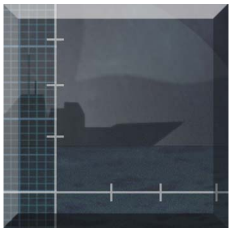

A Science Team for the Littoral Warfare Advanced Development Sea Test Program

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The Littoral Warfare Advanced Development (LWAD) program fulfills the need for at-sea testing of littoral anti-submarine warfare technologies by providing science, planning, and logistic support to enable cost-effective experimentation and demonstration. A dedicated science team from APL's National Security Technology Department was chosen by the Office of Naval Research to provide scientific oversight for LWAD and to be responsible for all supporting science measurements and predictions necessary to ensure successful testing.

INTRODUCTION

During the Cold War we faced a single adversary with a large fleet of nuclear submarines supplemented by an even larger fleet of conventional ships. The goal of this fleet was to interdict our sea lines of communication and threaten the American homeland with strategic missiles. Over time, this open-ocean threat has been replaced by regional adversaries with small, quiet, diesel/electric submarines operating in the littoral. Our anti-submarine warfare (ASW) forces must now adapt by developing effective and affordable capabilities to detect, track, classify, and neutralize submarines and other subsurface weapon systems in challenging shallow water environments.

To ensure the development of new littoral anti-submarine warfare (LASW) technologies, the Office of Naval Research (ONR) established the Future Naval Capabilities (FNC) program. The FNC focuses on fulfilling technology commitments to funded acquisition programs. Currently, ONR funds a variety of LASW FNC programs covering a range of acoustic and nonacoustic technologies deployed from a variety of platforms. Each technology must be successfully tested and demonstrated before it can make the transition to operational status.

Because sea testing entails months of detailed planning, Fleet coordination, research vessel charters, test execution, and careful analyses, the overall cost for individual programs quickly becomes prohibitive. To mitigate such expense, ONR established the Littoral Warfare Advanced Development (LWAD) sea test program. The primary function of LWAD is to plan, coordinate, and conduct cost-effective testing and demonstrations of FNC technologies. To accomplish this objective, it conducts field tests in which multiple complementary technologies can participate. The leveraging of test assets, science measurements, etc., results in significant cost savings across projects. Furthermore, the bringing together of complementary technologies often yields new insight into the applications and limitations of each technology.

The LWAD mission is to provide the infrastructure; Fleet, aircraft, and research vessel coordination; operational planning; reconstruction; and science support required by principal investigators (PIs) to robustly test and demonstrate LASW FNC technologies, thus ensuring transition to acquisition programs. In addition, LWAD provides test opportunities for other science and technology (S&T)/research and development (R&D) LASW-related projects. Ultimately LWAD enables the PIs to concentrate on the science or technology under test or demonstration without the distraction of the myriad details that must be attended to in the conduct of a successful sea test.

This mission is accomplished through the coordinated efforts of the LWAD organization as it

1. Identifies the at-sea testing requirements of LASW FNC technologies
2. Identifies other LASW-related S&T/R&D projects that can leverage at-sea testing of FNC technologies
3. Formulates a comprehensive, coordinated test plan for the identified technologies to meet the objectives of the projects, including plans for coordinated tracks, project and *in situ* environmental data collection, at-sea modeling support and communications, and sea test reconstruction data collection.
4. Ensures that environmental compliance procedures are followed for all sea tests
5. Provides environmental site characterization, data collection, and analysis to support pre-test, real-time, and post-test analyses of the technologies
6. Provides post-test reconstruction to support post-test analyses of the technologies

LWAD ORGANIZATIONAL STRUCTURE

LWAD is managed by the ONR LWAD Program Manager. It consists of science, planning, and logistics teams (Fig. 1). The leaders of these teams are the Chief Scientist, Test Director, Assistant Test Director, and Planning Team Leader. The Program Manager, together with his deputy and the team leaders, form the LWAD

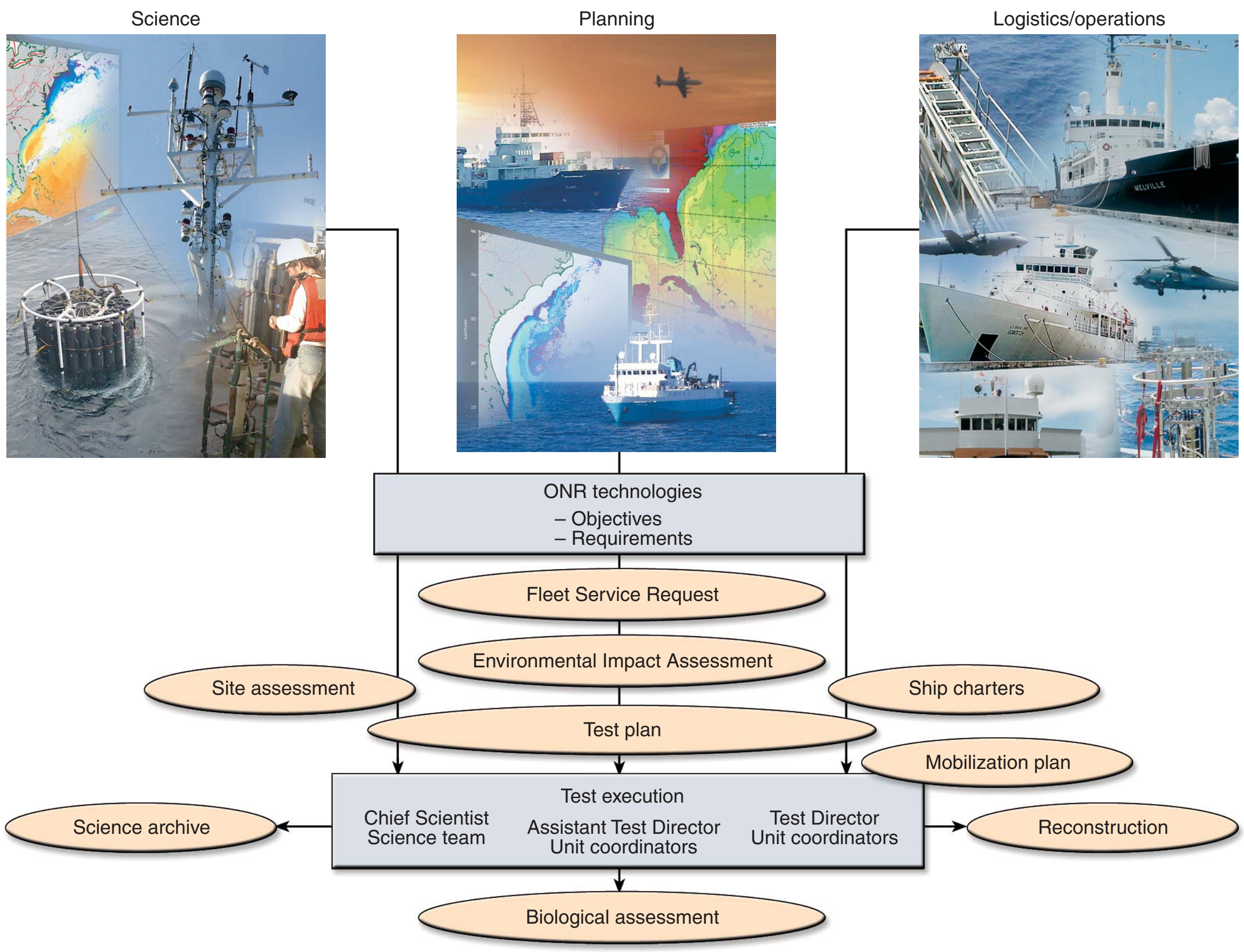

Figure 1. Organizational structure and products of the Littoral Warfare and Advanced Development (LWAD) program.

Executive Committee. The science team also includes a liaison for the Naval Oceanographic Office (NAVOCEANO). The cooperative effort of the Executive Committee, LWAD teams, and organizational liaison enables LWAD to accomplish its mission.

During field tests, the LWAD at-sea organization executes the formulated sea test plan. The LWAD at-sea organization places the Test Director in command, with assistance from the Chief Scientist and Assistant Test Director. The at-sea organization consists of designated members of the LWAD science team, planning team, and logistics team as approved by the LWAD Executive Committee.

LWAD SCIENCE TEAM

In January 2001, ONR selected an LWAD science team from APL's National Security Technology Department (NSTD). The choice of NSTD was largely a result of our extensive experience with at-sea test design, execution, and analysis for the Submarine Security Program. Furthermore, our innovative ideas on the quick turnaround of field test results were very attractive to ONR.

Led by the Chief Scientist, the science team has two primary objectives: to ensure the scientific integrity of LASW FNC testing and to provide all required supporting science data and predictions for each test. Specific duties and responsibilities are as follows:

1. Identify project science inputs and requirements for sea test planning
2. Provide pre-test environmental assessments of the test site's environmental and acoustic characteristics
3. Provide test plan inputs for at-sea environmental and environmental/acoustic measurements
4. Provide at-sea environmental support as needed to satisfy the requirements for collecting project data and conducting tests, e.g., satellite imagery and weather forecasts, atmospheric measurements, oceanographic measurements, environmental acoustic measurements, and propagation modeling
5. Prepare a post-test interactive science archive on CD-ROM
6. Maintain test planning, execution, and analysis material in an electronic archive and prepare a final DVD archive upon completion of each test

Since joining LWAD, the NSTD science team has participated in the following field tests:

- February 2001, LWAD 01-1, Onslow Bay, South Carolina
- July–August 2001, LWAD 01-2/SHAREM-138 (Ship ASW Readiness Effectiveness Measuring), East China Sea
- August 2001, MultiSail, Western Pacific Ocean
- July 2002, TMAST-02, Northeast Atlantic Ocean

The at-sea scenario for the July 2001 LWAD 01-2/SHAREM-138 appears in Fig. 2. This test provided LWAD with a unique opportunity to test, demonstrate, and evaluate emerging ASW technologies against foreign and U.S. targets in a tactically significant overseas shallow water environment. Some of the supported programs included LASH (Littoral Airborne Sensor Hyperspectral), MACE (Multistatic ASW Capability Enhancement), LWSS (Lightweight Sound System), ARPDD (Affordable Radar Periscope Detection and Discrimination), BTEC (Beartrap Environmental Characterization), HEP (Harsh Environment Program), and LSM RECO (Littoral Sea Mine Remote Control).

Although Typhoon Toraji resulted in some loss of at-sea testing, the LWAD technical objectives were adequately met with 110 h of dedicated test time and approximately 120 h of environmental survey and system checkout time. Eleven S&T projects benefited from the collaboration between SHAREM and LWAD, including eight FNC LASW-supported efforts. The resulting data sets will significantly contribute to understanding and improving technology performance and concept of operations development in tactically significant areas. The LWAD team won the ONR group award for outstanding service for the critical roles that team members played in the success of this challenging exercise.

Looking to the future, we are currently planning three additional sea tests, which will take place during FY2003, including at least one more test combined with SHAREM. This aggressive test cycle has required a test team approach within NSTD, with the science team positions of Test Scientist, Acoustic Scientist, Ocean Scientist, and Systems Engineer being appointed for each test. Under this scenario the Chief Scientist need not attend every test and thus has more freedom to oversee the entire program.

SEA TEST LIFE CYCLE

The goal of LWAD is to conduct approximately three sea tests per year, with one of these held overseas. The entire life cycle of a typical LWAD sea test lasts from about 12 months before the test to 3 months after it. The involvement of the LWAD science team through the entire life cycle of each test is captured in Fig. 3. The specific contributions of the science team to the various stages of sea test planning, execution, and analysis are described next.

Planning the Test

Long-range planning begins up to a year before a test. During this initial phase, the science and planning teams solicit input from FNC program managers and PIs to identify the test and demonstration requirements for each technology. Since long-term planning is critical to the success of the LWAD process, an LWAD planning form

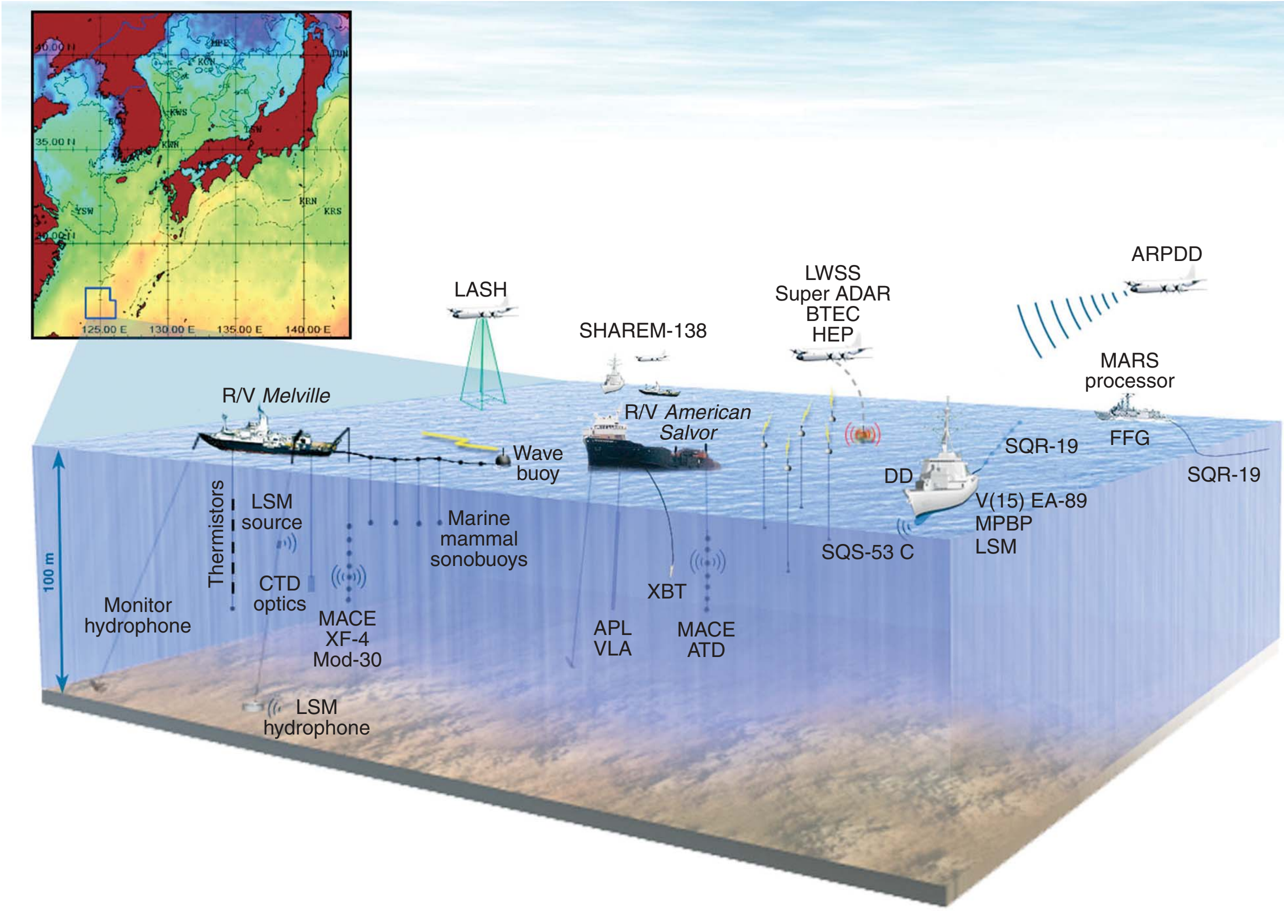

Figure 2. Sea test scenario for LWAD 01-2, conducted July–August 2001 in the East China Sea.

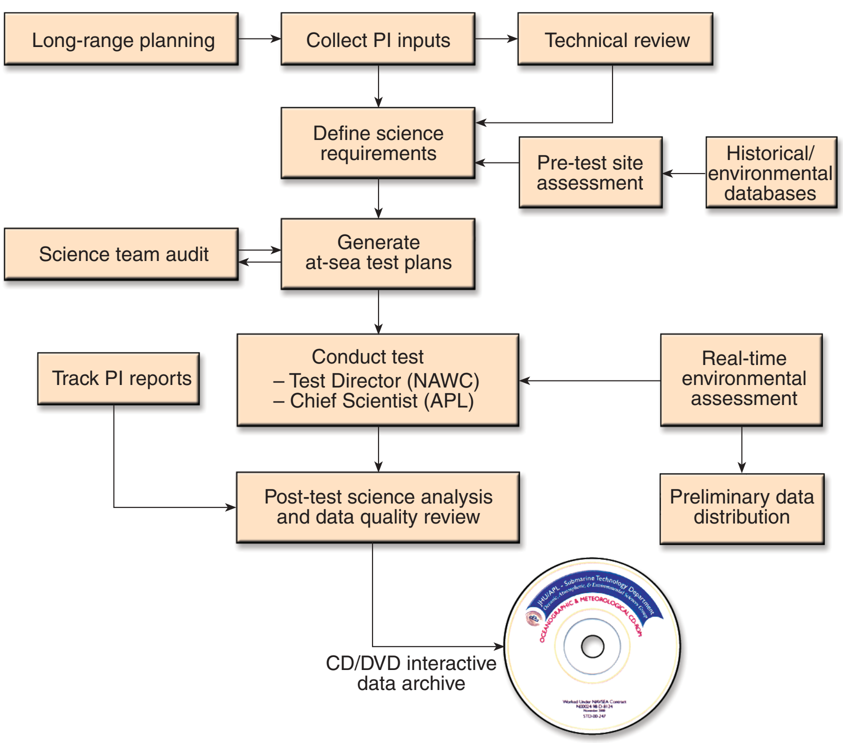

Figure 3. LWAD science support process during the test life cycle.

was generated for distribution to the project leaders. Required inputs included a description of project objectives, identification of participating sponsors, points of contact, planned schedule, benefit to the Fleet, measures of success, sea test objectives, test limitations, preferred season and location for testing, at-sea data collection requirements, and logistic support requirements.

The project planning inputs are reviewed by the Executive Committee, and preliminary sea test plans are recommended that bring together multiple technologies having common requirements (such as season, location, and Fleet assets) that can be tested simultaneously with minimal interference. Throughout the months that follow, the Chief Scientist conducts a series of planning meetings. These meetings gather all the details that allow a comprehensive test plan to be developed. The interactions between the various project investigators and the LWAD team during these meetings are of paramount importance to the planning process.

Also crucial to the development of these plans is the science team's preparation of a detailed pre-test site assessment on CD-ROM. This product is typically distributed 3 to 4 months before the test to all test participants, LWAD team members, and ONR management. The site assessment CD-ROM contains data and displays collected from various sources, including historical surveys, environmental databases, and model predictions. The collected data range from atmospheric (wind speed, air temperature, cloud cover, etc.), to oceanographic (wave height, currents, sound speed profiles, etc.), to geologic (the ocean floor's topography, physiography, subbottom sediment structure, etc.), to acoustic (measured or predicted ambient noise, propagation loss, reverberation, etc.), to other critical information (shipping densities, known wrecks, obstructions, hazards, etc.). Here the LWAD science team draws on the experience of the Environmental Support System project within NSTD, which seeks to maintain a current, comprehensive archive of historical and model databases for field test planning, analysis of results, and validation of system performance models.

The science team then uses the site assessment information and the various project inputs to develop an at-sea oceanographic measurement and modeling plan that satisfies project requirements for supporting science data and information. This plan is folded into the comprehensive test plan prepared by the planning team and based on inputs from all test participants. The Chief Scientist, along with the rest of the Executive Committee, has the obligation to review and ultimately approve these plans for execution.

The planning team is in charge of generating a Fleet Service Request for any Navy ships and aircraft whose participation in the test will be required. In addition to the test execution plan, the planning team conducts a careful Environmental Impact Assessment of the test site (Fig. 1). This information is essential to ensure that the acoustic energy released into the ocean by the various test systems will not significantly impact or harm marine life. The test cannot go forward until all the proper documentation is approved by ONR and Code N45 of the Chief of Naval Operations.

Conducting the Test

The Chief Scientist (or Test Scientist) assists the Test Director and Assistant Test Director in the safe and effective execution of the test. The primary responsibilities of the Chief Scientist are (1) to ensure that each project fulfills its technical objectives, and (2) to oversee the work of the science team as it collects, analyzes, and distributes all required supporting environmental measurements and model predictions. Typical measurements and data products include

- Sound speed, temperature, and salinity profiles in the test area
- Wind velocity and associated meteorological parameters
- Wave height and direction
- Ocean current structure
- Optical clarity
- Acoustic transmission loss
- Volume and bottom reverberation and scattering strength
- Meteorological and oceanographic forecasts
- Satellite imagery

A primary science goal is to make accurate synoptic environmental measurements and model predictions available during the course of each test to support real-time decisions. For example, Fig. 4 summarizes the

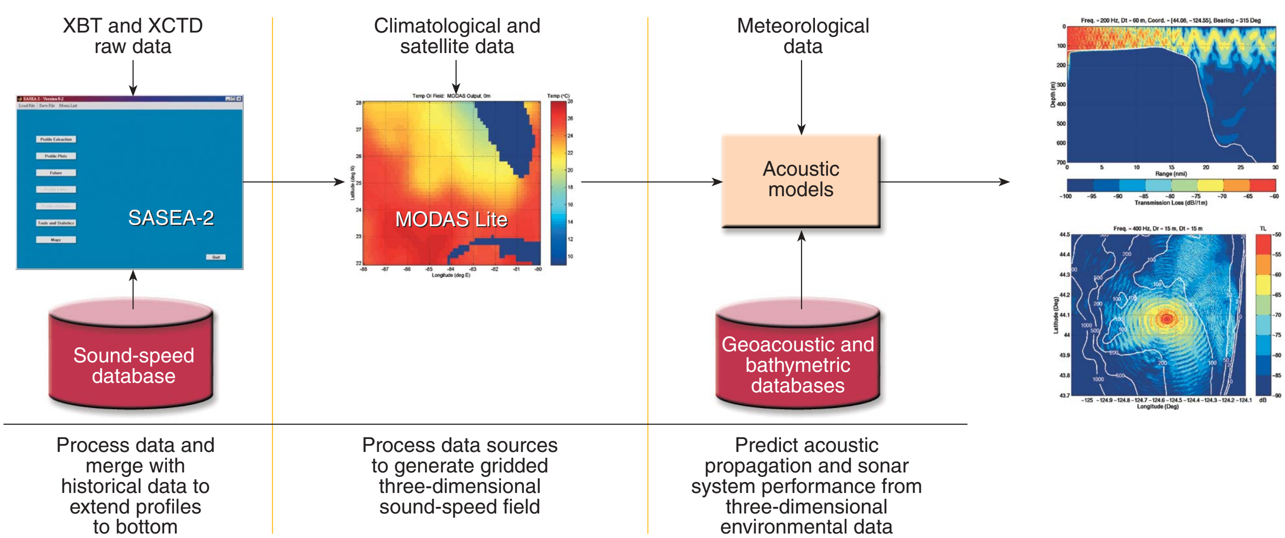

Figure 4. The process of real-time underwater acoustic prediction at sea.

process by which the science team measures the spatial and temporal variability of the speed of sound in the water column and uses the processed three-dimensional sound-speed field to predict the effect on underwater sound transmission. The ocean thermohaline structure is routinely measured by expendable bathythermograph (XBT) probes and conductivity-temperature-depth (CTD) sensors. The NSTD System for At-Sea Environmental Analysis (SASEA 2) is used to process these data by converting the measured temperature and salinity data to sound-speed as a function of depth. If the water column is too deep and the measured profiles do not extend to the ocean floor, SASEA 2 can merge the observations with historical data or climatologic databases to generate complete profiles. Large volumes of such profiles, spanning space and time, are typically collected during each test. The profiles are also merged with climatology and satellite data by the Modular Ocean Data Assimilation System (MODAS Lite) in order to generate and regularly update a three-dimensional gridded sound-speed field. This field is used as input to a variety of models to monitor the acoustic propagation conditions. These results help determine the optimal depth and locations for the acoustic sonar systems to maximize the probability of submarine detection.

The results of these measurements and predictions are archived at APL on an FTP site maintained by "shore support" members of the science team. As depicted in Fig. 5, this archive serves as a mechanism to make weather forecasts, oceanographic measurements, preliminary results, and acoustic predictions available to all test participants. Satellite communication networks are used to facilitate data transfers between APL and the sea-based participants.

Upon completion of each test a "hot wash-up" meeting is typically conducted in port. At this meeting the LWAD team and test participants review the test events and identify any outstanding data transfer issues. The science team provides preliminary environmental measurements and acoustic predictions to all test participants.

Post-Test Analysis

The science team is especially busy during a 2–3 month post-test analysis phase. All science data collected in support of the test must be fully processed and carefully edited so that a complete and accurate record of the test area conditions can be permanently archived. An HTML-based interactive CD-ROM format is used to distribute these data, along with finalized model predictions, data displays, digital photographs, and the

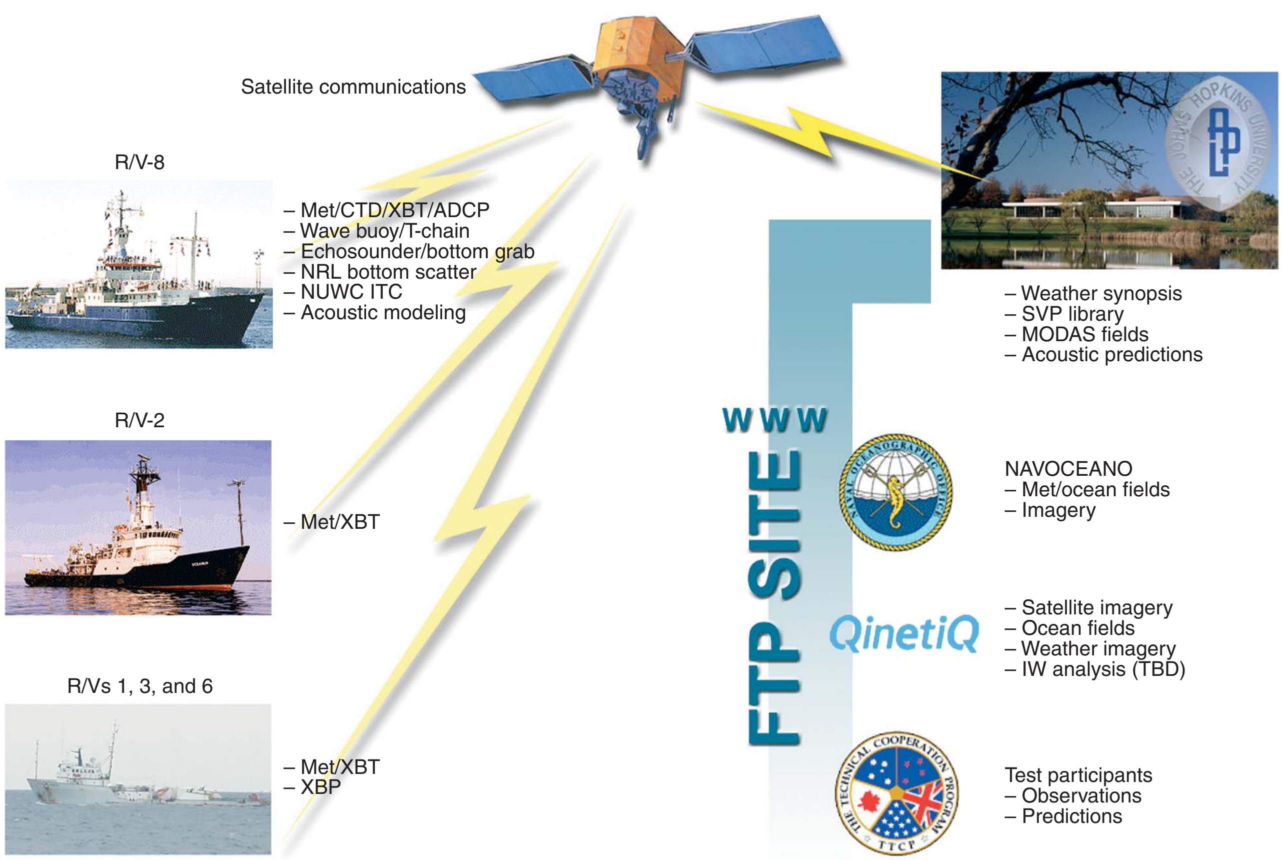

Figure 5. Science support for TMAST-02 (The Technical Cooperation Program [TTCP] Multiscale Active Sonar Technology project).

necessary supporting information for complete interpretation of the test results.

The LWAD team hosts a quick-look meeting during this analysis phase. Principal investigators have a chance to present preliminary results and provide feedback to the LWAD team. Upon conclusion of the quick-look, the LWAD science team compiles a complete archive on DVD of the reports, science and navigation reconstruction data, briefings, and test planning documents generated during the sea test life cycle. This serves as a final test archive and is distributed to all test participants.

CONCLUSION

The NSTD science team for LWAD plays a crucial role in the preparation of ONR LASW technologies for their transition to operational status. This activity directly supports the Navy's thrust to develop a more effective ASW capability against small diesel/electric submarines in littoral scenarios. Furthermore, our participation in LWAD brings NSTD in direct contact with a wide variety of the acoustic and nonacoustic technologies under development for the Fleet. This naturally leads to new business opportunities where we can further apply our technical strengths in ASW to challenging problems of national significance.

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