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SMOOTH COMPLIANT ANTIFOULANT COATINGS

Advanced Conformal Submarine Acoustic Sensor (ACSAS) Outer Decoupler Research and Development

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Final Technical Report for Flow Noise and Outer Decoupler Study.
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Fiber reinforced composites provide a wide array of structural and acoustic properties. The composites may be isotropic or extremely anisotropic, and offer considerable flexibility for designing underwater acoustic sensor flow noise outer decouplers. Compliant layers appear to be effective in suppressing flow noise; however, effectiveness diminishes with depth, in part because of material compressibility and distortions caused by own ship's speed. Composite materials can be fabricated with high strength and modulus to maintain shape under severe loads to eliminate erratic acoustic performance caused by outer decoupler distortion.

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SUMMARY

An initial study of antifoulants for the ACSAS outer decoupler has provided recommendations for outer decoupler research and development during fiscal years 1983 and 1984. The outer decoupler, which has a smooth, biocidal surface, is required to allow transmission of sound from a target to the hydrophones, suppress flow noise, and provide an outer surface that maintains structural and shape integrity at all operational depths.

Compliant layers in thick section have been developed to relatively high efficiency, but are compressible and lose effectiveness when submerged to great depths. In thin section, however, compliant coatings can be quite effective, particularly to control biocide leach rates. This program is developing composite, fiber reinforced polymers with tailored properties to provide optimum acoustical and structural performance.

The use of composites with selected properties of the fiber and the matrix and carefully designed structures offers the possibility of tailoring acoustic properties to meet specific requirements. As a bonus, polymeric matrices allow chemical integration with biocides to provide long-term biocidal action while permitting the formation of a smooth outer surface.

PREFACE

This document is the final report for the ACSAS outer decoupler antifoulant coating study conducted by Presearch Incorporated under Office of Naval Research contract number N00014-82-C-0592. Presearch, as prime contractor, was supported under subcontract by the Pennwalt Corporation, Fiber Materials Incorporated, and Rockwell International's Autonetics Marine Systems Division.

An interim technical report, Technical Memorandum No. 82-017, dated 7 July 1982, addressed technical concepts and approaches for developing composite material outer decouplers that incorporate biocidal antifoulants. This final report is a continuation of Technical Memorandum No. 82-017 with emphasis on results of the team's antifoulant technology survey, and a discussion of recommendations for fabrication and testing of candidate composite materials for the outer decoupler.

The contract statement of work directed the Presearch team to investigate smooth, compliant, antifoulant coatings with potential application to the ACSAS outer decoupler. The team's responding technical approach consisted of three principal tasks: (1) A survey of current biocide technology, (2) an analysis of composite materials for the outer decoupler, and (3) the development of a recommended plan for continuing antifoulant outer decoupler research and development during fiscal years 1983 and 1984. This final report presents the team's findings and recommendations.

This contract statement of work directed the Presearch team to study smooth, compliant antifoulant coatings. The team's analysis of ACSAS requirements determined at the outset that the antifoulant should be an integral part of the outer decoupler material composite, and should be designed to maximize structural rigidity with minimum coupling of the flow pressure fluctuations and structure-borne vibrations. If the necessary properties are designed into the outer decoupler composite material, the desired acoustic properties can be achieved without the structural limitations of elastomeric materials normally classed as compliant. Therefore, compliance, as used in this document, refers to an antifoulant that is compliant or transparent to acoustic energy, and that maintains sound structural properties.

CONTENTS

SMOOTH COMPLIANT ANTIFOULANT COATINGS FOR THE ADVANCED CONFORMAL SUBMARINE ACOUSTIC SENSOR

1. DESIGN CONCEPTS

1.1 Introduction. Properly designed fiber reinforced composite materials can provide excellent characteristics for ACSAS outer decoupler application because of their structural and acoustic properties. With a comprehensive understanding of the submarine operational profile, the engineer can design an ACSAS outer decoupler that incorporates an antifoulant as an integral part of the material substrate, and that has mechanical properties that transmit acoustic wave pressure to the hydrophone without distortion. Perhaps the most interesting characteristic of material composites is the property of certain fibers and matrices to transmit acoustic pressures anisotropically. This transmission characteristic can be used to design a material composite that attenuates near field pressure fluctuations associated with the flow and reduce surface structure-borne vibrations while effectively transmitting target signals to the hydrophone. Furthermore, material composites can be designed with the structural strength to withstand speed and depth stress encountered by high-performance submarines so as to maintain their acoustic fidelity. Compliant layers, on the other hand, are subject to severe material compression at great depths and high own-ship speeds. Thus compliant layer outer decouplers that appear effective in suppressing flow noise cause erratic acoustic performance at extreme speeds and depths as a result of material compression, which changes sound energy transmission properties.

The purpose of this study has been to identify experimental outer decoupler material structures for acoustic tests. These material composites will include an antifouling biocide as an integral part of the structure to assure a smooth outer decoupler surface during submarine operations between overhauls. The material structures identified by this study will be fabricated and tested during the recommended follow-on R&D for their ACSAS suitability, to verify flow noise and acoustic transmission models, and to provide additional data for math model modification. The next phase of Presearch's recommended outer decoupler R&D program will concentrate on the design and fabrication of different material structures to test new concepts for flow noise reduction, enhanced signal transmission to the hydrophone, drag reduction, extended antifoulant life, and electro-mechanical interaction with a large area polymer array. Our experimental outer decoupler designs will be based on established performance prediction models developed by the Navy laboratories and the Presearch team. A close working relationship with the designers of the large area polymer array and the marine architects responsible for submarine hull design will be maintained throughout the outer decoupler R&D phase to assure proper interface coordination between all elements of the array and hull.

2. BIOCIDE TECHNOLOGY SURVEY RESULTS

2.1 Overview. During this initial study, the Presearch team reviewed the state of the art in marine antifoulant technology. As part of this technology review, the team visited the Naval Ship Research and Development Center (NSRDC) in Annapolis, Maryland. NSRDC has a major antifoulant research and development program with the principal objective of developing a universal antifoulant that could be used on a wide variety of hull materials. In the course of this research, NSRDC rejected a number of antifoulant techniques that did not meet the universality criteria; however, several appear to be candidates for the ACSAS outer decoupler antifoulant. Of these, the organo-tin compounds are the most advanced in development and capability.

The Presearch team's biocide technology survey concentrated on two major issues:

- The biocide and its toxicity
- Vehicles to control leach rate.

As a result, the team was able to identify several highly effective biocide candidates and promising techniques to improve their release rate. One such technique with a potentially high payoff is the incorporation of the biocide within the substrate polymer chain. This permits the antifoulant to be held chemically rather than by the more conventional mechanical binding methods achieved through materials mixing.

2.2 Biocide Technology State of the Art. The U.S. Navy has traditionally used red lead as a basis for protection against marine fouling. The antifoulant coating consists of a metal pretreatment coat, four coats of an anticorrosive primer, and two coats of red lead antifouling vinyl material. The result is an antifoulant coating that provides 18 to 24 months of protection; however, it is brittle and subject to cracking, peeling, and erosion, thus inducing a noticeable increase in turbulent flow. Red lead antifoulants are unacceptable for sonar domes and outer decouplers.

Most recent biocide research has been done by Navy laboratories and has been directed along two lines: searches for better biocides and improved base materials to carry the biocide. Because of the high acoustic performance requirements of modern sonars, this research considered both the interrelationships of the biocide with its carrying vehicle and the relationship between the antifoulant materials and the substrate (i.e., sonar dome or outer decoupler). The most promising antifoulants identified by this research are the organo-metallic salts, particularly tri-n-butyltin oxide (TBTO) and tri-n-butyltin fluoride (TBTF). Taken by themselves in a conventio paint base, they leach out too quickly to be acceptable for ACSAS. However, chemical incorporation of the biocide within elastomers such as neoprene effectively retards the leach rate to acceptable levels. Biocide integration with epoxies and glass reinforced plastics also has been shown to be effective.

Biocide carrier research has revealed two promising techniques:

- The use of elastomers
- Incorporating the biocide into a polymer chain.

The elastomer approach uses a conventional elastomeric material, such as neoprene, as a basic vehicle. The biocide is then blended with it. The resulting mixture can be molded, formed into sheets, or dispersed into paints. The mixture is flexible, durable, easily applied, acoustically attractive in terms of specific acoustic impedance (ρc), lack of depth sensitivity, and exhibits excellent antifouling characteristics.

The polymer binding technique has received the most attention and shows great promise. Much of the research used methacrylates for the polymer backbone with organo-tin biocides incorporated into the polymer molecular chain. The resulting compounds exhibited excellent leach rates and antifoulant characteristics. They are also easy to apply and have satisfactory acoustic characteristics.

Although both techniques for carrying biocides proved to be effective, they were not acceptable as universal solutions for all Navy antifoulant problems. Further research was therefore discontinued. However, both of these biocide carrying techniques are very attractive for the material composite outer decoupler concept for ACSAS, and further research should be directed in this capacity to these promising techniques.

2.3 RECOMMENDED APPROACH

Based upon the team's findings thus far, a favored approach for chemical integration of the biocide with the outer decoupler matrix is the incorporation of biocidal organo-metallic salts directly onto polymeric backbones. This approach appears to have major advantages in leach rate control over more conventional mixture methods that combine resins and salts, such as epoxies or vinyls, with the biocide. The Presearch team recommends emphasis on chemical bonding techniques during the next phase of this R&D effort. Research should focus on two classes of organometal polymers: those using thermosetting resins (e.g., phenolics, polyesters, epoxies), and thermoplastics (e.g., methacrylates, vinyls, styrenes). The resulting polymer with its chemically bonded biocide releases the toxicant at a controlled rate as a result of oxidation or hydrolisis in sea water. The rate of toxicant release can be controlled by molecular weight and by the degree of biocide-polymer crosslinking. Crosslinking is controlled by varying the amount of biocide substituted for polymer molecules and its location within the polymer backbone. Several such antifoulant polymers have been synthesized and laboratory tested. They have exhibited excellent resistance to marine fouling, and appear to be promising candidates for integrating within a composite material matrix.

An alternative approach to developing an outer decoupler antifoulant coating would be the use of thick elastomers with controlled leaching. This approach has been investigated in U.S. Navy laboratories where research has concentrated on conventional elastomers comprised of chloro-butadiene-styrene compounds. The elastomers are then compounded with traditional biocides. This approach showed an appreciable improvement in retarding marine growth; however, the elastomer compounds were not compatible with metal substrates, hence further research was terminated by the Navy. Although unsatisfactory for metal hulls, these elastomers could prove to be satisfactory when used in conjunction with the ACSAS outer decoupler material composite. It is recommended that this research be continued and that other elastomers be investigated, particularly those with high tear resistance such as polyurethane.

A third class of antifouling technology that has received little research has high potential for ACSAS. These are the pure organic toxins such as oxybisphenoxarsine and chlorinated phenols. The leach rate for these toxins has been difficult to control; however, combining organic toxins with an elastomer or within a polymer backbone could provide a means for controlling these very effective biocides. It is therefore recommended that the next phase of ACSAS outer decoupler antifoulant research include the pure organic toxins.

2.4 CANDIDATE TECHNOLOGIES

As a result of our survey, three antifoulant technologies should be considered for the ACSAS outer decoupler. These are as follows:

- High toxicity biocides
- Release rate control by polymerization
- Release rate control with elastomers.

High toxicity biocides have toxicity levels and release rates that exceed acceptable levels for most antifoulant applications. These high toxicity biocides include the following:

- Chlorinated phenols
- Heavy metals such as arsenic and mercury
- Organic arsenic compounds such as oxybisphenoxarsine
- Variations on the tri-organo tin salts
- Napthenic acids and their heavy metal salts, particularly copper and mercury.

If satisfactory control of toxicant release rate can be achieved, these biocides could provide the source for long life, highly efficient protection for ACSAS against marine growth which severly degrades acoustic performance of the hydrophone.

Controlling toxic release rate by polymerization is a promising technique, and at this point is the team's preferred approach. Polymerization controls biocide release by chemically bonding it to the polymer backbone. This technology shows great promise; however, much research and development needs to be done before practical applications can be introduced into the Fleet. The Presearch team has particular interest in the following polymer materials:

- Acrylates
- Styrenes
- Vinyls.

Chemical bonding to the polymer backbone has been proven in laboratory experiments, and the acrylates appear quite promising. Other polymer candidates that must be investigated are the following:

- Thermosets, particularly the phenolics and the glyptals
- Polyamides
- High-strength polyaramides.

To date, little has been done with these last three polymers. They shall be thoroughly analyzed during the next phase of the team's research and development effort.

Release rate control with elastomers also offers extended antifouling protection. As a class, however, elastomers are compliant; therefore, when they are subjected to excessive pressures from high own-ship speeds and great depths, acoustic performance may be affected. Much research remains to be done before elastomer compliant coatings can meet the ACSAS requirements. Current elastomer research has tended to focus on relatively commonplace neoprene compounds. Other elastomers should be analyzed for characteristics such as their bonding and compatibility to a material composite substrate. In addition to neoprene, the following elastomers should be analyzed for ACSAS applicability:

- Polyurethane
- Hypalon
- Polyisobutylene
- Epoxy-polymides.

In summary, current biocide technology was surveyed and several promising ACSAS candidates identified for their potential as protective layers, or as integral parts of a fiber material composite to be developed for the outer decoupler. Of these, the organo-tin compounds are the most advanced in development and capability; however, other compounds also look promising.

The early problems of high organo-tin toxicity through rapid release can be controlled by the synthesis of organo-tin polymers in a blend with other materials to provide a slow, regulated release. The team's preferred outer decoupler development approach is to add the biocide compound to the composite material as an integral part of the material matrix rather than apply it as a coating. The Presearch team has determined that the versatility of selected antisotropic composites accommodates many of the biocides into the resin very well. This encourages the team's preferred approach of blending the antifoulant into the material matrix as an integral part rather than covering the outer decoupler with a protective layer.

3. MATERIAL COMPOSITES STUDY RESULTS

3.1 Overview. The building blocks available to achieve the desired acoustic properties in structurally sound materials are three-dimensional fiber-reinforced resin composites. A wide range of reinforcing fibers, compatible polymers, and structural designs are available to tailor the absorption and transmission characteristics of the outer decoupler. The ability of three-dimensional composites to survive severe mechanical stress has been demonstrated repeatedly in rocket nozzles and nose cones on reentry vehicles. The acoustic potential of composites has not been exploited.

By their nature, fiber-reinforced composites have an inherent mismatch of properties. The matrix is generally a relatively low modulus, compliant material. The fibers are generally high modulus and strong. Fibers are one dimensional; therefore, special structural designs are required for reinforcement in all directions. The discontinuous structure gives a mechanism to control the mismatch of acoustic impedence to achieve desired results. The high compressive modulus of the fiber will be used to transmit external signals while the low shear modulus of the matrix will absorb and attenuate the flow noise. A graphite/epoxy composite with an extensional modulus of about 30,000,000 psi and a sheer modulus of less than 300,000 psi was prepared in an internal FMI project, and provides our team with a basic working knowledge of how to integrate fibers within a matrix to yield desired acoustic characteristics.

3.2 Fibers. Reinforcing fibers are available in a wide range of properties. The next phase of the team's recommended research and development will investigate the sonic performance of composites with fiber moduli in three different ranges. The low modulus will be about 2,000,000 psi, obtained in a low-fired carbon fiber. The medium modulus range will be between 10,000,000 psi, typical of glass or Kevlar fiber; and 30,000,000 psi, typical of T300 graphite fibers. The high-modulus fiber is about 75,000,000 psi and is available in a graphite or ceramic fiber. This wide spread of properties will enable the selection of the optimum reinforcement and acoustic material for the composite outer decoupler.

3.3 Matrix. The matrix component may be compliant and has a much lower modulus than the fiber. It will absorb the sheer component of the acoustic wave and thereby attenuate flow noise. The matrix maintains the fiber array and with the fibers forms a nonporous, rigid outer layer. It will also act as the medium for the biocide. Since the composite is required to perform acoustically, mechanically, and biologically, the optimum properties of the matrix are not predictable. Three ranges of moduli of the polymeric matrix material will be incorporated into the composite for evaluation. As shown in our interim Technical Report (Technical Memorandum No. 82-017), the modulus of epoxy-urethane blends can be varied over two orders of magnitude, while the elongation shows an inverse trend of the same magnitude.

The epoxy-urethane blend was selected because it is castable and compatible with composite systems. However, other candidate materials may be used instead of the urethane. The Presearch team's experience with polysulfide blends indicates a similar range of properties and similar fabrication potential. Likewise, the new azelaic anhydride shows promise as an alternative blend in the three-dimensional composites. The acoustic behavior of these matrix materials in composites is not known. This study will permit the selection of the optimum matrix system for full-scale tests.

While composite fabrication and analysis is underway, the blending of selected biocides with the candidate matrix system will be studied. Since one advantage of composites is the ability to blend biocidal agents, it is likely that a long-lived, controlled release of the biocide can be maintained with retaining surface and structural integrity of the outer decoupler.

3.4 Structure. A three dimensional structure will be used to provide a stable substrate. The fibers normal to the surface will form the acoustic path for the incoming signal. The size of the fiber bundle and the center-to-center spacing of the bundle will be varied to obtain optimum acoustic behavior while maintaining adequate mechanical properties. It is anticipated that large fiber bundles will be necessary for acoustic transmission. These fiber bundles will be fabricated by plying commercial tows to the desired diameter. Three variations of structures will be selected to provide data for the analytical model.

The effect of the three variables: fiber, matrix, and design can be profiled by constructing a 3 x 3 x 3 matrix of experiments wherein each of the variables is at three different levels. This results in a total of 27 different compositions. When these compositions are tested and evaluated, data necessary for a model will be available for optimum design of the phase-three outer decoupler.

4. R&D PROGRAM PLAN

The Presearch team recommends a near-term outer decoupler research and development effort composed of three phases. This technical effort will address the specific R&D tasks for the ACSAS outer decoupler during FY 1983 and 1984. The three phases, with a brief summary of their content, are presented below.

- Phase 1: Initial Materials Screening
    - Define composite candidates
    - Define antifoulant candidates
    - Define selection criteria
    - Establish laboratory test procedures
    - Conduct limited material tests to support sample selection
    - Evaluate, screen, and select laboratory test samples
- Phase 2: Selected Laboratory Sample Fabrication and Testing
    - Refine and expand selection criteria
    - Refine and expand test procedures
    - Design and fabricate test samples
    - Test and evaluate composite material samples
    - Select candidate for Phase 3
- Phase 3: Develop Outer Decoupler Test Panels
    - Define outer decoupler test procedures
    - Design and fabricate large test panels from Phase 2 selection

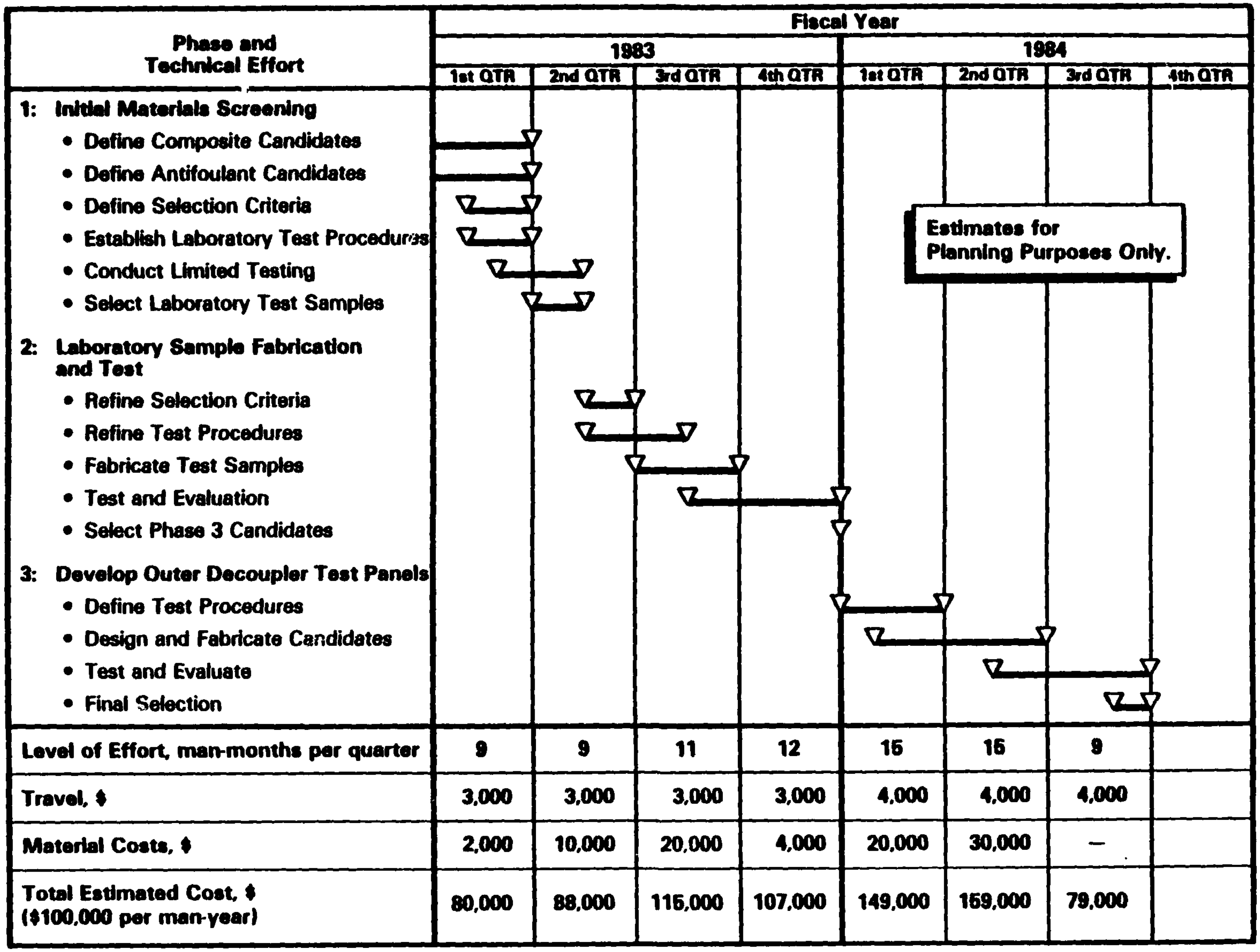
- Test and evaluate candidate panels
- Select most viable outer decoupler material combinations.

Each phase is discussed more fully in the following paragraphs. Figure 1 presents a schedule of activities with an estimate of the manpower, travel, and material requirements projected by quarter for fiscal years 1983 and 1984. It should be noted that the projections for Phase 3 are dependent upon the number of test panels selected and the complexity of the test procedures required to evaluate the selected materials. The Phase 3 cost estimates in Figure 1 are based upon approximately four test panels.

4.1 Phase 1: Initial Materials Screening. The purpose of this initial phase is to define acceptable composite candidates that meet ACSAS operational and environmental requirements, and to establish a set of screening criteria for selecting the most promising for laboratory testing.

Composites may be composed of many different fibers and matrices that bind the materials together. Material composites will be tailored to ACSAS acoustic, antifoulant, and structural needs for evaluation and screening. This evaluation will include a comparison of the new material composites with compliant layers having similar characteristics.

An assessment of new biocidal antifoulant materials developed by the Navy will be addressed for the ACSAS outer decoupler application. It is of fundamental importance that antifouling materials be selected on the basis of compatibility with the outer decoupler and surface characteristics that minimize acoustic distortion, and that they contribute to long-term hydrophone effectiveness.



	1983 1st QTR	1983 2nd QTR	1983 3rd QTR	1983 4th QTR	1984 1st QTR	1984 2nd QTR	1984 3rd QTR	1984 4th QTR
Level of Effort, man-months per quarter	9	9	11	12	15	15	9	
Travel, $	3,000	3,000	3,000	3,000	4,000	4,000	4,000	
Material Costs, $	2,000	10,000	20,000	4,000	20,000	30,000	—	
Total Estimated Cost, $ ($100,000 per man-year)	80,000	88,000	115,000	107,000	149,000	159,000	79,000	

FIGURE 1

ACSAS OUTER DECOUPLER R&D PROGRAM PLAN FY 1983 AND FY 1984

The antifoulant research will concentrate on developing a toxic material that can either be an integral part of, or a compatible layered covering for the outer decoupler substrate. Candidate biocides, polymers, and elastomers will be evaluated to establish the most likely combinations of biocide and vehicle for use with the outer decoupler material matrix. The major part of the antifoulant material selection phase will be the identification of candidates for the polymerization and elastomer release rate control. The work involved will be to cross match the characteristics of biocides with the characteristics of polymer and elastomer candidates. This analysis and limited laboratory testing will further screen the antifoulants to a select few for evaluation with the outer decoupler composite research and development effort.

In this first R&D phase, criteria and test procedures for the evaluation of candidate materials will be defined. The applicability and availability of test equipment and facilities in the Navy and private sector will also be identified. During this initial program definition study from 4 June to 30 September 1982, a set of broad screening criteria was established for the team's technology survey of antifoulant materials. These criteria used to eliminate the obvious misfits were the following:

- Smooth coating
- 24-month minimum antifouling life
- Effective biocide dispersion control
- Acoustic transparency
- Compatibility with possible composite substrates.

These criteria will be extended and refined to provide definitive material acceptance and rejection ground rules during the test and evaluation phase.

The end result of Phase 1 will be the definition of a set of desired properties of composite materials that weigh the parameters of acoustic, structural, and antifoulant properties. These guidelines will be used in the design and fabrication of test samples in Phase 2.

4.2 Phase 2: Selected Laboratory Sample Fabrication and Testing. In this phase the acoustics, sonar systems, and submarine architectural requirements will be applied to the refinement of the screening process. There are two major tasks in this phase:

- Design and fabrication of test samples
- Testing.

It is anticipated that at least two dozen configurations will be fabricated. The samples will be chosen to demonstrate the capabilities of composites with different fiber and matrix properties in designed configurations. With a wide range of available properties, it will be possible to provide a range of characteristics for consideration, including composites, in which the modulus of the matrix can vary from the outer to inner surfaces.

The design and fabrication of structural composite materials will include the incorporation of biocides as an integral part, either as a matrix ingredient or as a coating. The deployment of biocides will depend on the materials used. In some cases the antifoulant may be blended throughout the matrix. In others it will be a coating or a gradient dispersion. The exact deployment technique will be determined by the chemical engineering, the sonar engineering, and the operational experience of the Presearch team.

In parallel with the candidate fabrication process, the team will refine and expand its test procedures. This process will draw on both submarine operational experience and sonar systems knowledge. Specialized laboratory tests will be developed to test the efficiency of each of the performance requirements, such as signal-to-noise improvement, antifouling, change in acoustic characteristics, flow noise generation with time, and many others. These tests will be kept simple and easy to conduct.

The team's test program will include three principal types of testing: acoustic, materials physical properties tests, and environmental tests. Acoustic transmissibility testing can be easily performed on samples of the outer decoupler material candidates under consideration. These tests are important to identify materials that provide minimum attenuation of incoming target signals. Physical properties tests will include the following:

- Tensile
- Hardness (durometer)
- Impact
- Flex
- Tear
- Abrasion resistance
- Adhesion.

In addition to normal mechanical testing of compressive, sheer, and tensile strength and moduli, the dynamic modulus as a function of frequency will be determined. The sheer wave and transmission wave components will be derived from the dynamic modulus for each of the 27 specimens (Section 3.4). The fractional derivative method of evaluating compliant coatings developed by Dr. Walter Madigosky of NSWC will be investigated and, where appropriate, used to evaluate material samples under consideration.

From a statistical analysis of the data accumulated in the study of the variables, it will be possible to develop an analytical model that will be used to select and design the optimum acoustic and structural composite for large-scale testing during Phase 3 of the recommended R&D program.

The environmental tests will evaluate the antifouling performance and other critical factors such as change and rate of change in physical properties caused by interaction with sea water. The team expects the environmental testing to take at least 2 years to assure that the long-term antifouling capabilities of the selected candidates have been fully evaluated. The team also expects that some candidates will reveal unsatisfactory antifouling longevity within a few months. These materials will be rejected to permit continuing redirection of the team's R&D efforts along the most promising lines.

The outputs from the performance tests will be evaluated along with other factors, such as environmental suitability, fabrication impact, logistic support, and maintainability. From these criteria "semi-finalists" will be selected for Phase 3 test and evaluation.

4.3 Phase 3: Develop Outer Decoupler Test Panels. This phase will be similar to Phase 2 in that there will be refinements in fabrication and test procedures. This phase, however, will involve fabricating large panels and conducting tests in much more detail and with a small number of prime candidates. Fabrication development will focus on enhancing desirable properties, suppressing less desirable characteristics, and refining the candidates for practical production. Similarly, the test refinement task will focus on real-world testing as opposed to laboratory screening tests.

Increased testing rigor is required for more stringent evaluation of the limited materials selected during the first two phases. These tests should include an assessment of mechanical coupling as a function of direction and frequency, and determination of the acoustic transmissibility of the outer decoupler. The most directly applicable test will involve exciting the outer surface by fluid flow and measuring the coupling directly. A full assessment of meaningful tests will be developed during this program in concert with appropriate Navy laboratory personnel and ACSAS team members.

The team expects some tests to be conducted on vibration tables utilizing accelerometers. Acoustic pools or instrumented lake facilities will be used for acoustic transmissibility tests, while water tunnels, tow tanks, or pop-up test vehicles will be used for the flow excitation tests. These tests will be assessed, and acceptable procedures defined. The expertise of the entire Presearch team will be used, and the team will work closely with the Navy during this process.

The culmination of Phase 3 will be the actual testing of outer decoupler test panels. It is anticipated that this testing will be performed at several sites, including facilities at Rockwell and Navy laboratories. Upon completion of the testing, a final report with recommendations will be published.