GEO-CENTERS

Synthesis and Characterization of Advanced Materials

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GEO-CENTERS, INC. programs in support of the Naval Research Laboratory Materials Chemistry Branch have addressed the development, characterization, and improvement of a variety of materials of interest to the Navy. A major program was directed to investigations of composite sonar dome structures and materials, dome failures and nondestructive evaluation. Also in support of sonar dome programs, computer database modernization and web site development tasks were accomplished. GEO-CENTERS also conducted research in the area of polymer synthesis and characterization and provided research and documentation support to the Office of naval Research ocean, atmosphere, and space programs.

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1.0 INTRODUCTION

This report is a summary of GEO-CENTERS' research efforts for the Naval Research Laboratory (NRL) under Contract Number N00014-94-C-2195, entitled "Synthesis and Characterization of Advanced Materials." The period of performance was from August 15, 1994, through December 8, 2000. The work was carried out at NRL using NRL Chemistry and Material Science Division facilities and at other locations in collaboration with government and other contractor scientists. The various research projects under this contract are divisible into four main groups:

- Reliability improvement of sonar dome rubber windows (SDRWs) and sonar rubber domes (SRDs)
- Computer support
- Polymer synthesis and characterization
- Ocean, atmosphere, and space (OAS) support

The sonar dome work involved fleet support functions as well as research. We provided interpretation and analysis of radiographic inspection data in support of a routine inspection program. We also maintained a database of inspection results and conducted reliability analyses from the data statistics. Research projects were focused on testing new fiberglass/elastomer composite materials and structures, developing a new nondestructive evaluation (NDE) capability based on x-ray backscatter tomography (XBT), and investigation of other new NDE methods applicable to the new materials.

Computer support included network, workstation, and server administration, database and web site development, the operation of a computer trouble desk in support of the NRL Chemistry Division, and special projects such as Y2K and network security surveys.

In the area of polymer synthesis, we continued ongoing research on fluoropolymers and modified nylons and initiated new work on polysiloxanes.

In addition to polymer characterization work in support of the synthesis efforts, we supported the Navy program to develop an elastomeric torpedo ejection system and participated in developing a novel elastomeric ozone detector.

Our effort in support of ONR's OAS programs comprised researching, compiling, and publishing several major reports and other documentation.

In addition to the monthly progress report deliverables required by the contract, the COR has requested and GEO-CENTERS has submitted three special "annual" progress reports covering periods of from one to two years. Our previous reports are listed under Section 7.0. As requested by the COR, this report will not repeat material already provided in the Annual Reports. Where tasks have been previously reported in their entirety, we will provide a brief summary and reference to these reports. Where previously reported work has been continued we will provide a summary and an update here. New work will also be reported in detail. Where the work has been published in the scientific literature, summaries are provided with appropriate references. Unpublished work is presented in more detail. Section 9.0 contains a list of publications of research accomplished under this contract. A glossary of acronyms appearing in this report is included as Appendix D.

2.0 SONAR DOME RELIABILITY

2.1 Background

Sonar dome rubber windows (SDRW) and sonar rubber domes (SRD) installed on Navy surface combatants provide a window for the transmission of sonar signals. They form a hydrodynamic fairing surrounding the sonar transducer arrays to eliminate turbulence and resulting system self-noise and hydrodynamic drag. They also protect the sonar system from the action of the sea and collision with debris. These sonar domes are fabricated of a composite steel cord reinforced rubber material, similar to that used in tires. The SDRW is a large bow-mounted structure currently in service on four classes of cruisers and destroyers. SRDs, also known as keel domes, are associated with the AN/SQS-sonar systems installed on *Oliver Hazard Perry* class frigates. In the following discussion, we will refer to all of these structures as "sonar domes." The acronyms SDRW or SRD will be used when specifically applicable.

Sonar domes have a history of rupturing during service. NRL has determined that the SDRW failures are due to corrosion fatigue failure of the steel reinforcement cords in a spliced area of the composite structure. SRD failure is less well understood, although we have identified corrosion fatigue and other mechanisms in SRD failure analyses. X-ray radiography is used to detect incipient corrosion fatigue damage. An inspection program has been developed, with the goal of maintaining an up-to-date evaluation of the entire antisubmarine warfare fleet's sonar domes. Since replacement domes are subject to the same problems as the originals, the need to inspect, monitor, and repair or replace them remains. Radiographic inspection is routinely used as a basis for determining these options. In addition, the accumulated radiographic data has contributed to the failure analysis effort by revealing patterns of damage distribution and correlation with other data. The inspection and analysis methods developed in response to the SDRW failure problem have since become applicable to similar problems with the smaller keel domes.

GEO-CENTERS has continually supported the sonar dome corrective action programs (CAP) since the early 1980's. During the period of performance reported here, our support has been in the areas of radiographic inspection, database management, reliability analysis, materials development, and improved methods of nondestructive evaluation.

2.2 Radiographic Inspection

GEO-CENTERS' role in the radiographic inspection program involves the interpretation of radiographs provided by the Navy's inspection contractors, the development and maintenance of standards for the radiographic data, and the development of criteria for actions taken.

When sonar dome radiographs arrive for processing, they are given the highest priority and read immediately. Any damage or other pertinent features are located, measured, and diagrammed, either as a hand sketch or as an image generated by the database. The appropriate recommendation is determined according to our standardized criteria. The results are then communicated verbally to the NRL task manager, and/or others designated by NRL (typically NAVSEA PMS 411E2). Then the data are entered into a database and a report is generated and posted on both our developmental web site and the PEO USW web site.

The reports detail our findings, including illustrations of inspection coverage and damage locations, and our recommendation, according to the currently established criteria. The following information appears on the report:

- Report heading
  - Sequential x-ray file number
  - Ship name and hull number
  - Dome's Navy serial number and manufacturer's layup number

- Inspection data
  - X-ray date
  - Facility name and location
  - X-ray contractor
  - Availability type (pierside/drydock)
  - Result (damage/no damage)

- Damage summary (location and extent of each damage site)

- Recommendation (Routine, Monitor, Repair, Replace, or Reinspect)

- Next inspection due date (if applicable)

- Ship historical background
  - Dome installation sequence
  - Current dome installation date
  - Dome age in months
  - Dome type and other design variants

- List of previous inspections (number, date, availability, location, and recommendation)

When damage is detected, our report will also contain a damage location diagram in an appropriate standardized format. Figure 1 illustrates the format used to report SRD damage.

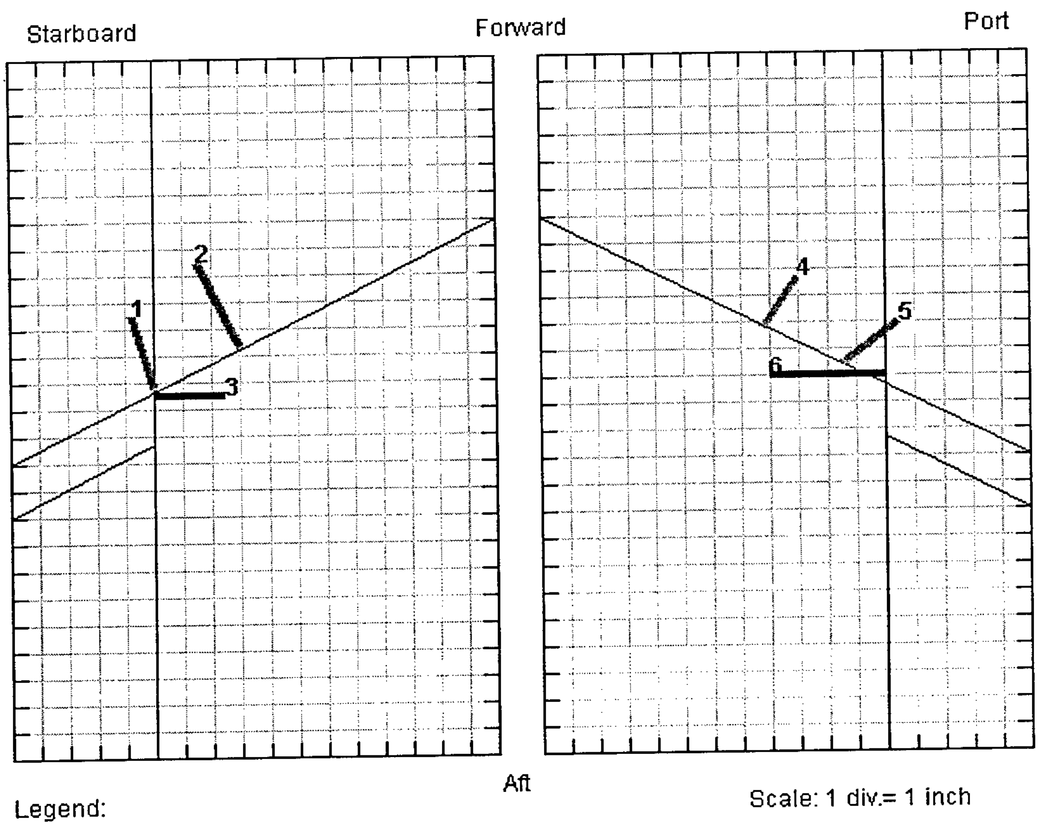


Figure 1. Typical damage diagram from an x-ray inspection report for the USS VANDEGRIFT (FFG 48) SRD. Solid vertical lines represent keel band edges and diagonal lines represent bead band edges. Six damage sites, or "runs" of broken cords, are shown.

During the period of performance, GEO-CENTERS evaluated radiographic inspections of 143 SDRWs and 31 SRDs. Accumulations of the reports were provided to the COTR for inclusion as appendixes to NRL letter reports distributed to NAVSEA as an official communication of these results. To reduce the volume of paper in this final report, we will not include the inspection reports here. SDRW and SRD inspections are listed and summarized in Appendix A.

2.3 Six-Ply SDRW Reliability Analysis

In our Annual Reports, we have provided statistical analyses of the improvement in reliability associated with the design change from five- to six-ply construction. We found that six-ply SDRWs were demonstrably less likely to rupture during service and recommended liberalization of the routine inspection schedule first to 48-month intervals and then, with increasing statistical confidence, to 72 months. In practice, this means that inspection when in drydock will be sufficient. As of March 1998, the distribution of operating times for six-ply SDRWs represented 474 years of cumulative operation without a rupture. In comparison, 31 of the five-ply SDRWs had ruptured after the same amount of cumulative service. Since our last report, a single 6-ply SDRW has failed at sea, while in an overdue inspection status. Five-ply SDRWs, being more likely to fail, continue to be inspected at one to two-year intervals, depending on their condition.

2.4 Data Requirement Document for SDRW Inspection

SDRW radiography prevents dome failures at sea by detecting incipient corrosion-fatigue damage in time to repair or replace an SDRW. The x-ray data is also useful for research on SDRW failure, non-destructive testing, and structural design, and for logistic planning. The program has been successful in managing the population of defective SDRWs. We recently surpassed our 900th SDRW evaluation.

Rather than specify a procedure for SDRW radiography, we have developed a "technical data requirement" that is a specification for the quantity and quality of the images produced by the inspection. The area covered is specified, as are the format, labeling, and image quality. With this approach, contractors are free to develop improved procedures and to reduce costs while keeping within the limitations of the data requirement.

We periodically revise the data requirement in response to changing inspection methods, repair configurations, SDRW engineering changes, and damage statistics. In the previous revision, we acknowledged the diminishing need for research data and reduced the cost of pierside inspections by establishing minimum coverage requirements for different situations. In addition to the changes in the data specification, we have also increased the required inspection intervals in response to both actual and expected improvement in SDRW reliability.

Recently, we have observed a decline in compliance with our data specification and the quality of the inspections. In one case, a non-approved contractor conducted an inspection. In other cases, lines of communication with NRL have been disturbed by changes in contractor organizations and points of contact or by introduction of additional layers of management or subcontracting. We also attribute some of the inconsistency to confusion caused by informal verbal communication of changes to our requirements.

The seventh and most recent revision seeks to address the problems by codifying the verbal changes made since the last revision, tightening specifications in problem areas, rewriting the document to be clearer, and updating the figures. After evaluating the accumulated inspection data, we have also adjusted the inspection area for six-ply SDRWs. Specific changes in the revision include the following:

- The drydock inspection coverage requirement for 6-ply SDRWs has been changed to eliminate centerline coverage below 24 inches from the upper marriage line and move the exposure positions outward, now centered on lines 11 inches from the centerline. This will improve coverage of the splice edges without requiring additional exposures.

- As a result of the number of different coverage requirements for 6-ply, 5-ply, damaged, patched, or undamaged SDRWs and pierside or drydock inspection methods, contractors will continue to be required to obtain the appropriate coverage for each inspection from NRL on a case-by-case basis. For convenience, we will now post up-to-date coverage requirements on a NAVSEA web site accessible by contractors.

- Coverage requirements for inspections of repaired SDRWs have been deleted. Bow splice repairs have been discontinued due to their poor reliability record.

- The recommended film type has been changed to Kodak Industrex type M (or equivalent) from DuPont NDT-45 due to the discontinued availability of the latter.

- An inspection information sheet is now required that includes general inspection information, technical x-ray parameters, and a point of contact for any questions regarding the inspection.

- Inspection contractor qualification requirements are now included and a new requirement for approved contractors to submit their written procedure to NRL is also established.

Revision 7 (included as Appendix B) was published as an NRL letter report and becomes effective upon approval and distribution by the NAVSEA Surface Ship Mine and Undersea Warfare Combat Systems Program Office (PMS 411).

2.5 X-Ray Backscatter Tomography

Our Annual Reports have described our major program to develop a pierside inspection method based upon x-ray backscatter tomography (XBT). This program culminated in pierside trials resulting in a partial or complete inspections of SRDs on four *Oliver Hazard Perry* (FFG-7) class frigates and our recommendation that the system be utilized by the fleet to provide a much needed pierside inspection capability (Figure 2). In this report, we will not repeat background material on theory, the XBT system's development, or its operation already presented in the Annual Reports. To summarize the current state of the program, the following have been accomplished:

- Study of various one-sided inspection technologies applicable to SRDs

- Selection of XBT as most promising technology

- Feasibility study using existing laboratory XBT systems and commercial system

- Selection and procurement of Philips Comscan x-ray scanner
- Removal and transport of damaged SRDs to NRL CBD
- Fabrication of transportable electronics van/control room
- Determination of effective XBT inspection parameters and procedures
- Engineering design and fabrication of remotely operated underwater system
- Series of pierside inspection trials and minor design changes in response to problems encountered
- Development of support requirement document and letters to fleet explaining new capability
- Evaluation of XBT for SDRW application

The successful development of a pierside SRD inspection system described above has not resulted in the expected benefit because the fleet has not made use of the new capability. We attribute this to a combination of factors:

- SRD failure problem less visible or perceived as less important
  - Reduced size of FFG-7 fleet
  - Plans for further FFG-7 decommissioning
- SRD failures infrequent (many defective domes replaced and improved reliability due to corrective action program (CAP))
- Pierside inspection requirements are costly
  - Inspection team requires specialized expertise
  - Dive team support
  - Transportation of large electronic, mechanical, and hydraulic systems
  - Additional support required from the ship and port facility
- Pierside inspection would add the cost of an expensive new requirement to maintenance budgets that are already seen as inadequate

We have proposed a detailed approach to making XBT a viable alternative for use in the fleet by addressing each of the problem areas described above under the follow-on contract. Alternatively, other applications should be sought to make use of the unique and valuable XBT facility.

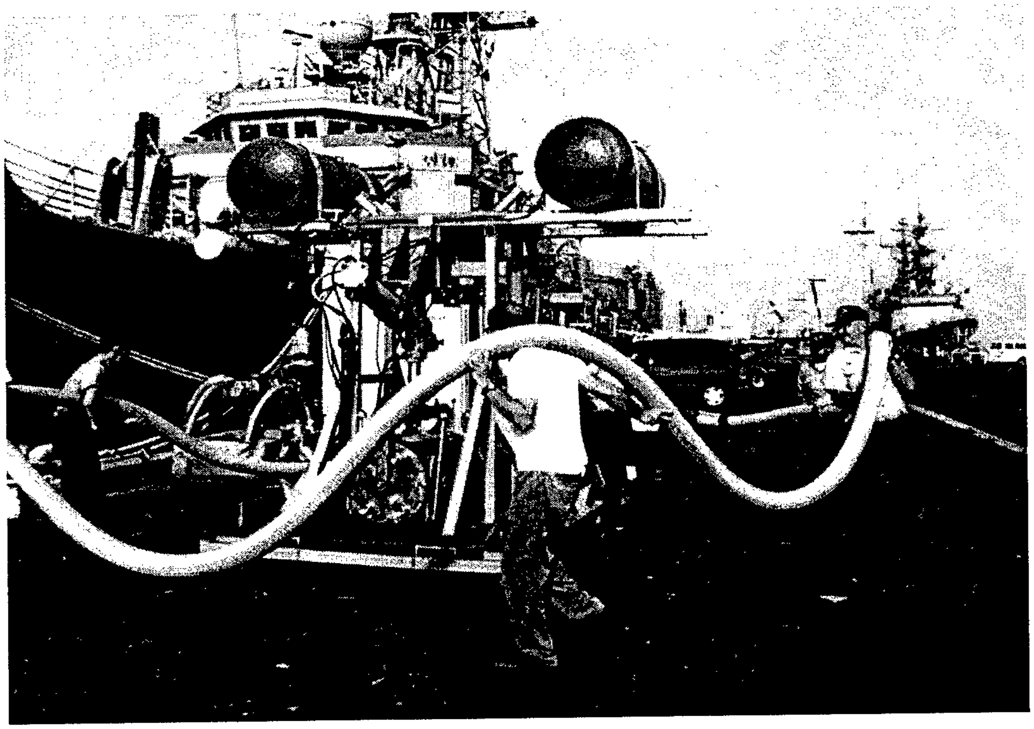


Figure 2. GEO-CENTERS' XBT team leader with members of the ship's force, in preparation for a trial pierside inspection of the USS ROBERTS sonar dome.

2.6 Advanced Composite Materials

A program was begun in 1993 to replace the current wire reinforced rubber Sonar Dome Rubber Windows (SDRW) and Sonar Rubber Domes (SRD) with a composite sandwich structure. The prime motivation for the change in material systems was the future unavailability of the wire reinforcement that is critical in the wire/rubber domes. A secondary motivation is to develop sonar domes that will be less expensive to manufacture, perform better as acoustic windows to sonar energy and are less costly to maintain. The failure history of the rubber domes and the Navy's reliance on a single source for their procurement were also factors supporting a change.

2.6.1 Composite Keel Dome

GEO-CENTERS' work in support of the highly successful Navy composite dome (NCD) project, known by BF Goodrich (BFG), its manufacturer, as the RHO-COR® Keel Dome (RCKD), has been reported in its entirety under the previously submitted Annual Reports. Topics addressed in those reports include:

- Hydro-peel testing of high temperature cure RHO-COR®
- RHO-COR® test plan
- RCKD installation
- Ultrasonic inspection of the RCKD
- Modified pressurization system for the RCKD
- Removal of equipment from the USS KAUFFMAN
- TBTO investigation

Continued work on our proposed modified NCD pressurization system is reported under Section 2.8.

2.6.2 Navy Sonar Dome Composite Window

GEO-CENTERS has collaborated with BF Goodrich (BFG), NRL, NAVSEA, and other Navy entities on a major program to develop a replacement for the current steel-reinforced rubber SDRWs. The Sonar Dome RHO-COR® Window (SDRCW) is a prototype sonar bow window that could replace the existing SDRW. This prototype will be constructed using a glass-reinforced plastic (GRP) and elastomer layered "sandwich" composite. BFG refers to this dome as the SDRCW and the Navy refers to it as the "Navy Sonar Dome Composite Window" (NSDCW). The terminology is used interchangeably, but in this report NSDCW will be used when referring to NRL functions.

In our previously submitted Annual Reports we have described our work in the following NSDCW program areas:

- Program and materials evaluation support
- Non-destructive inspection of NSDCW
- Compression-after-impact testing
- Hydro-peel testing of NAC RHO-COR® samples
- Coatings evaluation

Since our last Annual Report, we have continued to provide program support in the following areas:

- Reviewed technical documentation and test results
- Attended program review meetings at NAVSEA, NRL, and BFG locations
- Traveled to BFG production facility to monitor progress on materials and manufacturing issues
- Performed of laboratory tests on proposed materials

Continued work on the NSDCW program since March 1999 will be described below in terms of three subtask areas:

- NSDCW Fabrication
- Large-scale Impact Test (LSIT)
- Compression After Impact (CAI) Testing

2.6.2.1 NSDCW Fabrication

The following accomplishments are in support of the effort to fabricate a prototype NSDCW.

- Received and reviewed many technical documents provided by Naval Sea Systems Command (NAVSEA) PMS 411 and BFG including:
  - Several SSBN documents
  - Monthly Cost, Technical and Progress Schedule Reports
  - Program Technical Risk Assessment Summaries
  - Original and revised manufacturing and test plans
  - A proposal to replace the materials currently being evaluated for the composite sonar dome with a high temperature (epoxy) material system.
- Discussed the implications of a new BFG surface adhesion modifier with the Program Manager and BFG. Submitted a report to the Program Manager and NAVSEA PMS 411 with our concerns.
- Prepared and maintained a calendar for scheduling of visits to BFG to observe the progress of the NSDCW fabrication.
- Prepared and maintained a spreadsheet documenting the samples received from BFG for testing.

- Arranged to have several .060-inch thick knitline slices cut at a waterjet cutting facility. The knitline is the interface between two separate pours of polyurethane. The slices were delivered to NRL personnel. Dogbone tensile samples were cut from the strips using the ASTM D 638 Type IV die and tested at NRL. We evaluated the results of the tensile tests and examined the fracture surfaces of the failed samples. We documented concerns and questions regarding the integrity of the knitline.

- Evaluated issues regarding the fabrication technique of the NSDCW bead area establishing that fill/core knitline samples must be tested to evaluate the integrity of the bond in this area. We contacted BFG to have samples prepared for testing. These samples were not prepared due to a proposed replacement of the C-55 core elastomer with C-54 urethane. BFG performed testing of the C-54 urethane to qualify the material as a replacement for the C-55 urethane in the composite sandwich core.

- Reviewed reports of test results on the C-54 core elastomer and C-55 fill elastomer submitted by NRL and BFG.

- Reviewed finite element analysis (FEA) from BFG that compares the C-55 core elastomer and C-54 fill elastomer when used for the RHO-COR® sandwich core. We later reviewed a BFG report that contained an updated C-55/54 core comparison.

- Prepared a letter to respond to the proposal by BFG to change the core material in the RHO-COR® sandwich from the original C-55 elastomer to the C-54 elastomer.

- Prepared a statement of work (SOW) for testing the C-54 elastomer for use as the core material in the RHO-COR® sandwich structure.

- Contracted a waterjet cutting company to cut strips from an elastomer block supplied by BFG. One half of the block was cast on 10 March 2000; the other half was cast on 18 May 2000. The strips were nominally 0.060-inch thick.

- Tested dogbone tensile samples to evaluate the tensile strength of the individual C-54 casts and the knitlines formed at the interface between the two casts. Six-dogbone samples cast on 10 March 2000, six samples cast on 18 May 2000 and five knitline samples were tensile tested.

- Performed Shore A hardness tests on the individual casts of the C-54 elastomer block. The results from both the tensile and hardness tests were reported to the Program Manager and presented during a Program Review.

- Ordered additional 0.060-inch thick strips cut from the elastomer block at a waterjet cutting company due to the results from the knitline tests. Dogbone samples were produced from the strips and were presented to BFG for additional knitline tensile tests and surface analysis of the failed knitlines. We speculated from the low knitline tensile strength data and the appearance of the fracture surfaces that contamination at the interface might have occurred between pours of the elastomer.

- Received a fiber reinforced plastic (FRP) panel from BFG. This panel was the de-bonded inner-septum from the second large vertical panel. The panel measured 1.3 by 5-feet and is five plies thick. We retained the panel for possible future testing.

- Received two large full-thickness RHO-COR® panels, a cast elastomer/insert sample from the bead area and heat-treated steel inserts from BFG for testing. No testing was performed on the RHO-COR® panel due to material changes in the sandwich composition after the panel was produced (the panel was made with the C-55 core material before the decision to use C-54 as the core).

- Performed periodic Shore A hardness tests on a cast elastomer/insert sample to evaluate aging effects on the C-54 urethane.

- Performed metallurgical testing on heat-treated steel bead inserts. The findings were discussed with BFG personnel and a report detailing the results was submitted.

- Sent four 2 by 2-foot panels that were impact tested at the Naval Surface Warfare Center Carderock Division (NSWCCD) to BFG for C-Scan mapping of the impact damage zones.

- Critiqued a proposal by BFG to use a LASER cutter to cut glass cloth prior to lay-up for the NSDCW. A written report was submitted to the Program Manager detailing our concerns about the cutting technique.

- Prepared a cutting plan for three full-thickness RHO-COR® panels to be sectioned by a waterjet company to produce samples for testing. The cutting plan was thoroughly discussed with the waterjet cutting personnel to avoid any mistakes in cutting. The samples were produced and are being retained for future flexural and impact testing at GEO-CENTERS.

- Compiled a photographic database of images generated in the NSDCW program including digital images of the fabrication process received from BFG.

- Held discussions with NRL acoustic personnel about a grid system/structure to be used with linear variable displacement transducers (LVDT) and acoustic emission sensors to measure displacement and cracking of the NSDCW.

- Reviewed several applicable data acquisition systems. Alternate at-sea methods of gathering sonar dome deflection data were also discussed. Topics included non-obtrusive LVDTs, attachment methods and positioning equipment.

- Maintained contact with and attended meetings of the submarine bow dome working group, because of similarities between the NSDCW and submarine bow dome programs.

Future Activity

We plan to continue to support the effort to fabricate a prototype composite sandwich bow dome through communication with BFG and visits to the production facility. In addition we will continue to supply engineering and materials testing support for this effort. We currently have plans to perform the following tests:

- periodic hardness tests on aging C-54 elastomer samples

- tensile tests to failure of bead area RHO-COR® samples

- small panel RHO-COR® impact tests

- flexure tests of RHO-COR® samples

- impact of a large bead-to-bead RHO-COR® panel (described in detail below).

In summary, future work will involve refining materials and fabrication procedures to improve the NSDCW.

2.6.2.2 Large-Scale Impact Test (LSIT)

GEO-CENTERS has played a lead role in designing and planning the LSIT. The objective of this experiment is to impact a bead-to-bead section of the NSDCW constructed by BFG and collect data during the impact event. This test will also be used to satisfy the Sonar Dome Window Design Requirements with respect to impact tolerance. During the impact event we wish to measure strain, deflection and induced loads. In addition, we hope to study damage propagation, insertion loss and damage repair. This experiment will assist us in understanding how the NSDCW responds to large impulse loads and to verify the FEA developed by BFG.

The bow dome design requirement states that the dome structure will need to adsorb the impact energy from a collision of a 350-ton YTB class tugboat at 2 knots. The inelastic impact energy is approximately 10^5 ft-lbs. We believe that this requirement is poorly written and not realistic. We intend to impact a large bead-to-bead panel under well-defined conditions to evaluate the impact damage resistance of the RHO-COR® sandwich material. Our goal is a new design requirement based on the results.

BFG has constructed a NSDCW sample using the existing SDRW mold. The sample is to be installed on the hydrotest fixture at the 90°-mold location. BFG is to construct suitable side support structures to prevent the sample from buckling under static and impact (dynamic) loads. In addition, the dynamic holding structure will need to support and restrain a water-pressurized bladder. The bladder, placed behind the impact sample, will simulate the pressurization of the dome. A pressure transducer, provided by NAVSSES, will be used to measure pressure changes during the impact. The impact unit will consist of a 6-inch diameter semi-spherical steel tip attached to a cylindrical steel standoff. The impact unit will be attached to a pendulum impact arm. The impact arm is to be attached to the upper structure of the hydrotest fixture at BFG. The arm and impact unit will contain an anti-rebound mechanism to prevent multiple impacts during the test. The impact arm will have provisions for adding mass to achieve the desired impact energy. An accelerometer will be installed on the impact unit. The standoff will be replaced with a MTS load cell for a static test that will be performed before the impact test. During the static test, load/displacement data will be obtained that will be used to finalize the desired impact energy for the LSIT.

We developed an outline of the tasks and responsibilities for the LSIT. The current version of this task flowchart is outlined below.

- Construction of sample and sample holder and pressurized bladder: BFG
- Impact unit construction and instrumentation: NRL
- Instrumentation of sample and holder: BFG and NRL
- NDT base line reading: BFG and NRL
- Static loading of sample: BFG and NRL at JAX facility
- Transport sample to the Naval Underwater Warfare Center (NUWC) for insertion loss testing and base line reading
- Transport sample to test facility and set-up: NRL
- Data acquisition set-up, data gathering, and impact test: NRL
- NDT of damaged sample: BFG and NRL
- Transport damaged sample to NUWC for insertion loss testing
- Transport sample to BFG for repairs
- Damage area removal and transportation to NRL for analysis: NRL and BFG

- BFG to repair sample
- Failure analysis of damaged area: NRL
- NDT of repaired sample: BFG and NRL
- Transport repaired sample to NUWC for insertion loss testing
- Transport sample to final destination for sample storage
- Generate final report and provide presentation to PMS-411

During a visit to BFG we took measurements of the hydrotest fixture to aid in the design of the impact test apparatus. In collaboration with BFG personnel, we made progress in the design work and energy calculations for the pendulum impact test. Made drawings of possible anti-rebound catch mechanisms to eliminate multiple impacts to the sample by the impact mass during the test. Preliminary drawings indicating sizes and positions of the impact apparatus components were also produced.

The LSIT includes obtaining insertion loss (IL) and non-destructive testing (NDT) evaluations of the panel. We plan to gather base line IL data before we impact the sample, perform a second IL test after impact and a third after repair of the impact damage by BFG. Discussed IL measurements and sample orientation with NRL and BFG personnel. We plan to use a bead and nut plate attachment device to hold and stabilize the large-scale impact sample during IL testing.

Other accomplishments on the LSIT project include the following:

- Began the design and programming of a high-speed data acquisition system to record strains measured by strategically placed strain gages. Our current plans are to place strain gages located 6 inches from the impact diameter in a circular pattern at 45-degree intervals on both the inner and outer septum (16 gages). In addition, strain gages are to be located at all corners and linear midpoints of the sample on both the inner and outer surfaces (16 gages). If resources allow, additional strain gages can be located on the sample support structure and sample hold down castings. A small accelerometer will be located on the surface of the inner septum centered along the impact point line from the outer septum.

- Witnessed the impact test of a vacuum assisted resin transfer molding (VARTM) glass reinforced plastic (GRP) panel from the submarine composite bow dome program at NSWCCD. Observed the anti-rebound mechanism, the data collection instrumentation and the high-speed digital camera used to record the impact event.

- Traveled to NSWCCD to inspect a RHO-COR® panel prior to preparing a cutting pattern to be used by NSWCCD to section the panel into samples of the desired size and shape. The cutting pattern was sent to NSWCCD and the panel was cut as per our specifications. Four 2 by 2-foot samples were cut from the panel and impacted at NSWCCD using various energies. We received and reviewed the impact test data. The samples were subsequently picked up from NSWCCD and we performed visual and UT examinations of the impact damage.

- Began energy calculations for a pendulum impact test to be used for the large-scale impact panel. Performed calculations to attempt to correlate the impact of a 350-ton tug at 2-knots with an attainable impact energy value for the LSIT. The size of the impact anvil was calculated in order to produce an energy/area value equivalent to the tug test. The calculated anvil size allows the use of a reasonable impact energy value in the LSIT. The goal is to develop a quantitative impact standard through analytical and experimental work that can be used for future material qualifications. Also performed energy calculations using test data from the 2 by 2-foot full thickness panels impacted at NSWCCD as well as FEA data from BFG.

- Discussed defects found on the outer septum of the LSIT sample with BFG personnel. It was decided that the defects might provide additional information on the acoustic and damage tolerance properties of the sandwich structure during the LSIT program.

- Held several meetings with product engineers from National Instruments to determine what data acquisition equipment is necessary to perform the LSIT. In addition, we have determined the accelerometer and pressure transducer required for the LSIT. A list of necessary equipment was generated and the equipment was ordered. The data acquisition equipment was received and we reviewed the equipment manuals to understand the operation of the data acquisition components. We also ordered and received an accelerometer to be used in the test.

- Attended a National Instruments LabVIEW™ class.

- Attended a Marine Composites Overview Course presented by Eric Greene Associates for the Marine Composites Technology Center (MCTC) and Structural Composites.

- Developed data acquisition (DAQ) program flow charts for the LSIT.

Future Activity

Calculate impact loads, pendulum arm rotational speeds and mass requirements. Complete and test the data acquisition system. Conduct the LSIT and analyze the test data.

2.6.2.3 Compression-After-Impact (CAI) Testing

Two separate CAI studies were undertaken to evaluate the effects of ply lay-up and seawater exposure on the post-impact residual strength of GRP panels. In the first study, samples of two different ply lay-ups were impacted at the same impact energy to evaluate the effect of lay-up on the severity of impact damage. In the second study, samples of the same lay-up were impacted at different energies. Samples impacted at each energy level were then exposed to high velocity flowing seawater directed toward the impact damage area, quiescent seawater and ambient dry conditions. The purpose of this study was to evaluate the synergistic effects of impact and environmental exposure to simulate situations commonly encountered in underwater applications. In both studies, the samples were compression tested and the failure loads were recorded.

In previous work, twelve 4 by 6-inch panels of the NSDCW GRP material were impacted at various energies. Three samples each were impacted at 10, 20, 30 and 40 joules. These samples were sent to BFG to have ultrasonic inspection performed to map the extent of the damage. In addition, ten GRP panels from the submarine program were impacted at 6.7 joules per millimeter of sample thickness (51 joules), as specified in the Suppliers of Advanced Composite Materials Association (SACMA) test method SRM-2R-94, and sent to NSWCCD for compression testing.

The following tasks were performed during the reporting period in the CAI evaluation:

- Picked-up the CAI samples from the submarine program at NSWCCD after completion of the compression testing. Examined the compression damage visible on the samples. Received and reviewed the load-deflection data from the compression tests performed by NSWCCD. We analyzed the load-deflection data in an attempt to correlate the data with the appearance and failure mode of the samples and the results were incorporated into a manuscript on CAI testing.

- Received and evaluated the results from the ultrasonic inspection of the NSDCW GRP samples. Traveled to Naval Research Laboratory Marine Corrosion Facility (NRLMCF) in Key West, FL for impingement flow exposure of the CAI GRP samples from the NSDCW program to evaluate damage propagation and strength reduction resulting from seawater ingress into the impact damage zones. On this trip, the impingement flow apparatus was cleaned, restarted and repaired as necessary. The sample holder was also modified to allow testing of the 4 by 6-inch CAI samples. A trip report was submitted to the Program Manager. After 3 months of exposure to flowing seawater, the CAI samples were removed from the test tank at the NRLMCF, Key West, FL and subsequently sent to the NSWCCD for compression testing. We prepared a SOW to have the samples tested to failure in compression at NSWCCD. After compression testing, we received the compression data and samples from NSWCCD. The compression test data was analyzed and correlated with the appearance and failure mode of the samples and the results were incorporated into a manuscript on CAI testing.

- Prepared two abstracts for presentation and publication at the Marine Applications of Composite Materials (MACM) 2000 meeting. The abstracts were circulated to appropriate parties for input/approval prior the submission to MACM 2000. After making suggested changes, the abstracts were submitted and accepted.

- Prepared a draft manuscript on CAI testing of GRP panels for the MACM 2000 conference. Due to delays in receiving all of the compression data, we were unable to present the work at MACM 2000. We intend to publish/present the work at a future date.

- Made minor modifications to the low energy impact apparatus at GEO-CENTERS to perform impact tests on full thickness RHO-COR® samples to qualitatively compare damage zone appearance with that observed in the 4 by 6-inch CAI panels. The sizes of the damage zones were very close in diameter.

2.6.2.4 Non-Destructive Inspection

In the Annual Reports we have described our effort to develop NDI methods for the RHO-COR® sandwich composite material, including ultrasonic testing (UT) and fiber optic smart system monitoring.

More recently, we have investigated the application of novel microwave imaging methods to detecting NSDCW impact damage (Figure 3). The details of our collaboration with Colorado State University's Applied Microwave Nondestructive Testing Lab (AMNTL) were reported in a paper, " Microwave NDE of Impact Damaged Fiberglass and Elastomer Layered Composites" published in the Review of Progress in Quantitative NDE, vol. 19, 2000.

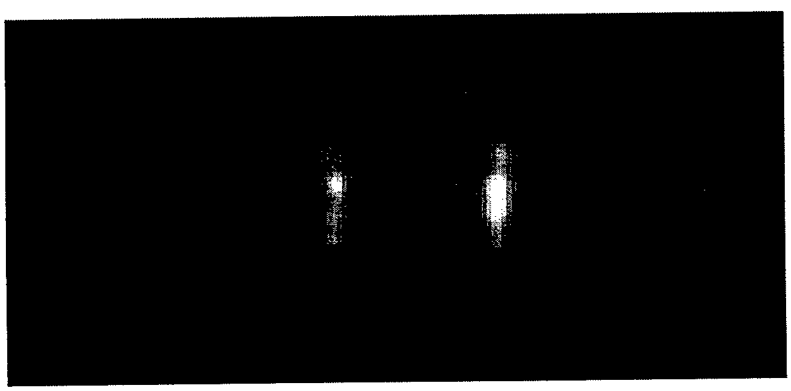


Figure 3. Scanning microwave image of impact damage to a RHO-COR® composite coupon.

In this paper, we presented our preliminary microwave NDE results from RHO-COR® impact test coupons. The coupons were scanned using a near-field microwave probe that responds to the composite's dielectric properties. The unprocessed scan data was displayed in an image format to reveal damaged areas. Results were compared with those from x-ray backscatter imaging and ultrasonic testing. The difficulties posed by the application were discussed, as were the operating principles and advantages of the microwave methods. The importance of optimizing inspection parameters was emphasized for future work.

2.7 Anti-Fouling Coatings Evaluation

Underwater ship structures such as the hull and sonar domes are often treated with anti-fouling compounds to prevent the attachment and growth of marine organisms. In the past, these compounds have been composed of toxic ingredients that leach into the water and kill marine organisms thereby preventing fouling. Of particular interest for protecting Naval sonar domes is the use of neoprene rubber impregnated with bis (tri-n-butyl tin) oxide (TBTO). The BFG TBTO-impregnated rubber is trademarked as NOFOUL®. However, due to increased governmental regulations restricting the use of such toxic materials, effective, environmentally friendly methods of combating fouling must be found. We initiated a program to evaluate a series of non-toxic, silicone-based fouling release coatings for use on sonar domes. These coatings function by preventing or deterring adhesion of the fouling organism to the silicone surface and also by facilitating easy removal of the fouling by virtue of their "slick" nature. Coatings from various manufacturers have been evaluated in a number of tests to determine their suitability for use on current wire/rubber domes as well as future composite domes. Tests have been and are currently being performed to evaluate the structural integrity and adhesion of the coating to rubber and urethane substrates as well as the ability of the coatings to hydrodynamically self-clean. Work in this program is divided into the following subtasks:

- Large Panel Coating Evaluation
- Evaluation of Adhesives for Attaching Neoprene and C-54 Urethane to Steel
- Measurement of Coating Bond Adhesive Strength
- Impingement Flow Test to Evaluate Coating Durability

Details of work performed on this project since our last report are described below.

Large Panel Coating Evaluation

A program was initiated to evaluate the performance of fouling release coatings on large panels that would be more representative of the scale that will be seen when an entire sonar dome is coated. A number of 2 by 4-foot panels were coated to evaluate the fouling, cleanability, durability and adhesion of perspective coatings. Work that was performed in this effort is detailed in this section.

In early work to test 2 by 4-foot coated panels, consideration was given to using the large flow channel at the Naval Surface Warfare Center Carderock Division (NSWCCD) to hydro-dynamically clean panels that were exposed to fouling at Miami Marine Research and Testing Station (MMRTS). We received four 2 by 4-foot neoprene panels from BFGoodrich Engineered Polymer Products (BFG) to send to International Paints and General Electric (GE) for application of coatings. To better understand the coating process used by International and GE, we made arrangements to visit their facilities to observe the coating application technique and further discuss the program. Visited GE and observed the application of two different topcoats on the 2 by 4-foot neoprene panels. A trip report was submitted to the Program Manager. We also traveled to International Paint, Houston, TX, met with representatives of International Paint and observed the application of the Intersleek 425 topcoat on a 2 by 4-foot neoprene rubber panel. A trip report was submitted to the Program Manager.

We prepared a Statement of Work (SOW) to have the panels tested at NSWCCD. Problems with changes of the tie coat used by GE raised questions about the integrity of the bond of the coating to neoprene and prompted us to concentrate our efforts on the International Intersleek coating.

Due to the decision to concentrate on International Intersleek and concerns about contamination of the flow channel at NSWCCD from marine organisms, a decision was made to change the test to evaluate large panels attached to the hull of a Navy ship. We prepared a preliminary SOW for placing two 2 by 4-foot coated panels on the hull of a Navy ship. We decided to coat one urethane and one neoprene panel with International Intersleek for testing on a hull. We discussed with BFG personnel the necessary preparation of the ship's hull to facilitate adequate adhesion of the panels to the ship. A test plan was developed to evaluate various adhesives to attach the panels to the steel hull (details of the adhesive testing are presented in the following section of this report). Prepared a procedure detailing the steps involved in attaching the panels to the ship. This procedure involves both mechanical and adhesive fastening of the panels to the ship. The attachment procedure will be integrated into the final version of the SOW after a suitable adhesive system has been identified.

BFG fabricated 2 by 4-foot by 0.25-inch urethane elastomer and neoprene panels to be coated and attached to the hull of a Navy ship for evaluation. We inspected the panels and arranged to have them coated. The urethane panel and a neoprene panel were sent to International for application of the Intersleek coating and returned to GEO-CENTERS, where they were inspected and photographed. The panels are currently stored until they can be attached to the hull of a Navy ship after the evaluation of adhesives has been completed.

We have prepared a memo detailing the purpose and procedure for attaching the two 2 by 4-foot panels (one C-54 and one neoprene) to a ship's hull. The memo will be sent to the Type Commander once a suitable adhesive has been identified.

Evaluation of Adhesives for Attaching Neoprene and C-54 Urethane to Steel

We developed a test of adhesives to secure the urethane and neoprene panels to steel substrates that are coated with a primer commonly used by the Navy on the hull of a ship. We intend to flow high velocity seawater over the leading edge of urethane and neoprene panels for a period of time to evaluate the quality of the adhesive bond between the elastomers and the primed steel. We plan to conduct the test in the flow trough or impingement test tank (or both) at the Naval Research Laboratory Marine Corrosion Facility (NRLMCF) in Key West, FL. This test is a precursor to the attachment of coated 2 by 4-foot neoprene and urethane panels on the hull of a Navy ship as discussed above.

We have held numerous teleconferences with NRL Code 6136 personnel to discuss the testing of the prospective adhesive(s) for securing the panels on a ship and arranged for them to provide four steel panels coated with a 2-part epoxy primer commonly used on Navy ships. The steel substrates were shipped to GEO-CENTERS and photographed to document the appearance of the primer coating. Two 6 by 10-inch neoprene panels and two 6 by 10-inch C-54 urethane panels, all coated with International Intersleek, were cut from larger panels.

After conferring with BFG, the following matrix was formulated for adhesive testing.

Sample	Panel Material	Adhesive System
1	C-54 Urethane	Fusor 305 (350)
2	C-54 Urethane	Fusor 305 (350) plus Versathane
3	35046 Neoprene	Chemlok 7701 plus Fusor 305 (350)
4	35046 Neoprene	Chemlok 7701 plus Fusor 305 (350) plus Versathane

The 6 by 10-inch C-54 urethane and neoprene panels along with the primed steel substrates were shipped to BFG for attachment of the elastomer panels to the steel substrate. BFG agreed to attach the urethane and neoprene panels to the substrates due to the intricacies involved with the application of the adhesives and the fact that BFG had all of the adhesives on hand.

We have installed the test samples in the high velocity hydro-peel/impingement flow tank at NRLMCF and maintained contact with NRLMCF to determine the status of the work to restore electrical power to the pumps. We are currently waiting for NRLMCF personnel to restore power to the set-up so the impingement flow test of the prospective adhesives can begin.

Measurement of Coating Bond Adhesive Strength

We performed adhesion tests in which aluminum stubs (dollies) were glued to the coating and a measurement of the bond strength of the coatings to neoprene and urethane substrates was made with an Elcometer 106 Adhesion Tester. The adhesion tester pulls the dollies from the coated samples and the force required to pull the dolly off is read from the tester. The type of failure (adhesive, cohesive) is also noted after the dolly is removed.

A great deal of effort was expended in trying to find an adhesive that would bond the aluminum dollies to the coated panels. The inability to adhere objects to the samples is favorable considering that the intended purpose of the coatings is to resist secure attachment of marine organisms. However, this property makes evaluation of the quality of the coating bond to the substrate with this technique very difficult.

We have continued to evaluate the bond quality of the GE and Intersleek coatings both on the C-54 fill elastomer and on neoprene with the use of the Elcometer Model 106 Adhesion Tester. Additional successful pulls were performed on the Intersleek coating on the C-54 fill elastomer substrate and the GE1154 on a neoprene substrate. Numerous attempts were made to attach test dollies to the GE coatings on the C-54 fill elastomer substrates. A new cyanoacrylate ester (super glue) adhesive was tried as well as a number of different surface preparations for the dollies and the coatings surface. We were unable to obtain sufficient adhesion on any of the four GE coating/tie coat combinations to evaluate the coating bond. We are trying to understand why adhesion of the dollies occur on the GE1154 coated neoprene samples but there is no adhesion on the GE1154 coated C-54 fill elastomer samples.

We have requested an adhesive from GE that may allow aluminum dollies to be attached to the prospective coatings in order to evaluate the bond of the coatings to various elastomeric substrates.

We have acquired new adhesives to resume adhesion testing of the leading candidate coating to neoprene and urethane substrates. This evaluation was halted due to the inability to find a suitable adhesive to bond adhesion test dollies to the coating so quantitative measurements of the bond between the coating and substrate could be made. We expect that the new adhesives will allow measurements to be made.

After unsuccessfully trying a number of various types of adhesives, a silicone adhesive was found that successfully attached aluminum dollies to the International Intersleek silicone fouling release coating. After the adhesive cured, the dollies were pulled off of the coatings with the Elcometer Model 106. A series of tests were performed to evaluate the adhesion of the coating to neoprene and C-54 elastomer substrates. Preliminary results indicate that the adhesion of the coating to the C-54 urethane substrate is comparable to the adhesion of the coating to neoprene. The coating on the C-54 panels was applied with a brush by hand. As a result of the brush application, the coating thickness is greater than in a typical spray application and the coating thickness profile is less uniform. In all tests performed with the C-54 substrates, the coating failed cohesively within the topcoat. The neoprene panel tested was coated using an airless spray system and showed mainly adhesive failure between the tiecoat and the neoprene. The thickness and variability of the brushed -on coating is greater than the coating applied by airless spray. We believe that the greater thickness of the coating on C-54 results in the cohesive failures within the finish coat shown in Figure 4.

Photos were taken to document the results of adhesion tests. The results for International Intersleek on C-54 urethane elastomer are shown in Figure 4 and the results for the same coating on neoprene are shown in Figure 5.

Dollies Substrate

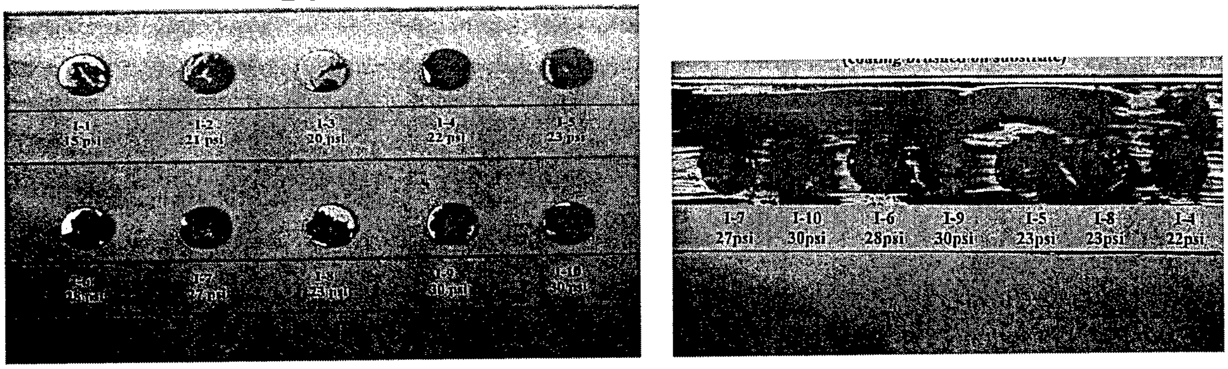


Figure 4. Coating adhesion results for International Intersleek applied by brush on A C-54 urethane elastomer substrate. All failures shown are predominately cohesive within the finish coat.

Dollies Substrate

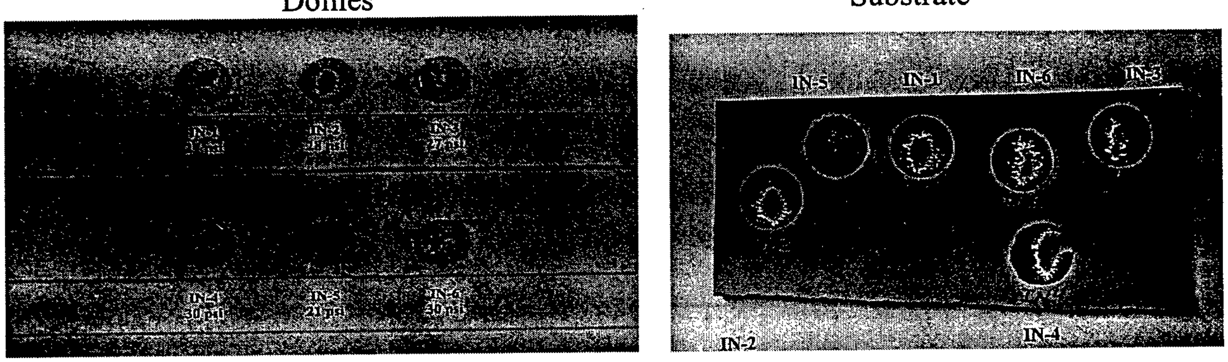


Figure 5. Coating adhesion results for International Intersleek sprayed on a neoprene substrate. All failures are predominantly adhesive between the tiecoat and the substrate.

The average adhesion strength for all 10 samples in Figure 4 is 23.9 psi. Samples 1-3 were tested before a silicone adhesive was found to successfully attach the dollies to the coating. As a result, there was a great deal of failure between the adhesive and the coating yielding artificially low adhesive strength values. If results for samples 1-3 are discarded, the average adhesion strength is 26.1 psi. The average adhesion strength for the samples in Figure 5 is 27.2 psi.

We requested and received a C-54 panel coated with International Intersleek using airless spray in order to perform additional adhesion tests. We attached aluminum dollies onto the coated C-54 urethane panel. Numerous tests were conducted and the bond strength exceeded the capacity of the Elcometer Model 106 Adhesion Tester (30-psi) in every test. Alternate methods for measuring the bond strength were being explored. No suitable method for quantitatively removing the dollies was found so three of the dollies were pulled off by hand to qualitatively evaluate the bond between the coating and the C-54 elastomer. The three dollies that were pulled by hand were considerably more difficult to remove than any samples tested previously. This includes dollies attached to Intersleek on neoprene and Intersleek that was brush applied on small C-54 panels. In addition, all of the three current tests yielded cohesive failure within the coating topcoat. The results of the manual pull-off adhesion tests are shown in Figure 6.

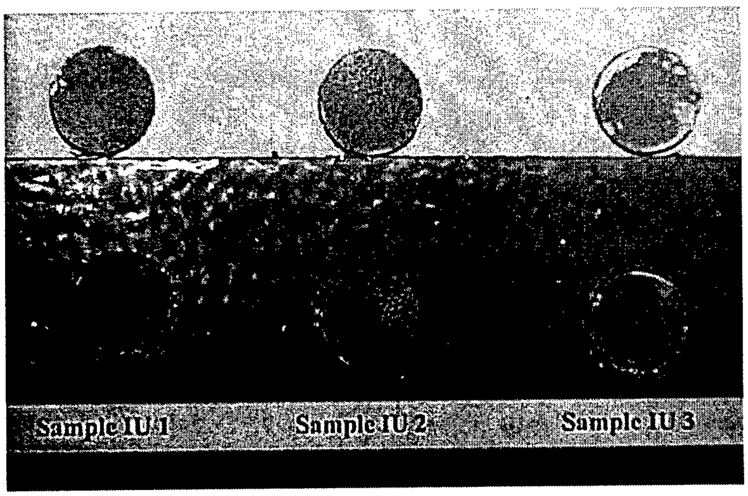


Figure 6. Results of adhesion tests of a prospective coating sprayed on C-54 urethane elastomer.

Six dollies remain attached to the C-54 substrate. We are continuing to attempt to devise a quantitative method to measure the bond strength.

BFG attached neoprene and C-54 panels to four primed steel substrates with various adhesive systems. We will use the four samples in flowing seawater tests to evaluate the adhesive systems for mounting 2 by 4-foot panels to a Navy ship.

<u>Impingement Flow Test to Evaluate Coating Durability</u>

We report the following accomplishments:

- Discussed with the sponsor the possibility of using the impingement flow apparatus in Key West, FL to evaluate the durability of the coatings. We have previously used this set-up for similar measurements. The degradation of the coatings would be evaluated and a comparison between coatings would be made. The sponsor advised us to proceed with this plan. The coatings to be tested include two types from GE and one from International Paint. The two-coated panels have been received from GE and once the coated panel is received from International Paint the coating durability test will be implemented.

- Cut samples of appropriate sizes from the 2 by 4-foot panels coated by GE and International for coating durability testing which will be conducted in the impingement flow apparatus in Key West, FL low temperature exposure testing and coating adhesion tests.

- Traveled to NRLMCF to setup impingement flow testing of coating samples. A trip report was submitted to the Program Manager.

- Traveled to the NRLMCF in Key West, FL on 8-11 February 2000 to remove coatings samples from the impingement flow test. The test apparatus (pumps, tank, etc.) were conditioned for storage after the samples were removed. A trip report was submitted to the Program Manager.

Miscellaneous Tasks

In addition to the work detailed above, a number of miscellaneous tasks were performed in the course of evaluating fouling release coatings.

- Received and began reviewing a large number of documents from GE concerning fouling release coatings.

- Reviewed information supplied by International Paint and GE on their respective web sites.

- Reviewed documents provided by GE concerning fouling release coatings. We are compiling a list of critical points that need to be addressed.

- Began gathering data and photographs from our testing of GE coatings, this information will be sent to GE.

- Communicated with a representative of International Paint regarding points of contact from the Coast Guard with experience using Intersleek in marine applications. The International representative promised to provide the contacts as well as performance track records for Intersleek and also low temperature data.

- Communicated with a representative of International Paint to discuss the use of the Intersleek coating system in marine applications. International provided information on testing of Intersleek as well as Naval points of contact who have experience with the coating. These contacts are currently being pursued.

- Reviewed and organized electronic photographs of coatings samples removed from test in Key West.

- Investigated a 3M tie coat product that may inhibit TBTO migration through a silicone coating.

- Performed low temperature bend tests on two prospective coating systems applied to C-54 elastomer substrates. The coating samples were stored in a freezer for over a month, removed and immediately flexed. The results of the tests were recorded.

- Continued organizing all photographs of coatings samples collected during testing into a readily accessible database.

- Contacted a coatings expert from Ingalls Shipbuilding in Pascagoula, Mississippi. Discussed paint systems commonly used on Naval ships and procedures for application of the coated neoprene and C-54 panels to the hull of a ship.

2.8 Navy Composite Dome Pressurization System Modification

The USS KAUFFMAN has been fitted with a composite sandwich keel dome that is called the Navy Composite Dome (NCD). The NCD is a very rigid structure compared to the typical rubber dome used on this class of ship. The current pressurization system was designed with the rubber dome in mind using technology of the day. The current pressurization system is maintenance intensive, requiring many man-hours to keep it in operating condition. An important consideration in the utilization of the current pressurization system with the NCD have been reports from the ship's crew of the incessant water hammering and over pressurization alarms since the installation of this new dome.

In order for the NCD to absorb shock while maintaining constant pressure, a pressurized dampening system must be utilized. To maintain NCD operational pressure, we proposed the use of a hydraulic accumulator in a closed system. The accumulator will serve the function of maintaining a pre-set pressure as well as acting as a whole system "shock absorber." Since this is a closed system, no loss of water will occur, even in the most severe cases. The accumulator will be of sufficient capacity that it will be able to handle the water displacement that occurs during maximum deflection of the sonar dome under the most severe conditions. The maximum deflection was calculated through a BFG finite element analysis (FEA) model. A safety factor will be added to the capacity to ensure response in excess of that required for the maximum structural deflection.

We first gained approval from Naval Ship Systems Engineering Station (NAVSSES) to install an accumulator tank on the USS KAUFFMAN. The accumulator will be temporarily installed in the special clothing storeroom adjacent to the sonar dome pressurization station. It will be connected to the 2-inch fill/drain pipe. The accumulator will be attached to the non-pressurized bulkhead in the forward part of the room using a shock mount clamp. The existing pressurization system and alarms will remain intact and be kept in working order during the trial period. In addition, watering, de-watering and air pressurization systems will function as normal during the trial period. Monitoring of the new system will be accomplished using a GEO-CENTERS developed data acquisition system. Sonar technicians will also monitor the system on a daily basis. GEO-CENTERS will train personnel on system operation and maintenance.

Considerable work was performed to gain approval from Naval Sea Systems Command (NAVSEA) and the type desk to allow the installation of the accumulator tank system on the USS KAUFFMAN. At the request of NAVSEA PMS 411, we compiled an estimate of the total cost of the tank and corresponding equipment. We provided NAVSEA with basic drawings of the accumulator system to assist in the approval process. We requested and received a cost estimate from NAVSSES for their effort in the installation of the accumulator tank on the USS KAUFFMAN. We received a "menu" of items to be completed before the installation of the tank from the Type Desk and we were able to coordinate with the manufacturer of the accumulator tank to meet Navy specifications.

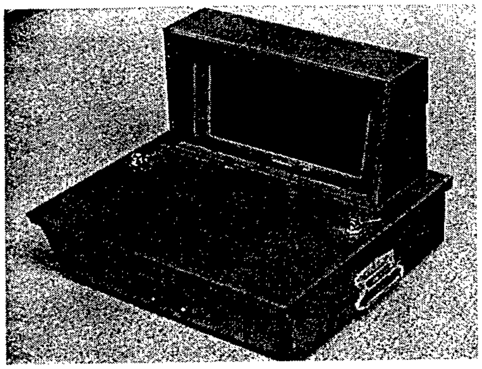
We held meetings to discuss the tank type, equipment required and modifications needed to adapt the accumulator to the ship's existing pressurization system. Also discussed were preventative maintenance, standard operating procedures and installation requirements. Finally, we received NAVSEA approval to proceed with the installation of the accumulator.

A Navy directive specified that the prototype tank/system must meet ASME X (10) standards. A number of tank manufacturers were contacted and a vendor was chosen. The manufacturer that was chosen gave assurance that they could comply with the standard and certify the tank as such. A 50-gallon capacity filament wound composite tank was ordered from the vendor. Frequent communication with the vendor was required during the fabrication of the tank, base support structure and side bulkhead braces. Details of the piping system were also worked out with the manufacturer.

National Instruments (NI) LabVIEW data acquisition (DAQ) software and NI hardware were chosen to monitor the accumulator system. Necessary hardware components were selected, ordered and received. A large effort to program the DAQ system was undertaken and after a great deal of effort the DAQ program was completed and tested. During the programming of the DAQ, we held a number of meetings at GEO-CENTERS with a representative of NI to discuss programming techniques and errors that were found in the NI system manuals.

Three pressure transducers and cables to be used for data acquisition were acquired from NAVSSES and tested.

We performed a vendor search to find an enclosure to house the DAQ equipment on board the USS KAUFFMAN. When no suitable off-the-shelf enclosure was found, we designed an enclosure to be fabricated in-house and prepared a materials list for the construction. Electronic components such as cooling fans, power supplies, wiring, connectors, etc. were chosen and acquired from various sources. The cabinet was constructed out of polyvinyl chloride (PVC) sheet and a polycarbonate screen to protect the computer display. After construction, the entire cabinet was coated with several coats of a conductive paint system to shield against electromagnetic interference (EMI), and a gray protective coating. The cabinet is shown in Figures 7 and 8.



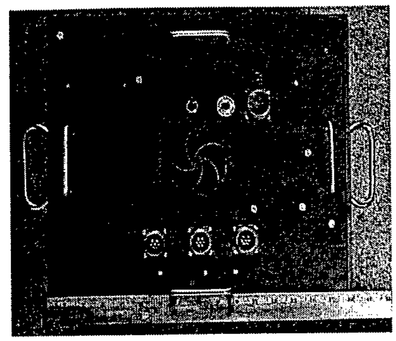


Figure 7. Top and bottom views of the DAQ equipment cabinet.

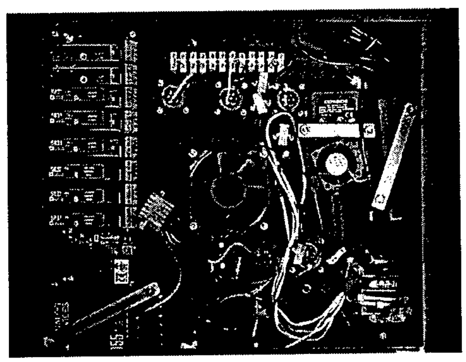


Figure 8. The instrumentation layout inside the DAQ cabinet.

Brass mesh was added along the air intake and exhaust of the cabinet to further reduce EMI glitches and a button was installed on the outside of the instrument cabinet that will be used to activate the computer screen.

Options for the fabrication and application of labels for lights, switches, plugs, etc. on the instrument cabinet were explored and a list of the necessary label entries compiled. A vendor was selected for engraved plastic labels.

During a preliminary test of the DAQ system by feeding air pressure from a compressor into the pressure transducers, the system operated as expected.

We also continued to refine the DAQ software. We have met all of the new requirements of NAVSSES that specify independent channel alarm activation settings as well as multi-channel recording selection.

Using air pressure from the compressor we performed further testing of the DAQ system. Air pressure was varied and the DAQ output was compared with a pressure gage in-line with the compressor. The system functioned as intended. We made minor adjustments to the appearance of the gages on the computer display to facilitate pressure monitoring, tested the data recording capability of the DAQ program and the ability to view/access the data in a spreadsheet program. Finally, we demonstrated the system for NAVSEA.

We have coordinated with NAVSSES to test the accumulator system, conduct training for the new pressurization system protocol and develop a manual detailing the new protocol. The tank and associated hardware were transported to Analysis and Technology, Norfolk VA in preparation for testing of the system.

We have begun a comprehensive documentation package on both the DAQ system and the functions of the accumulator.

In expectation of extending use of the accumulator tank pressurization system to future composite sandwich bow domes, we traveled to Bath Iron Works to examine a sonar dome rubber window (SDRW) installation module. The prototype composite sandwich bow dome, termed the Naval sonar dome composite window (NSDCW), is currently under construction. The accumulator system that would be used in the module assembly process would be installed prior to the installation of the NSDCW.

We plan on having an installation kit prepared to minimize any disruption of routine on board the ship. We need to document the details of the accumulator system and create a training manual/course for the ship's personnel. In addition, we need to gather enough data to qualify this system for Navy use.

NAVSEA intends to incorporate the accumulator system on ships with NCSDWs if and when this type of dome is put into service. Also, plans to automate the sonar dome pressurization system through computer control are underway.

2.9 Monolithic Sonar Dome Rubber Window (SDRW)

GEO-CENTERS' support of a major effort to develop and then to instrument and monitor the prototype monolithic SDRW has been reported in its entirety in the three previous Annual Reports. These reports detailed the following topics:

- Equipment and testing
- Installation requirements
- Installation of the deflection measuring system
- Equipment removal
- Instrumentation hardware failure analysis

2.10 Support for Miscellaneous Projects

The following miscellaneous tasks were accomplished in support of sonar dome programs:

- Provided *ad-hoc* engineering consultations, materials analysis, and reliability analysis, as needed. Provided topical papers to NAVSEA in response to various Navy investigations.

- Reviewed and discussed dry-docking procedures with NAVSSES and BFG prompted by a collision incident involving the USS RADFORD. The pressurization system was rendered inoperative and we discussed possible scenarios for de-watering the dome. We remained in contact with NAVSEA and NNSY to assist as needed. We held several conference calls with the Type Desk, Ship and NNSY to discuss the removal of the wave height Doppler equipment. The accelerometer, junction box, and the display unit had been removed from the ship. We traveled to NNSY to retrieve the wave-height monitoring equipment.

- MTS Hydraulic machine renovation.

- Researched equipment requirements and suppliers for a variety of program needs.

- Researched and tested imbedded fiber optics for composite condition monitoring.

3.0 COMPUTER SUPPORT

3.1 PEO/MUW Web Site

Previous Annual Reports have described the development of a web site to provide NAVSEA sonar dome program information for users in the fleet. Topics covered in detail were:

- System hardware
- System software
- Web site description
- Directory structure and file list
- Content
- Maintenance

As of the last report, the system was essentially complete and running smoothly. Work since that time has centered on adding content and functionality in response to requests from NAVSEA, fixing bugs as they show up, and supporting the relocation of the site host necessitated by organizational changes at NAVSEA. A major improvement has been the addition of x-ray inspection report archives to the site and the development of Java software to generate the damage diagrams associated with these reports. This has been coordinated with the database development work described below.

We have also worked with NAVSEA vendor Lockheed Martin to install a web browser-compatible version of their CD-ROM based Interactive Electronic Technical Manual for SDRWs.
The SDRW X-Ray Inspection Schedules are updated monthly and, along with the X-Ray Inspection Report Archives, are updated with every new x-ray inspection conducted and every change in ship assignments or dome installation.

The site's URL is https://www.muwinfodesk.navy.mil/sonardomes. (An account and password must be obtained from NAVSEA for access.)

3.2 SDRW/SRD Database

The existing computer databases of sonar dome program data were developed in the early 1980's and nearing the end of their useful life span. Written in R:Base for DOS, they would not run on Windows NT, the Navy's new desktop and server operating system standard. The database had to be updated using a new database program compatible with Windows NT. After evaluating both the latest R:Base upgrade and Microsoft Access97, we chose the latter for its ease of use, wide support network, excellent documentation, wealth of reference and support information on the World Wide Web, and ease of integration with Microsoft Internet Information Server. Previous Annual Reports have described our application development work as well as the effort to convert and import the data backlog. Work since then has consisted of verifying the entered data, debugging the menus and forms, and adding new functionality as requested by NAVSEA.

To support the posting of schedules and reports on the PEO MUW web site, Visual Basic codes were written to generate HTML-formatted material from the database content. Data on damage location and severity was also formatted for input to Java applet calls embedded in the x-ray report pages to draw damage diagrams on the fly rather than use large, slow to download, graphics files.

The existing R:Base database was maintained in parallel during the development of the new Access97 database application. Duplicate entry of new data in the old database has been suspended as confidence in the new database is established. We continue, however, to maintain the R:Base databases as archives. We also plan to import data from the obsolete AN/SQQ-23 keel domes, now all decommissioned, to the new database for reference. This will ensure that theses archives will remain accessible when future operating system upgrades become incompatible with the legacy R:Base codes.

We also previously reported our development of a program to digitally record sonar dome historical images from old negatives and prints and a database to facilitate the retrieval of images and to annotate historical information to individual images. As of our last report the program was running smoothly and we had loaded all the historical images.

We have continued to add new images and information to the database as requested by NAVSEA.

3.3 Sonar Dome Group Web Server, File Server, and Mail Server

3.3.1 Maintenance

We have continued to perform all normal maintenance actions on the Dell PowerEdge 4100/200 file server and web server, and the SGI Indigo 2 Graphics Workstation and Email Server, including tape backups, anti-virus checks, anti-virus signature file updates, log file monitoring, etc. We upgraded the web server to Microsoft Internet Information Server 4.0 and the web browser to Internet Explorer 5.0. We performed all normal maintenance actions on the SGI including setting up new user accounts, creating email accounts for new users, performing tape backups, regularly monitoring the log file for unusual activity or system problems. We ultimately removed the SGI from the network as described below.

3.3.2 Security

We have continued to respond to NRL directives regarding security and participated in security reviews and tests. When NRL directives required that we install additional software to eliminate known security weaknesses, we evaluated our use of the SGI workstation and determined that our needs could be met by the more secure NRL e-mail system. Accordingly, we have removed the SGI from the LAN and are no longer using it as a mail server.

3.4 Trouble Desk

We established a new computer technical support trouble desk in support of the NRL Chemistry Division to respond to users' requests for assistance with a broad range of computer problems. A computer support expert from our subcontractor, Global Paperless Solutions, staffed this service. Usage was tracked to determine the need for and effectiveness of this service. Periodic reports were provided to the division supervisor and to branch heads for their use in monitoring usage.

3.5 Y2K Audit

We provided a comprehensive audit of Chemistry Division and Branch administration computer systems to detect and fix problems and address published NRL compliance requirements resulting from the millennium date roll-over. A complete report was submitted containing detailed findings in each of these areas:

- Firmware (BIOS RTC Y2K rollover and leap year) test
- Operating System tests and fixes
- Application software inventory and known Y2K issues
- Y2K compliance issues
- Application data files compliance

During the testing process we also discovered that all PCs identified by an "EXPO" logo failed the Y2K test. This was reported to the Division.

3.6 Network Security Survey

Due to an increase in the number of security directives issued by NRL and a general increase in awareness of network security issues, a network engineer from Global Paperless Solutions was retained to assist computer users in resolving these issues. Assistance was provided to Chemistry Division personnel in installing software patches and operating system and application software upgrades to resolve known issues where required. A list of Unix (IRIX) systems with problems was also developed with specific remedies either implemented or recommended.

4.0 POLYMER SYNTHESIS AND CHARACTERIZATION

All work accomplished in several topics under this task area was reported in its entirety in the three Annual Reports submitted:

- Fluorinated polymers
- L-proline modified nylons
- Silicone fouling-release coatings
- Dielectric spectroscopy
- Elastomeric ejection system (EES)

- Rubber elasticity studies

We have also collaborated with NRL and Korea's Han Nam University on projects in two additional areas:

- Non-linear optical (NLO) materials using organic/polymer materials

- Light-emitting diode (LED) applications using organic based materials

NRL's approach to the NLO problem has been based on a nonpoling technique using spontaneous self-poling supramolecular assembly of chromophores. We sought to further develop an enhanced nonlinearity by synthesizing a uniquely engineered NLO-active chromophore for the supramolecular assembly. For the development of NLO materials based on this, the chromophores must be incorporated into polymers and electrically poled. The resulting polymers can attain a marked enhancement of polar stability and a large nonlinearity as well.

Our work on the LED problem, based on the NLO materials, focussed on a series of material syntheses for [pi]-conjugated emissive components based on fused terthiophene and for unique hole/electron carrier transport systems, as well as the construction of LED devices based on the selected material systems.

Results of the NLO and LED research projects have been documented in four publications (Section 9.0, 2, 4, 5, and 6).

5.0 SHIPBOARD SOLID WASTE ZERO DISCHARGE TECHNOLOGY

All work accomplished in this task area was reported in its entirety in monthly progress reports for April-July 1996 and March and April 1997. The effort was towards the development of a Plasma Arc Waste Destruction System (PAWDS).

6.0 OCEAN, ATMOSPHERE, AND SPACE SUPPORT

All work accomplished in this task area was reported in its entirety in the Annual Reports dated December 15, 1997 and December 7, 1998. The following topics were covered:

- Arctic Nuclear Waste Assessment Program (ANWAP)

- NATO Committee on the Challenges of Modern Society (CCMS) Pilot Study

- Miscellaneous support

7.0 PREVIOUS REPORTS UNDER THIS CONTRACT

As required by the contract, GEO-CENTERS has submitted detailed monthly progress reports (numbered GC-PR-2801-01 through 73) as well as interim reports, as requested by the COR. Three "Annual" reports were provided:

- "Annual Report: Synthesis and Characterization of Advanced Materials," GC-TR-97-2801, 22 December 1997.
- "Annual Report: Synthesis and Characterization of Advanced Materials," (No GC number) December 1998.
- "1998 Annual Report: Synthesis and Characterization of Advanced Materials," GC-TR-2801, October 1999.

8.0 TRAVEL

Considerable travel was necessary to support the above tasking, particularly in support of the sonar dome reliability task. Trip reports were submitted to the COR for each trip. Appendix C contains a complete list of individuals and their trips taken under the contract.

9.0 PUBLICATIONS

The results of our research under this contract have also been disseminated in the following publications:

P.H. Mott and C.M. Roland, "Elastomeric Ozone Detector," *Materials Science and Engineering A.* (in press).

O.-K. Kim, H.Y. Woo, K.-S. Lee, J.K. Kim, D.Y. Kim, H.-K. Shim, and C.Y. Kim, "Photo/Electroluminescence Properties of Novel Bipolar Oligomers," *Synth. Metals* (in press).

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C. Poranski, K. Campbell, H. Schrader, J. Smallhorn, and J. Robinson, " Flow Trough Testing of Fouling Release Silicone Coatings on Neoprene Rubber," *Proceedings of the Seventh International Conference on Marine Applications of Composite Materials* (1998).

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C. Poranski, E. Greenawald, E. Bellinger, and L. Levenberry, "Pierside Inspection of Sonar Rubber Domes, Mayport Naval Station, January 1997," *Proceedings, 46th Defense Working Group on Nondestructive Testing*, Yuma, Arizona, November 1997.

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C.F. Poranski, E.C. Greenawald, and Y.S. Ham, "Depth-Resolved Flaw Detection Via X-ray Backscatter Tomography," presented to the Meeting of the Materials Research Society, Boston, MA (1994).

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10.0 PATENTS

Research under this contract resulted in several patent applications and 3 patents awarded to date.

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Y.S. Ham and E.C. Greenawald, "Collimator for Scattered Radiation Imaging," Navy Case No. 77,724.

H.S.-W. Hu, J.R. Griffith, and S.L. Snyder, "Silicone Fouling Release Coatings Cured by Germanium Hydrides," patent disclosed 1996.

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APPENDIX A

X-Ray Inspection Summaries

X-RAY INSPECTION SUMMARIES
August 15, 1994 through September 30, 2000

Date	Report	Hull	Ship	Dome Type	S/N	L/U	Fleet (Current)	Availability Type	Inspection Category	Location	Contractor	Recommended
9/7/94	726	DD986	Hill	SDRW	N156	212	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Routine
9/8/94	733	D28	CT PARAIBA	SDRW	102	149	FOREIGN	Drydock	In-service	Rio de Janeiro, Brazil	BRAZIL	Routine
9/12/94	727	CG60	Normandy	SDRW	N126	178	SURFLANT	Drydock	In-service	Greece	MQS	Routine
9/27/94	729	PF936	HAE YANG	SDRW	N48	78	FOREIGN	Drydock	In-service	Long Beach, CA	MQS	Routine
10/7/94	730	DDG54	Wilbur	SDRW	N174	230	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Routine
10/18/94	731	CG54	Antietam	SDRW	L1	162	SURFPAC	Drydock	In-service	Long Beach, CA	MQS	Monitor
10/22/94	732	DD963	Spruance	SDRW	N142	198	SURFLANT	Drydock	In-service	Norfolk, VA	NNSY	Routine
11/5/94	734	DD968	Radford	SDRW	N105	187	SURFLANT	Pierside	In-service	Norfolk, VA	MQS	Monitor
12/28/94	737	DD988	Thorn	SDRW	N137	193	SURFLANT	Drydock	In-service	Newport News, VA	MTL	Monitor
12/29/94	738	DD997	Hayler	SDRW	N109	156	SURFLANT	Drydock	In-service	Portsmouth, VA	MQS	Routine
1/11/95	739	DD992	Fletcher	SDRW	N158	214	SURFPAC	Drydock	In-service	Pearl Harbor, HI	MQS	Routine
1/19/95	740	CG58	Philippine	SDRW	CG58	180	SURFLANT	Drydock	In-service	Greece	NNSY	Routine
1/23/95	741	CGN41	Arkansas	SDRW	N139	195	SURFPAC	Drydock	In-service	Unknown Location	MQS	Monitor
2/7/95	130	FFG13	Morison	SRD-56	A009	999	SURFRES	Drydock	In-service	Charleston, SC	MQS	Routine
2/8/95	742	DD964	Foster	SDRW	N68	108	SURFPAC	Drydock	In-service	Long Beach, CA	MQS	Monitor
2/17/95	743	CG73	Port Royal	SDRW	N172	228	SURFPAC	Drydock	In-service	Pearl Harbor, HI	MQS	Routine
2/24/95	751	F457	HS THRACE	SDRW	N136	192	FOREIGN	Drydock	In-service	Greece	(Unknown)	Re-inspect
2/26/95	744	CG56	San Jacinto	SDRW	CG56	166	SURFLANT	Drydock	In-service	Greece	MQS	Routine
3/2/95	746	D30	CT PERNAMBUCO	SDRW	N93	137	FOREIGN	Drydock	In-service	Rio de Janeiro, Brazil	METAL-CHEK	Routine
3/23/95	747	DDG55	Stout	SDRW	N171	227	SURFLANT	Drydock	In-service	Pascagoula, MS	GFS	Routine
3/23/95	134	FFG12	Philip	SRD-56	A012		SURFRES	Drydock	In-service	San Diego, CA	MQS	Monitor
3/23/95	748	DD977	Briscoe	SDRW	N122	173	SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Routine
3/28/95	749	CG63	Cowpens	SDRW	N132	186	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Routine
4/3/95	750	DD966	Hewitt	SDRW	N114	161	SURFPAC	Drydock	In-service	Yokosuka, JA	GFS	Monitor
4/20/95	136	FFG15	Estocin	SRD-56	A050	999	SURFRES	Drydock	In-service	Norfolk, VA	GFS	Monitor
4/26/95	137	FFG37	Crommelin	SRD-56	A073	999	SURFPAC	Drydock	In-service	Pearl Harbor, HI	MQS	Monitor
5/18/95	753	CGN35	Truxtun	SDRW	N7	7	SURFPAC	Drydock	Post-patch	Greece	PSNS	Monitor
5/18/95	138	FFG58	Roberts	SRD-56	A065		SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Replace

Date	Report	Hull	Ship	Dome Type	S/N	L/U	Fleet (Current)	Availability Type	Inspection Category	Location	Contractor	Recommended
6/10/95	754	DDG60	Hamilton	SDRW	N186	242	SURFPAC	Drydock	In-service	Portland, ME	GLITSCH	Routine
6/26/95	755	DD970	Caron	SDRW	L8	34	SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Monitor
7/5/95	140	FFG33	Jarrett	SRD-56	A028	999	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Replace
7/10/95	141	FFG52	Carr	SRD-56	A021	999	SURFLANT	Drydock	In-service	Unknown Location	GFS	Replace
7/20/95	756	DDG99	Kidd	SDRW	L1	93	UNKNOWN	Pierside	In-service	Unknown Location	MQS	Monitor
7/31/95	758	DD965	Kinkaid	SDRW	N128	183	SURFPAC	Drydock	In-service	Long Beach, CA	MQS	Routine
8/10/95	759	DD979	Conolly	SDRW	N79	121	SURFLANT	Pierside	In-service	Norfolk, VA	MQS	Monitor
8/20/95	760	DDG57	Mitscher	SDRW	N173	229	SURFLANT	Drydock	In-service	Pascagoula, MS	GFS	Routine
8/25/95	761	DD983	Rodgers	SDRW	N124	177	SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Routine
9/13/95	763	DD969	Peterson	SDRW	N116	167	SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Routine
9/15/95	146	FFG49	Bradley	SRD-56	A043		SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Replace
9/21/95	764	CG65	Chosin	SDRW	N133	188	SURFPAC	Drydock	In-service	Pearl Harbor, HI	MQS	Routine
10/2/95	765	CG55	Leyte Gulf	SDRW	CG59	176	SURFLANT	Drydock	In-service	Greece	GLITSCH	Routine
10/5/95	766	DDG58	Laboon	SDRW	N184	240	SURFLANT	Drydock	In-service	Portland, ME	GFS	Routine
10/26/95	769	F252	TCG KOCATEPE	SDRW	N22	31	FOREIGN	Pierside	In-service	Ismit, Turkey	MQS	Routine
10/27/95	768	CG48	Yorktown	SDRW	L2	125	SURFLANT	Drydock	In-service	Unknown Location	MQS	Monitor
11/17/95	770	DDG51	Burke	SDRW	N145	201	SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Routine
12/19/95	771	DD989	Deyo	SDRW	N153	210	SURFLANT	Drydock	In-service	Norfolk, VA	MTL	Re-inspect
1/1/96	772	DD989	Deyo	SDRW	N153	210	SURFLANT	Drydock	In-service	Norfolk, VA	MTL	Routine
1/4/96	153	FFG61	Ingraham	SRD-56	30	127	SURFPAC	Drydock	In-service	Portland, OR	MQS	Replace
1/13/96	773	CG53	Mobile Bay	SDRW	L3	145	SURFPAC	Drydock	In-service	Yokosuka, JA	MQS	Routine
1/18/96	774	CG47	Ticonderoga	SDRW	N113	160	SURFLANT	Pierside	In-service	Portsmouth, VA	MQS	Monitor
2/19/96	155	FFG31	Stark	SRD-56	A034		SURFLANT	Drydock	In-service	Charleston, SC	GFS	Monitor
2/25/96	776	DDG61	Ramage	SDRW	N179	235	SURFLANT	Drydock	In-service	Pascagoula, MS	GLITSCH	Routine
3/6/96	156	FFG24	Williams	SRD-56	A009	999	FOREIGN	Drydock	In-service	Portsmouth, VA	MQS	Replace
4/2/96	779	DDG63	Stethem	SDRW	N185	241	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Routine
4/5/96	780	DD974	C.D.Grasse	SDRW	N143	199	SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Routine
4/15/96	781	CG57	Champlain	SDRW	CG57	174	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Routine
4/22/96	783	461	P. CHULALOK	SDRW	N65	103	FOREIGN	Drydock	In-service	Thailand	MQS	Monitor
4/25/96	784	F251	TCG ADATEPE	SDRW	N73	114	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Monitor
5/8/96	789	F250	TCG MAUVENET	SDRW	N155	211	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Routine
5/24/96	785	DDG62	Fitzgerald	SDRW	N188	244	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Routine

Date	Report	Hull	Ship	Dome Type	S/N	L/U	Fleet (Current)	Availability Type	Inspection Category	Location	Contractor	Recommended
5/31/96	786	CG61	Monterey	SDRW	N129	182	SURFLANT	Pierside	In-service	Greece	MQS	Routine
6/1/96	787	DDG99	Scott	SDRW	N175	231	SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Routine
6/3/96	159	FFG51	Gary	SRD-56	A056		SURFPAC	Drydock	In-service	San Diego, CA	MQS	Replace
8/17/96	796	F-254	TCG Trakya	SDRW	N86	129	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Routine
8/26/96	795	D27	CT PARA	SDRW	N30	43	FOREIGN	Drydock	In-service	Rio de Janeiro, Brazil	AMRJ	Routine
9/27/96	792	DDG64	Carney	SDRW	N190	246	SURFLANT	Drydock	In-service	Portland, ME	GLITSCH	Routine
10/2/96	794	DDG65	Benfold	SDRW	N187	243	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Routine
10/6/96	793	DD967	Elliot	SDRW	N120	171	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Monitor
10/6/96	798	F253	TCG ZAFER	SDRW	N58	95	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Monitor
10/14/96	160	F916	ENS TABA	SRD-56	002	96	FOREIGN	Drydock	In-service	Pascagoula, MS	MQS	Monitor
10/25/96	797	DDG52	Barry	SDRW	N151	205	SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Routine
10/29/96	161	FFG58	Roberts	SRD-56	41	138	SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Routine
11/5/96	800	D28	CT PARAIBA	SDRW	102	149	FOREIGN	Drydock	In-service	Rio de Janeiro, Brazil	BRAZIL	Routine
11/7/96	804	F257	TCG Akdeniz	SDRW	N28	39	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Monitor
12/4/96	801	CG56	San Jacinto	SDRW	CG56	166	SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Routine
12/17/96	814	F256	TCG EGE	SDRW	N95	140	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Routine
12/20/96	803	DDG99	Kidd	SDRW	N207	264	UNKNOWN	Drydock	In-service	Norfolk, VA	MQS	Routine
1/17/97	807	DD988	Thorn	SDRW	N137	193	SURFLANT	Pierside	In-service	Norfolk, VA	MQS	Monitor
1/17/97	806	CG52	Bunker Hill	SDRW	N157	213	SURFPAC	Drydock	In-service	Yokosuka, JA	MQS	Routine
1/22/97	167	FFG28	Boone	SRD-56	27	124	SURFRES	Pierside	In-service	Jacksonville, FL	(Unknown)	Monitor
1/27/97	808	DDG67	Cole	SDRW	N189	245	SURFLANT	Drydock	In-service	Pascagoula, MS	GFS	Routine
2/12/97	809	DDG55	Stout	SDRW	N171	227	SURFLANT	Drydock	In-service	Greece	MTL	Routine
2/18/97	162	FFG48	Vandegrift	SRD-56	A041	999	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Monitor
3/6/97	163	FFG14	Sides	SRD-56	007	101	SURFRES	Drydock	In-service	San Diego, CA	MQS	Monitor
3/13/97	811	DD968	Radford	SDRW	N105	187	SURFLANT	Drydock	In-service	Norfolk, VA	NNSY	Re-inspect
3/18/97	164	FFG59	Kauffman	SRD-56	22	119	SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Re-inspect
3/22/97	811	DD975	O'Brien	SDRW	N87	130	SURFPAC	Drydock	In-service	Yokosuka, JA	MQS	Monitor
3/24/97	166	FFG60	Davis	SRD-56	12	106	SURFPAC	Drydock	In-service	Yokosuka, JA	MQS	Replace
3/26/97	812	DD968	Radford	SDRW	N105	187	SURFLANT	Drydock	In-service	Norfolk, VA	NNSY	Replace
3/26/97	165	FFG59	Kauffman	SRD-56	22	119	SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Monitor
3/27/97	815	F252	TCG KOCATEPE	SDRW	N22	31	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Routine
3/31/97	819	D29	CT PARANA	SDRW	N61	98	FOREIGN	Drydock	In-service	Rio de Janeiro, Brazil	AMRJ	Monitor

Date	Report	Hull	Ship	Dome Type	S/N	L/U	Fleet (Current)	Availability Type	Inspection Category	Location	Contractor	Recommended
4/8/97	813	CG47	Ticonderoga	SDRW	N113	160	SURFLANT	Pierside	In-service	Pascagoula, MS	MQS	Monitor
4/15/97	817	CG62	Chancellorsville	SDRW	N135	191	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Monitor
4/25/97	818	DDG56	McCain	SDRW	N181	237	SURFPAC	Drydock	In-service	Pearl Harbor, HI	MQS	Routine
7/7/97	822	DDG69	Milius	SDRW	N191	247	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Routine
7/22/97	823	DDG66	Gonzalez	SDRW	N192	248	SURFLANT	Drydock	In-service	Bath, ME	MQS	Replace
8/14/97	825	F255	TCG KARADENIZ	SDRW	N1	190	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Routine
8/26/97	824	F251	TCG ADATEPE	SDRW	N73	114	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Monitor
9/16/97	827	462	P. NAPHALAI	SDRW	N149	207	FOREIGN	Drydock	In-service	Portland, OR	MQS	Routine
9/22/97	828	DDG68	The Sullivans	SDRW	N193	249	SURFLANT	Pierside	In-service	Portland, ME	GFS	Routine
10/27/97	168	FFG41	McClusky	SRD-56	031	130	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Monitor
12/5/97	835	F250	TCG MAUVENET	SDRW	N155	211	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Routine
1/16/98	831	DDG53	Jones	SDRW	N170	226	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Routine
2/9/98	169	FFG50	Taylor	SRD-56	6	100	SURFLANT	Drydock	In-service	Norfolk, VA	NNSY	Replace
2/20/98	170	FFG43	Thach	SRD-56	031	128	SURFPAC	Drydock	In-service	Yokosuka, JA	MQS	Monitor
2/22/98	832	DD969	Peterson	SDRW	N116	167	SURFLANT	Drydock	In-service	Norfolk, VA	NNSY	Monitor
4/2/98	837	DDG70	Hopper	SDRW	N217	274	SURFPAC	Drydock	In-service	Pearl Harbor, HI	MQS	Routine
4/2/98	836	DDG71	Ross	SDRW	N194	250	SURFLANT	Drydock	In-service	Pascagoula, MS	GFS	Routine
4/7/98	171	F906	ENS EL ARISH	SRD-56	023	120	FOREIGN	Drydock	In-service	Charleston, SC	MQS	Routine
4/22/98	838	DD988	Thorn	SDRW	N137	193	SURFLANT	Pierside	In-service	Norfolk, VA	MQS	Monitor
4/28/98	839	CG66	Hue City	SDRW	N144	200	SURFLANT	Pierside	In-service	Mayport, FL	MQS	Routine
4/29/98	840	CG64	Gettysburg	SDRW	N131	184	SURFLANT	Pierside	In-service	Mayport, FL	MQS	Routine
5/2/98	841	CG47	Ticonderoga	SDRW	N113	160	SURFLANT	Pierside	In-service	Pascagoula, MS	MQS	Monitor
5/5/98	172	FFG54	Ford	SRD-56	A059	999	SURFPAC	Drydock	In-service	Seattle, WA	MQS	Monitor
5/18/98	843	F253	TCG ZAFER	SDRW	N58	95	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Monitor
7/15/98	845	CG49	Vincennes	SDRW	L1	133	SURFPAC	Drydock	In-service	Yokosuka, JA	MQS	Replace
7/22/98	846	DDG78	Porter	SDRW	N209	266	SURFPAC	Drydock	In-service	Pascagoula, MS	GFS	Routine
7/25/98	847			SDRW	N38	60	FOREIGN	Drydock	In-service	Charleston, SC	MQS	Monitor
9/1/98	848	CG51	Gates	SDRW	N178	234	SURFLANT	Pierside	In-service	Pascagoula, MS	MQS	Routine
10/11/98	850	DDG74	Mc Faul	SDRW	N196	253	SURFLANT	Drydock	In-service	Pascagoula, MS	GFS	Routine
10/22/98	851		YI YANG	SDRW	N64	101	FOREIGN	Drydock	In-service	Charleston, SC	MQS	Monitor
10/23/98	853	DDG73	Decatur	SDRW	N200	257	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Routine
11/12/98	854	CG52	Bunker Hill	SDRW	N157	213	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Routine

Date	Report	Hull	Ship	Dome Type	S/N	L/U	Fleet (Current)	Availability Type	Inspection Category	Location	Contractor	Recommended
1/4/99	859	D28	CT PARAIBA	SDRW	102	149	FOREIGN	Drydock	In-service	Rio de Janeiro, Brazil	BRAZIL	Routine
1/12/99	856	CG68	Anzio	SDRW	N146	202	SURFLANT	Pierside	In-service	Norfolk, VA	MQS	Routine
1/17/99	857	DD975	O'Brien	SDRW	N87	130	SURFPAC	Drydock	In-service	Yokosuka, JA	MQS	Monitor
2/2/99	858	DD970	Caron	SDRW	L8	34	SURFLANT	Drydock	In-service	Newport News, VA	MQS	Replace
2/6/99	860	CG50	Valley Forge	SDRW	L2	138	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Monitor
2/6/99	173	FFG32	Hall	SRD-56	32	129	SURFLANT	Drydock	In-service	Pascagoula, MS	GFS	Routine
3/8/99	862	CG67	Shiloh	SDRW	N150	204	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Monitor
3/16/99	870	F257	TCG Akdeniz	SDRW	N28	39	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Monitor
4/8/99	869	F256	TCG EGE	SDRW	N95	140	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Routine
4/26/99	864	DD985	Cushing	SDRW	N164	220	SURFPAC	Drydock	In-service	Yokosuka, JA	MQS	Routine
4/28/99	865	CG63	Cowpens	SDRW	N132	186	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Routine
5/3/99	866	CG71	St.George	SDRW	N165	221	SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Routine
5/12/99	868	DD992	Fletcher	SDRW	N158	214	SURFPAC	Drydock	In-service	Pearl Harbor, HI	MQS	Routine
5/14/99	867	F494	TCG GOKCEADA	SRD-56	A026	999	FOREIGN	Drydock	In-service	Charleston, SC	MQS	Replace
5/26/99	872	DD987	O'Bannon	SDRW	N176	232	SURFLANT	Pierside	In-service	Mayport, FL	MQS	Routine
6/8/99	873	DDG75	Cook	SDRW	N199	256	SURFLANT	Drydock	In-service	Portland, ME	GFS	Routine
7/3/99	880	F255	TCG KARADENIZ	SDRW	N1	190	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Routine
7/6/99	874	CG59	Princeton	SDRW	N119	170	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Monitor
7/22/99	878	PF932	CHIU YANG	SDRW	N101	148	FOREIGN	Drydock	In-service	Taiwan	(Unknown)	Routine
8/12/99	876	DDG55	Stout	SDRW	N171	227	SURFLANT	Drydock	In-service	Norfolk, VA	Conam	Routine
8/29/99	877	DDG78	Porter	SDRW	N209	266	SURFPAC	Drydock	In-service	Pascagoula, MS	GFS	Routine
9/1/99	879	CG69	Vicksburg	SDRW	N161	217	SURFLANT	Pierside	In-service	Mayport, FL	MQS	Routine
10/7/99	881	DDG76	Higgins	SDRW	N202	259	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Routine
10/20/99	886	PF934	FENG YANG	SDRW	N40	64	FOREIGN	Drydock	In-service	Taiwan	(Unknown)	Monitor
10/26/99	882	DD991	Fife	SDRW	N141	197	SURFPAC	Drydock	In-service	Bremerton, WA	MQS	Monitor
11/8/99	908	CG64	Gettysburg	SDRW	N131	184	SURFLANT	Drydock	In-service	Newport News, VA	Adams	Routine
11/10/99	883	CG58	Philippine	SDRW	CG58	180	SURFLANT	Drydock	In-service	Norfolk, VA	GLITSCH	Routine
11/16/99	884	CG72	Vella	SDRW	N167	223	SURFLANT	Pierside	In-service	Norfolk, VA	MQS	Routine
11/18/99	885	DD978	Stump	SDRW	N148	206	SURFLANT	Pierside	In-service	Norfolk, VA	MQS	Routine
12/29/99	887	FFG40	Halyburton	SRD-56	36	133	SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Replace
2/1/00	888	FFG8	McInerney	SRD-56	14	108	SURFLANT	Drydock	In-service	Charleston, SC	MQS	Replace
2/3/00	889	DD965	Kinkaid	SDRW	N128	183	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Replace

Date	Report	Hull	Ship	Dome Type	S/N	L/U	Fleet (Current)	Availability Type	Inspection Category	Location	Contractor	Recommended
2/9/00	893	F252	TCG KOCATEPE	SDRW	N22	31	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Routine
2/17/00	890	CG65	Chosin	SDRW	N133	188	SURFPAC	Pierside	In-service	Pearl Harbor, HI	MQS	Monitor
2/22/00	891	CG70	Erie	SDRW	N154	209	SURFPAC	Drydock	In-service	Pearl Harbor, HI	MQS	Routine
3/8/00	892	DD964	Foster	SDRW	N68	108	SURFPAC	Drydock	In-service	Puget Sound, WA	MQS	Repair
3/31/00	894	FFG11	Clark	SRD-56	003	97	FOREIGN	Drydock	In-service	Charleston, SC	MQS	Repair
4/13/00	895	DDG54	Wilbur	SDRW	N174	230	SURFPAC	Drydock	In-service	Yokosuka, JA	MQS	Routine
4/19/00	896	F253	TCG ZAFER	SDRW	N58	95	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Monitor
4/21/00	909	D30	CT PERNAMBUCO	SDRW	N93	137	FOREIGN	Drydock	In-service	Brazil	BRAZIL	Routine
5/11/00	897	DD969	Peterson	SDRW	N116	167	SURFLANT	Pierside	In-service	Norfolk, VA	MQS	Monitor
5/16/00	898	CG55	Leyte Gulf	SDRW	CG59	176	SURFLANT	Drydock	In-service	Norfolk, VA	MQS	Routine
5/17/00	899	CG47	Ticonderoga	SDRW	N113	160	SURFLANT	Pierside	In-service	Pascagoula, MS	MQS	Monitor
5/24/00	903	F256	TCG EGE	SDRW	N95	140	FOREIGN	Drydock	In-service	Ismit, Turkey	GNSY	Routine
6/1/00	900	DDG56	McCain	SDRW	N181	237	SURFPAC	Drydock	In-service	Yokosuka, JA	MQS	Routine
6/11/00	901	DD963	Spruance	SDRW	N142	198	SURFLANT	Drydock	In-service	Jacksonville FL	MQS	Routine
6/14/00	902	DD988	Thorn	SDRW	N137	193	SURFLANT	Pierside	In-service	Norfolk, VA	MQS	Monitor
8/29/00	904	CG73	Port Royal	SDRW	N172	228	SURFPAC	Drydock	In-service	Pearl Harbor, HI	MQS	Re-inspect
9/8/00	905	FFG46	Rentz	SRD-56	A033	999	SURFPAC	Drydock	In-service	San Diego, CA	MQS	Replace
9/29/00	906	CG73	Port Royal	SDRW	N172	228	SURFPAC	Drydock	In-service	Pearl Harbor, HI	MQS	Routine

APPENDIX B

X-Ray Data Requirements

NRL TECHNICAL DATA REQUIREMENTS FOR THE RADIOGRAPHIC INSPECTION OF SONAR DOME RUBBER WINDOWS (SDRW), REVISION 7, OCTOBER 2000

1. INSPECTION AREA

1.1 Due to the varying requirements for different splice designs, service histories, and inspection circumstances, the coverage required for each inspection is determined by NRL on a case-by-case basis.

1.2 Inspection coverage is described based on the exposure identification chart shown in Figure B-1. This chart establishes an identification scheme with exposures labeled in terms of the side (starboard or port), the column (A-E), and the row (1-10). Rows are determined by dividing columns into ten equal divisions of the distance between the upper and lower rubber lines, i.e. the marriage lines between the rubber dome and the hull. Columns consist of overlapping 14 x 17 inch film positions centered on pairs of parallel lines at multiples of 11 inches from the centerline. Film is oriented with the 17-inch dimension horizontal.

1.3 All measurements are made with reference to the outside surface of the SDRW at an allowed tolerance of +/- one inch. Note that the 11-inch lines on the charts are not <u>limits</u> to an exposure's coverage, but serve to identify overlapping exposures <u>centered</u> on pairs of the lines. For example, film in column B is expected to cover an area from 8 to 25 inches from the centerline. Labeling of the 11-inch lines is described below.

1.4 Upon request, NRL will provide the inspection coverage requirement for an SDRW by listing the individual exposures required from Figure B-1, by reference to standard sets of exposures in Figures B-2 through B-5, or a by a combination of standard sets and individual positions. For example, inspection of a known damaged SDRW might require the Figure B-5 coverage plus an exposure at location PB3 from Figure B-1. For convenience, a list of the coverage requirements for all ships will be maintained on the NAVSEA Program Executive Office for Mine and Undersea Warfare (PEO MUW) web site. See Contacts and Information Sources, below.

2. LABELING OF INSPECTION AREA

2.1 The inspection area shall be identified on the film by means of lead numbers and letters attached to the dome surface as follows. Lines of numbers at 2-inch intervals, beginning with 0 at the upper rubber line (URL), shall be placed at the SDRW centerline and at multiples of 11 inches port and starboard for the extent of the coverage. Every 10 inches, the numbers shall be accompanied by a "P" for port side or an "S" for starboard side, and a "B", "C", or "D" to indicate the 22, 33, or 44-inch outboard number lines, respectively. (An "A" may be used for the 11-inch line, but is not required.) Examples of the appearance of these number lines on the film are shown in Figure B-6.

2.2 To minimize interference with the images, numbers appearing on the film shall be no greater than 3/8 inch in height.

2.3 To facilitate interpretation, the numbers and letters shall appear in the same orientation as in Figure B-6. They shall be readable with the film image oriented to represent the SDRW as seen from its exterior, with starboard on the left and port on the right, regardless of the inspection procedure used (pierside or drydock).

3. OVERLAP OF INDIVIDUAL RADIOGRAPHS

To insure continuity of data, all radiographs shall be overlapped with adjacent radiographs a minimum of 1 inch.

4. IDENTIFICATION OF INDIVIDUAL RADIOGRAPHS

4.1 In addition to the number interval markers described above, each radiograph shall be labeled with the inspection date and the ship's hull number (or name), using letters and numbers no greater than 3/8 inch in height.

4.2 No company names or logos, or information other than the inspection date and hull number and the number lines described in section 2, above, shall appear on the radiographs. This exclusion applies to information formerly required, such as SDRW pressure and dome serial number.

4.3 Identification labeling may be done using lead numbers, film identification printer, or any other clearly readable permanent method.

4.4 The labels may appear along any edge of the exposures except the edges nearest to the 11-inch number lines, but should not interfere with any number line.

4.5 Labels shall be readable from the same side of the film as the number lines described in paragraph 2, with starboard on the left and port on the right.

5. RADIOGRAPH QUALITY REQUIREMENTS

5.1 ASTM E94-84 shall serve as a guide to producing high quality radiographs.

5.2 Fourteen- by seventeen-inch Kodak Industrex type M or equivalent fine grain film shall be used.

5.3 Radiographic sensitivity shall be maintained at a high level, such that resolution of the 0.005 inch diameter wire from an ASTM E 747-97, set A, material grade 1, penetrameter is obtained in the thinnest part of the inspection area. At least one radiograph shall display this penetrameter placed at approximately 45 degrees to the vertical. The penetrameter shall be placed source side at any convenient location from 50 to 70 inches from the upper rubber line, if included in the inspection area. Otherwise, it shall be placed source side at the outermost exposure of the inspection area and as far from the URL as possible. Figures B-2 through B-5 indicate preferred penetrameter locations for the various standard coverages.

5.4 Lead oxide intensification screens are recommended as an aid to obtaining sufficient radiographic sensitivity.

5.5 At least one radiograph must be submitted for each required exposure. The double loading of cassettes is not required but may be done at the discretion of the contractor to obtain imagery within the acceptable density range.

5.6 Film density and contrast shall be maintained within the limitations defined by an SDRW standard density strip traceable to a standard density strip approved by the Naval Research Laboratory.

5.7 Film density exceptions may be made as follows:

5.7.1 Areas of four square inches or less (on a 14 x 17 inch film) with densities outside the limits indicated on the standard density strip are acceptable.

5.7.2 Exposures located at those rows adjacent to the upper and lower rubber lines cover an area where the SDRW thickness change is greatest and uniform density is difficult to achieve. Up to 2/3 of these radiographs may be in the too light range, providing the remainder of the radiograph is acceptable.

5.8 Either high quality automatic processing or manual processing may be used. If manual processing is used, running water shall be used for film washing. The use of hypo eliminator is recommended to insure low levels of residual fixer on the radiographs. In order to satisfy the long term storage requirements for the radiographs, the residual hypo (fixer) level on the film shall not exceed that indicated by stain patch #3 of the Kodak Hypo Estimator No. J-11, when the film is tested with Kodak Hypo Test solution HT-2. This stain test indicates an allowable maximum of 5 micrograms/ square centimeter of residual thiosulfate ion.

6. INSPECTION DATA SHEET

An inspection data sheet containing the following information shall be included with the radiographs:

6.1 Contractor Company Name.

6.2 Inspection date.

6.3 Inspection facility and location (for example, "Southwest Marine, San Pedro, CA.")

6.4 NRL data requirement used (revision number).

6.5 Ship name or hull number.

6.6 SDRW serial number obtained from identification plate inside the dome.

6.7 List or chart indicating exposures provided, in terms of Figure B-1. (A copy of one of the figures in this document may be used.)

6.8 X-ray parameters: Tube potential (KV), source-to-object distance, spot size, and film type.

6.9 Notes describing any visual indications of damage or other anomalies.

6.10 Explanation for any deviation from this data requirement or from the required inspection area.

6.11 Point of contact: Name and phone number of contractor's on-site person in charge during the inspection.

7. QUALIFICATIONS OF INSPECTION CONTRACTOR

7.1 Radiographs will only be accepted from an NRL approved contractor or approved Navy NDE facility.

7.2 Contractors are approved separately for drydock and pierside (underwater) inspections.

7.3 To become approved and eligible to conduct SDRW radiography, a contractor must request and obtain access to a ship and conduct a trial inspection at their own expense. Upon receipt of radiographs that satisfactorily comply with this data requirement and a copy of the contractor's written SDRW inspection procedure, NRL will recommend addition to the approved contractor list.

7.4 Previously approved contractors that have not provided a copy of their written SDRW inspection procedure with NRL must do so to remain qualified.

7.5 Prospective and current SDRW radiography contractors are encouraged to visit the NRL Sonar Dome NDE Lab for orientation as to the goals and requirements of the inspection program.

7.6 The approved contractor list is maintained on the NAVSEA Program Executive Office for Mine and Undersea Warfare (PEO MUW) web site, *uswinfo.com* for access by Navy facilities and contractors.

8. CRITERIA FOR RADIOGRAPH ACCEPTANCE AND REJECTION

8.1 Radiographs will be accepted that meet all of these requirements:

8.1.1 Provided by an NRL approved contractor, as defined above.

8.1.2 Satisfy the current inspection area requirement for the particular SDRW as determined and provided by NRL or posted on the PEO UMW web site.

8.1.3 Satisfy the image quality and identification requirements of this document.

8.2 Radiographs will be rejected, resulting in a recommendation to re-inspect the SDRW, if there is insufficient coverage of the required inspection area (or inability to determine the coverage) due to any of the following:

8.2.1 Missing required exposures

8.2.2 Missing imagery on required exposures (areas not exposed).

8.2.3 Lack of film overlap where required.

8.2.4 Density or contrast outside the limits given in paragraph 5.6

8.2.5 Double exposures.

8.2.6 Excessive distortion or blurring of the image.

8.2.7 Missing film identification or any required labeling.

8.2.8 Artifacts of handling or processing that interfere with interpretation.

9.0 RADIOGRAPH SHIPPING INSTRUCTIONS

9.1 Radiographs shall be shipped by overnight express to arrive at NRL for interpretation on the next business morning, if possible. Delivery of the processed x-ray film to NRL must be given a high priority because the results can impact drydock work schedules or ship deployments. The shipping address is:

Naval Research Laboratory
Bldg. 207, Room 112
4555 Overlook Avenue, S.W.
Washington DC 20375

Attention: E. Greenawald, Code 6120

9.2 Do not ship to NRL for Saturday delivery. NRL is closed on weekends, evenings, and federal holidays. If an urgent interpretation is required during these times, special delivery arrangements must be made through the NRL point of contact. On-site (at the ship) interpretation can also be arranged if required by the Navy.

10.0 CONTACTS AND INFORMATION SOURCES

10.1 For individual SDRW inspection coverage requirements and other matters pertaining to SDRW radiography, contact NRL Code 6120:

Mr. Ed Greenawald
Phone: (202) 767-3039
E-mail: ed.greenawald@xbt.nrl.navy.mil

10.2 For inspection results, required actions, and other sonar dome system inquiries contact NAVSEA PMS 411:

Mr. Stan Silverstein
Phone: (703) 604-5067, Ext. 217
E-mail: SilversteinST@navsea.navy.mil

10.3 The approved radiography contractor list, the current version of this data requirement, and the recommended SDRW inspection schedules with coverage requirements are posted on the Program Executive Office for Mine and Undersea Warfare (PEO MUW) web site, *uswinfo.com*. Instructions for obtaining an account and accessing this information are available from the NRL contact. account and accessing this information are available from the NRL contact.

	Starboard E	D	C	B	A	℄ A	B	C	D	Port E
1	SE1	SD1	SC1	SB1	SA1	PA1	PB1	PC1	PD1	PE1
2	SE2	SD2	SC2	SB2	SA2	PA2	PB2	PC2	PD2	PE2
3	SE3	SD3	SC3	SB3	SA3	PA3	PB3	PC3	PD3	PE3
4	SE4	SD4	SC4	SB4	SA4	PA4	PB4	PC4	PD4	PE4
5	SE5	SD5	SC5	SB5	SA5	PA5	PB5	PC5	PD5	PE5
6	SE6	SD6	SC6	SB6	SA6	PA6	PB6	PC6	PD6	PE6
7	SE7	SD7	SC7	SB7	SA7	PA7	PB7	PC7	PD7	PE7
8	SE8	SD8	SC8	SB8	SA8	PA8	PB8	PC8	PD8	PE8
9	SE9	SD9	SC9	SB9	SA9	PA9	PB9	PC9	PD9	PE9
10	SE10	SD10	SC10	SB10	SA10	PA10	PB10	PC10	PD10	PE10

44 33 22 11 0 11 22 33 44

Inches from SDRW centerline (locations of vertical lead number lines)

Figure B-1. SDRW radiograph exposure identification chart. Fourteen- by seventeen-inch exposures are oriented with the long dimension horizontal and centered between pairs of lines multiples of eleven inches from the centerline. The upper rubber line (URL) and lower rubber line (LRL) are where the rubber dome meets the hull. This chart is used to identify and communicate the required inspection coverage as determined on a case-by-case basis by NRL. For convenience, the following Figures B-2 through B-5 designate groups of exposures frequently required.

Starboard ℄ **Port**

	E	D	C	B	A	A	B	C	D	E
1		SD1	SC1	SB1	SA1	PA1	PB1	PC1	PD1	
2		SD2	SC2	SB2	SA2	PA2	PB2	PC2	PD2	
3					SA3	PA3				
4					SA4	PA4				
5					SA5	PA5 *				
6					SA6	PA6				
7					SA7	PA7				
8					SA8	PA8				
9					SA9	PA9				
10					SA10	PA10				

44 33 22 11 0 11 22 33 44

Figure B-2. Standard minimum inspection area for drydock inspection of 5-ply SDRWs. If required, additional exposures will also be designated in terms of Figure B-1.

* Recommended penetrameter location.

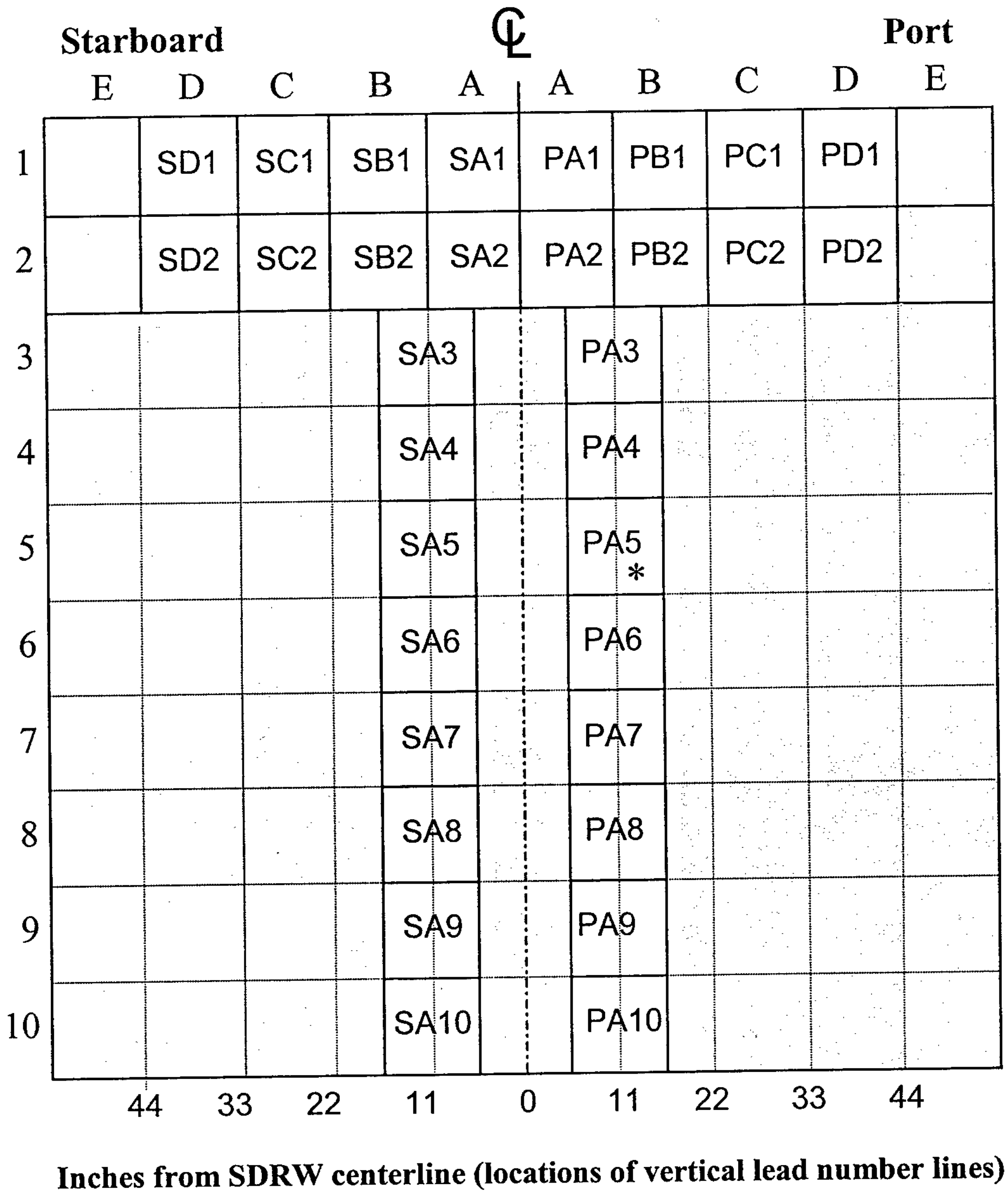

Figure B-3. Standard minimum inspection area for drydock inspection of 6-ply SDRWs. Note the deviation from Figure B-1 in the use of an alternate placement of the A column below row 2. These exposures are to be centered on the lines 11 inches from the centerline instead of between the 0 and 11 inch lines. If required, additional exposures will also be designated in terms of Figure B-1.

* Recommended penetrameter location.

	Starboard				℄					Port
	E	D	C	B	A	A	B	C	D	E
1			SC1	SB1	SA1	PA1	PB1	PC1		
2			SC2	SB2	SA2	PA2	PB2	PC2 *		
3										
4										
5										
6										
7										
8										
9										
10										

44 33 22 11 0 11 22 33 44

Inches from SDRW centerline (locations of vertical lead number lines)

Figure B-4. Standard minimum inspection area for pierside (underwater) on-schedule inspection of SDRWs with no known damage.

* Recommended penetrameter location.

Starboard ℄ **Port**

	E	D	C	B	A	A	B	C	D	E
1		SD1	SC1	SB1	SA1	PA1	PB1	PC1	PD1	
2		SD2	SC2	SB2	SA2	PA2	PB2	PC2	PD2 *	
3										
4										
5										
6										
7										
8										
9										
10										

44 33 22 11 0 11 22 33 44

Inches from SDRW centerline (locations of vertical lead number lines)

Figure B-5. Standard minimum inspection area for pierside (underwater) inspection of SDRWs that have known damage or are significantly overdue. Additional exposures may be designated in terms of Figure B-1.

* Recommended penetrameter location.

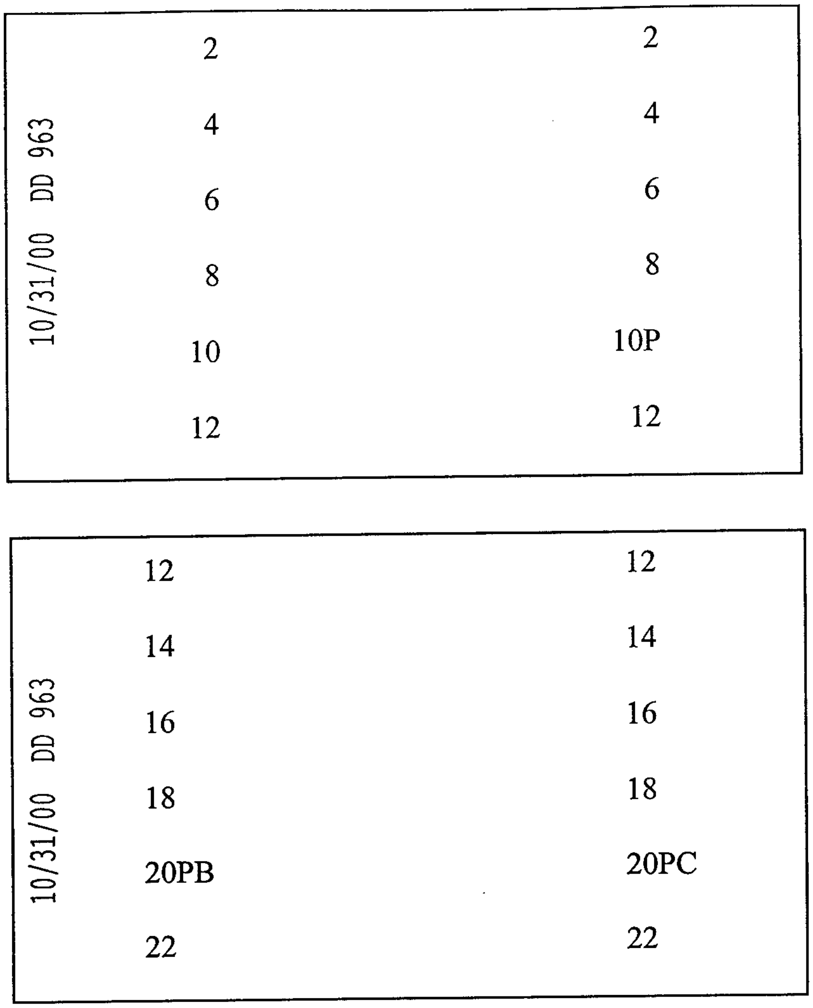

Figure B-6. Examples of required radiograph identification markings typical of exposures PA1 (top) and PC2. Exposures are centered on pairs of lead number lines 11 inches apart. Every 10 inches, letters identify the port or starboard side of the dome (P or S) and the 22, 33, or 44 inch number lines (B,C, or D). An ID strip along one edge contains the date and ship's hull number. Note that all markings are readable from the same view, with port to the right (as if facing the SDRW). The diagram is not to scale.

APPENDIX C

Travel Summary

GEO-CENTERS SUMMARY OF TRAVEL
Performed on Contract N00014-94-C-2195

Employee Name	Date	Location	Purpose
Howard Schrader	October 1994	Jacksonville, FL	Verify operation of load cells
Ed Greenawald	December 1994	Oakridge, TN	Program Review
Ed Greenawald	January 1995	Houston, TX	Commercial Diving Exhibit
Howard Schrader	January 1995	Newport News, VA	Bow measurements on USS THORN
Howard Schrader	February 1995	Key West, FL	Set up hydropeel experiment
Ken Campbell	February 1995	Key West, FL	Sample seawater testing
Ken Campbell	March 1995	Key West, FL	Sample seawater testing
Henry Hu	April 1995	Anaheim, CA	American Chemical Society Meeting
Charles Draper	May 1995	Norfolk, VA	X-ray interpretation for USS ROBERTS
Leroy Levenberry	May 1995	Norfolk, VA	X-ray interpretation for USS ROBERTS
Howard Schrader	May 1995	Jacksonville, FL	Instrumentation of SDRWs
Henry Hu	July 1995	Poughkeepsie, NY	International Conference on Advanced Polymers
Howard Schrader	August 1995	Newport News, VA	Inspect SDRW on USS STUMP
Ed Greenawald	August 1995	Seattle, WA	QNDE Conference
Ken Campbell	August 1995	Key West, FL	Sonar dome testing – check progress
Ed Greenawald	September 1995	New Orleans, LA	Composite Engineering International Conference
Charles Draper	October 1995	Dallas, TX	ASNT Fall Conference – present paper
Howard Schrader	November 1995	Jacksonville, FL	SDRW/RHO-COR
Jodi Smallhorn	November 1995	Jacksonville, FL	Verify operation of load cells/install cable retainers
Howard Schrader	December 1995	Melbourne, FL	Marine Composite Workshop
Howard Schrader	December 1995	Jacksonville, FL	RHO-COR Meeting
Kevin Riley	March 1996	Charleston, SC	Measure for rigging to do dome inspection
Ed Greenawald	March 1996	Charleston, SC	Visit USS STARK
Ken Campbell	March 1996	Miami/Key West, FL	Set up experiments

Employee Name	Date	Location	Purpose
Ken Campbell	March 1996	Melbourne, FL	MACM 96 Conference
Howard Schrader	March 1996	Miami/Key West, FL	Set up experiments
Howard Schrader	March 1996	Melbourne, FL	MACM 96 Conference
Henry Hu	April 1996	New Orleans, LA	American Chemical Society Meeting
Howard Schrader	June 1996	Norfolk, VA	SDRW discussions
Ed Greenawald	August 1996	Norfolk, VA	Planning for sonar dome inspection
Ken Campbell	August 1996	Key West, FL	Pick up samples for testing
Howard Schrader	August 1996	Key West, FL	Pick up samples for testing
Jodi Smallhorn	August 1996	Key West, FL	Pick up samples for testing
Ed Greenawald	September 1996	Norfolk, VA	Inspect sonar dome
Ed Greenawald	September 1996	Brunswick, ME	QNDE Meeting
Leroy Levenberry	September 1996	Norfolk, VA	Inspect sonar dome
Kevin Riley	September 1996	Norfolk, VA	Inspect sonar dome
Ken Campbell	September 1996	Jacksonville, FL	Site visit for sonar dome assembly
Leroy Levenberry	October 1996	Seattle, WA	ASNT Fall Conference – present paper
Ed Greenawald	October 1996	Norfolk, VA	Inspect sonar dome
Leroy Levenberry	October 1996	Norfolk, VA	Inspect sonar dome
Howard Schrader	October 1996	Jacksonville, FL	Examine RHO-COR SRD layout
Ed Greenawald	November 1996	Norfolk, VA	Inspect sonar dome
Leroy Levenberry	November 1996	Norfolk, VA	Inspect sonar dome
Howard Schrader	December 1996	Jacksonville, FL	View boring of RHO-COR dome flange
Ted Bellinger	January 1997	Jacksonville, FL	Inspect sonar domes on USS TAYLOR/PERRY
Ed Greenawald	January 1997	Jacksonville, FL	Inspect sonar domes on USS TAYLOR/PERRY
Leroy Levenberry	January 1997	Jacksonville, FL	Inspect sonar domes on USS TAYLOR/PERRY
Ken Campbell	January 1997	Key West, FL	Sample testing
Jodi Smallhorn	January 1997	Key West, FL	Sample testing
Howard Schrader	January 1997	Jacksonville, FL	RHO-COR keel dome hydrotest
Ted Bellinger	February 1997	Jacksonville, FL	Inspect sonar dome

Employee Name	Date	Location	Purpose
Ed Greenawald	February 1997	Jacksonville, FL	X-ray system maintenance
Leroy Levenberry	February 1997	Jacksonville, FL	X-ray system maintenance
Ken Campbell	February 1997	Key West, FL	Hydropeel test setup
Jodi Smallhorn	February 1997	Key West, FL	Hydropeel test setup
Ted Bellinger	March 1997	Monroeville, PA	Technical discussions
Jodi Smallhorn	March 1997	Norfolk, VA	Hardware removal
Howard Schrader	March 1997	Norfolk, VA	Hardware removal
Ken Campbell	April 1997	Norfolk, VA	Observe installation of sonar dome
Howard Schrader	May 1997	Norfolk, VA	Technical meetings
Ken Campbell	June 1997	Norfolk, VA	Install equipment on ship
Jodi Smallhorn	June 1997	Norfolk, VA	Install equipment on ship
Howard Schrader	June 1997	Norfolk, VA	Install equipment on ship
Ken Campbell	July 1997	Norfolk, VA	Install equipment on ship
Jodi Smallhorn	July 1997	Norfolk, VA	Install equipment on ship
Howard Schrader	July 1997	Norfolk, VA	Install equipment on ship
Peter Mott	July 1997	Salt Lake City, UT	Launch observation
Peter Mott	July 1997	Newport, RI	Program Review
Ed Greenawald	August 1997	San Diego, CA	QNDE Conference
Howard Schrader	August 1997	Key West/Miami/Jax, FL	Remove and test samples/SDRW meeting
Ken Campbell	September 1997	Key West/Miami/Jax, FL	Flow trough testing of coating samples
Leroy Levenberry	October 1997	Pittsburgh, PA	ASNT Fall Conference
Ed Greenawald	November 1997	Atlanta, GA	Meeting with NAVSEA at Phillips Industries
Peter Mott	November 1997	Newport, RI	Program Review
Ted Bellinger	December 1997	Dallas, TX	ASME Conference
Ken Campbell	January 1998	Norfolk, VA	Remove equipment from ship
Howard Schrader	January 1998	Norfolk, VA	Inspect sonar equipment/remove equipment
Jodi Smallhorn	January 1998	Norfolk, VA	Remove equipment from ship
Peter Mott	February 1998	Newport, RI	Program Review

Employee Name	Date	Location	Purpose
Ed Greenawald	April 1998	San Antonio, TX	SPIE Conference
Ken Campbell	April 1998	Jacksonville, FL	Technical meetings
Ken Campbell	April 1998	Melbourne, FL	MACM 98 Conference
Howard Schrader	April 1998	Jacksonville, FL	Technical meetings
Howard Schrader	April 1998	Melbourne, FL	MACM 98 Conference
Ken Campbell	June 1998	Key West, FL	Flow trough testing of coating samples
Jodi Smallhorn	June 1998	Key West, FL	Flow trough testing of coating samples
Ted Bellinger	July 1998	Las Vegas, NV	Composite Engineering International Conference
Ed Greenawald	July 1998	Salt Lake City, UT	QNDE Conference
Ed Greenawald	July 1998	Jacksonville, FL	Visit NDE laboratory
Howard Schrader	October 1998	Jacksonville, FL	Observe fusion process
Ed Greenawald	November 1998	Fort Collins, CO	NDT lab visit
Peter Mott	November 1998	Newport, RI	Program Review
Ken Campbell	December 1998	Jacksonville, FL	RHO-COR control panel construction
Ken Campbell	December 1998	Norfolk, VA	Trial fit mock-up
Howard Schrader	December 1998	Norfolk, VA	Trial fit mock-up
Howard Schrader	December 1998	Jacksonville, FL	RHO-COR control panel construction
Jodi Smallhorn	December 1998	Jacksonville, FL	RHO-COR control panel construction
Jodi Smallhorn	December 1998	Norfolk, VA	Trial fit mock-up
Jodi Smallhorn	January 1999	Jacksonville, FL	RHO-COR control panel construction
Ed Greenawald	March 1999	Jacksonville, FL	Observe ultrasonic testing
Ken Campbell	March 1999	Jacksonville, FL	Sonar dome meetings
Howard Schrader	March 1999	Jacksonville, FL	Sonar dome meetings
Jodi Smallhorn	March 1999	Jacksonville, FL	Sonar dome meetings
Peter Mott	March 1999	San Diego, CA	TMS Annual Meeting
Ed Greenawald	May 1999	Jacksonville, FL	Observe ultrasonic testing
Ken Campbell	May 1999	Jacksonville, FL	Observe panel fabrication
Howard Schrader	June 1999	Jacksonville, FL	RC sonar dome CAP meeting

Employee Name	Date	Location	Purpose
Jodi Smallhorn	June 1999	Jacksonville, FL	RC sonar dome CAP meeting
Ken Campbell	June 1999	Key West, FL	Set up hydropeel tank
Ken Campbell	June 1999	Jacksonville, FL	Sonar dome meeting
Jodi Smallhorn	June 1999	Key West, FL	Set up hydropeel tank
Howard Schrader	July 1999	Jacksonville, FL	Review progress of bow chains
Howard Schrader	July 1999	Bathe, ME	Inspect dome module
Peter Mott	July 1999	Manchester, NH	Present paper at conference
Ed Greenawald	August 1999	Montreal, Canada	QNDE Progress Review
Ken Campbell	August 1999	Jacksonville, FL	Submarine meeting/work with personnel
Howard Schrader	August 1999	Jacksonville, FL	Submarine meeting/work with personnel
Ed Greenawald	September 1999	Paris, France	Attend Workshop on Advanced Microwave NDE
Jodi Smallhorn	September 1999	Schenectady, NY	Meeting with coating manufacturer and sponsor
Ken Campbell	October 1999	Jacksonville, FL	Program Review
Ken Campbell	October 1999	Houston, TX	Meeting with representative of paint company
Howard Schrader	October 1999	Jacksonville, FL	Program Review
Ken Campbell	November 1999	Key West, FL	Hydropeel testing
Jodi Smallhorn	November 1999	Key West, FL	Hydropeel testing
Howard Schrader	December 1999	Jacksonville, FL	Meeting at BF Goodrich
Howard Schrader	January 2000	Jacksonville, FL	GFG-EPP meetings
Ed Greenawald	February 2000	Charleston, SC	Sonar dome meeting
Ken Campbell	February 2000	Key West, FL	Remove test samples
Ken Campbell	March 2000	Jacksonville, FL	Visit BF Goodrich
Jodi Smallhorn	March 2000	Key West, FL	Remove test samples
Ken Campbell	June 2000	Jacksonville, FL	Observe fabrication of panel/SDRW meeting
Ken Campbell	July 2000	Jacksonville, FL	NSDCW Program Review
Howard Schrader	July 2000	Jacksonville, FL	NSDCW Program Review
Ken Campbell	September 2000	Key West, FL	Flowing seawater test
Ken Campbell	September 2000	Jacksonville, FL	Sonar dome program review
Howard Schrader	September 2000	Jacksonville, FL	Sonar dome program review

APPENDIX D

Glossary of Acronyms

GLOSSARY OF ACRONYMS USED IN THIS REPORT

AMNTL	Applied Microwave Nondestructive Testing Laboratory
AS	accumulator system
ASNT	American Society for Nondestructive Testing
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BFG	B.F. Goodrich Co. Engineered Polymer Products Division, Jacksonville Florida
CAI	compression after impact
CAP	corrective action program
CCMS	Committee on the Challenges of Modern Society (NATO)
COR	contract officer's representative
CRADA	cooperative research and development agreement
EES	elastomeric ejection system
FEA	finite element analysis
FEM	finite element model
FRP	fiber reinforced plastic
GRP	glass reinforced plastic
HTML	hypertext markup language
JAX	Jacksonville, Florida
LVDT	linear variable differential transformer
MCM	mine countermeasures
MMRTS	Miami Marine Research and Testing Station
MTS	Materials Testing System
MUW	mine and undersea warfare
NAC	non-autoclave cure
NATO	North Atlantic Treaty Organization
NAVSEA	Naval Sea Systems Command
NAVSSES	Naval Ship Systems Engineering Station
NCD	Navy composite dome (composite keel dome)
NDE	nondestructive evaluation (a.k.a. NDI, NDT)
NDI	nondestructive inspection
NDT	nondestructive testing
NNSY	Norfolk Naval Shipyard
NRL	Naval Research Laboratory
NRLMCF	NRL Marine Corrosion Facility
NSDCW	Navy sonar dome composite window SDRCW)
NSWCCD	Naval Surface Warfare Center, Carderock Division
NUWC	Naval Undersea Warfare Center
OAS	Ocean, Atmosphere, and Space Department (of ONR)
ONR	Office of Naval Research

PAWDS	plasma arc waste disposal system
PEO	Program Executive Office
QNDE	quantitative nondestructive evaluation
RCKD	Rho-Cor keel dome
SACMA	Suppliers of Advanced Composite Materials Association
SCD	sonar composite dome (composite keel dome, a.k.a. RCKD, NCD)
SCSR	special clothing storeroom
SDCW	sonar dome composite window (composite bow dome, a.k.a. NSDCW, SDRCW sonar dome Rho-Cor window
SDRW	sonar dome rubber window (bow dome)
SGI	Silicon Graphics, Inc.
SOW	Statement of Work
SPIE	International Society for Optical Engineering
SPS	sonar dome pressurization station
SRD	sonar rubber dome (keel dome)
SRD-56	AN/SQS-56 sonar rubber dome
SRM	SACMA Research Method
SSBN	ballistic missile submarine, nuclear
TBTO	tri-butyl tin oxide
TMS	The Minerals Metals and Materials Society
URL	upper rubber line
URL	uniform resource locator (World Wide Web address)
USW	undersea warfare
UT	ultrasonic testing
XBT	xray backscatter tomography