applications. The Naval Facilities Engineering Service Center has constructed a seafloor target mapping and classification range to evaluate the effectiveness of new technologies for surveying underwater sites to accurately identify and map the locations of OEW on and under the sea floor.

Potential local government customers include port and waterway authorities in charge of cleaning up ports, rivers and lakes, and organizations involved in the conversion and commercial use of FUDS. For example, there are activities being conducted in the Pacific, such as those on and around the Hawaiian Island of Kaho'olawe to restore FUDS for commercial or other civilian use. Over $300 million in funds have been allocated for the detection and remediation of OEW on and around the Island of Kaho'olawe over the next 7-10 years. Part of this undertaking involves locating various types of ordnance buried in sand and soil in shallow coastal areas around the Island.

Potential industrial customers include engineering consultants and contractors, and environmental surveying companies. CENTRA has been in contact with a number of such companies, and has begun exploring possible interest in the SWESS.

Potential Market Strengths

While there are a number of commercial sidescan sonars available for OEW, MCM, and environmental surveying applications, most of these operate at higher frequencies than the SWESS, thus limiting their ability to detect objects buried in the silt and soil under the bottom. SWESS has a potential market advantage in this regard, with its projected ability to detect 15cm objects buried up to 30cm deep in silt. The CSS NSWC is developing a sonar system also designed to be able to detect and classify buried objects such as mines, by operating at 20kHz and high grazing angles to achieve good bottom penetration.

F. Documents/Reference List

1. Request for Quotation No. B319895, " Engineering Development of Shallow Water Imaging SonarSystems for Environmental Surveying," issued to Andreyev Acoustics Institute, Moscow, Russia, September 18, 1995.

2. V.V. Borodin,"Engineering Development for Shallow Water Imaging Sonar System-Stage-1, " Andreyev Acoustics Institute, Moscow, April 1996

3. V.V. Borodin,"Engineering Development for Shallow Water Imaging Sonar System-Stage-2, " Andreyev Acoustics Institute, Moscow, June 1996

4. V.V. Borodin,"Engineering Development for Shallow Water Imaging Sonar System-Stage-3, " Andreyev Acoustics Institute, Moscow, August 1996

5. V.V. Borodin,"Engineering Development for Shallow Water Imaging Sonar System-Stage-4, " Andreyev Acoustics Institute, Moscow, October 1996

6. V.V. Borodin,"Engineering Development for Shallow Water Imaging Sonar System-Stage-5, " Andreyev Acoustics Institute, Moscow, January 1997

7. V.V. Borodin,"Engineering Development for Shallow Water Imaging Sonar System-Stage-6, " Andreyev Acoustics Institute, Moscow, March 1997

8. V.V. Borodin,"Engineering Development for Shallow Water Imaging Sonar System-Stage-7, " Andreyev Acoustics Institute, Moscow, May 1997

9. V.V. Borodin,"Engineering Development for Shallow Water Imaging Sonar System-Stage-8, " Andreyev Acoustics Institute, Moscow, October 1997

10. V.V. Borodin,"Engineering Development for Shallow Water Imaging Sonar System-Stage-9, " Andreyev Acoustics Institute, Moscow, December 1997

11. USIC Connection, Volume 4, No.3, May-June 1997, USIC-LLNL-0112-RS

G. Acknowledgement

Participant's signature of the final report indicates the following:

1) The Participant has reviewed the final report and concurs with the statements made therein.
2) The Participant agrees that any modifications or changes from the initial proposal were discussed and agreed to during the term of the project.
3) The Participant certifies that all reports either completed or in process are listed and all subject inventions and the associated intellectual property protection measures generated by his/her respective company and attributable to the project have been disclosed or are included on a list attached to this report.
4) The Participant certifies that if real property was exchanged during the agreement, all has either been returned to the initial custodian or transferred permanently.
5) The Participant certifies that proprietary information has been returned or destroyed by LLNL.

4/28/98

[Harold Rosenbaum] Date
CENTRA Technology

4/30/98

[Lawrence C. Ng] Date
Lawrence Livermore National Laboratory