ERNEST L. HOLMBOE and SAMUEL J. SEYMOUR

APL'S SUBMARINE SECURITY PROGRAM

For over twenty years, the Applied Physics Laboratory, through technological investigations, tactical evaluations, and countermeasure development, has contributed significantly to maintaining the security of U.S. nuclear submarines, ensuring their survival as a strategic deterrent. Changing national security concerns, advances in technology, and innovations in engineering will continue to challenge the Navy and the Laboratory to develop improved submarine security systems for the future.

INTRODUCTION

The Navy's Strategic Submarine (SSBN) force has evolved from the *George Washington*–class submarines, which were deployed with the relatively short-range Polaris missiles in 1960, to today's *Ohio*-class submarines, which carry the long-range, highly accurate Trident II missile capable of being launched from anywhere within extremely large ocean areas. A major factor in the success of the SSBN force has been the assured security of the submarines while on patrol, which has been achieved through the fundamental technical understanding of submarine detectability developed at APL. The Laboratory's investigations, together with improved tactics and countermeasures, enable modern submarines to use a variety of means to minimize the risk of detection. Today, as the U.S. Navy nears completion of three thousand strategic submarine deterrent patrols, APL's Submarine Technology Department continues to play a major role in assuring SSBN security for the U.S. Navy.

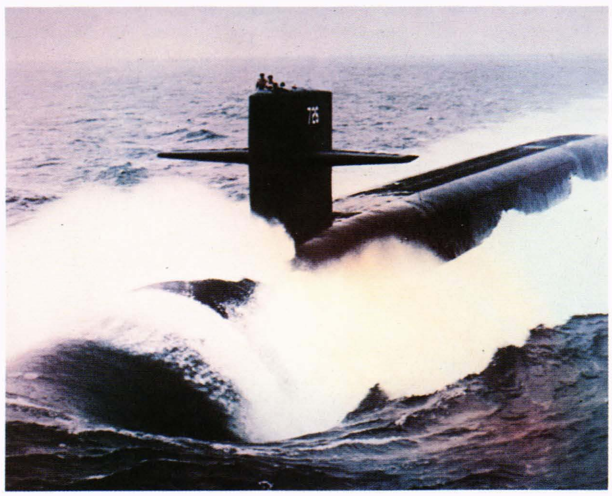

Figure 1. Nuclear-powered submarine on surface. The security of the submarines that carry the U.S. nuclear deterrent continues to be paramount to U.S. defense.

SUBMARINE SECURITY PROGRAM

Soon after the Navy's first strategic submarine force was deployed in the early 1960s, the Strategic Systems Project Office (SSPO), created to develop and deploy the Navy's strategic weapon system, raised questions about the security of the Navy's nuclear-powered ballistic missile submarine force (Fig. 1). Could the Soviets, using techniques we understood, such as passive acoustics, or techniques unknown to us at the time, locate and track or destroy a significant fraction of our submarines at sea?

By the late 1960s, it had become apparent that the security of the SSBN force was critically important to the strategic nuclear deterrence posture of the United States. A dedicated, rigorous research program to address submarine detectability was therefore proposed that would be based on what the physics would permit, rather than on what was currently feasible or observed. Following a series of memoranda and letters between the Office of the Secretary of Defense (OSD) and the Navy, a separate SSBN Security Program was formally established in 1969, with SSPO serving as Program Manager and with the Applied Physics Laboratory, a charter member of the original team assembled to develop, test, and deploy the Polaris weapons system, specifically identified as the Navy's technical agent for SSBN security. The Defense Science Board (DSB) was designated to provide technical oversight, and OSD would take an active role in reviewing, monitoring, and guiding the program.

John S. Foster, Jr., then Director of Defense Research and Engineering, outlined the objectives of the SSBN Defense Program and provided the rationale for having the effort conducted by an independent and objective organization in a memorandum to the Assistant Secretary of the Navy (R&D) written in 1968:

> In view of the Soviet buildup of submarine capability in terms of both quantity and advancing technology, I believe it prudent to take those actions which will ensure the continuing survivability of our SSBN force well into the future. Toward this end, I am considering formulation of a separate and new line item in the FY 70 R&D budget on SSBN survivability. The basic objective of such an endeavor would be to develop all relevant technologies, on a continuing basis, to

ensure the long term survivability of the present FBM force as well as providing the technological base for any future sea-based systems . . .

My rationale for considering a separate line item as opposed to doing the work as part of the ASW efforts is generally as follows. Although the technologies involved are admittedly similar, I believe that if the same people were working both the offense and defense problems there might be a tendency to gravitate to one position to the detriment of the other. With SSBN survivability a separate line item, pursued in part by different personnel than ASW, the competition that would naturally evolve should bring forth the best efforts in both activities.

Although the SSBN Defense Program was officially established in 1971, an APL team was established in 1969, under the leadership of Robert C. Morton, to address SSBN defense issues. Members of the team included C. D. West, W. P. Willis, R. Woodall, J. A. Razmus, J. B. Garrison, P. Lance, S. J. Brown, R. E. L. Johnson, B. R. Thompson, G. R. Thompson, J. W. Peterson, and E. A. Crittenden. Morton and Garrison continued to lead the APL SSBN Defense Program in the early 1970s. An early program organization is shown in Figure 2. In later years, the program was renamed the SSBN Security Technology Program and was successively directed at APL by James R. Austin, Gary L. Smith, Gordon D. Smith, and Ernest L. Holmboe. Key members of the first Defense Program planning team (shown in Fig. 3) are still guiding the program today in APL's Submarine Technology Department.

Why was APL selected to lead the technical aspects of the SSBN security investigation? As indicated in the Foster memo, OSD and the Navy did not want the organizations conducting U.S. antisubmarine warfare research and development to be distracted from their primary mission, but instead wanted an independent approach. The Applied Physics Laboratory became an obvious choice because it had extensive technical talent, a demonstrated ability to put together complex and novel experiments to address difficult technical questions, and a large reservoir of technical and operational SSBN data. Thus, in 1971, with OSD, DSB, SSPO, the Assistant Secretary of the Navy, and the Chief of Naval Operations looking over its shoulders, the APL team began to put together a submarine security and detection program with guidance to leave "no stone unturned," to gain technical understanding with minimal regard for costs, and to be guided by what the laws of physics permit rather than by intelligence observations.

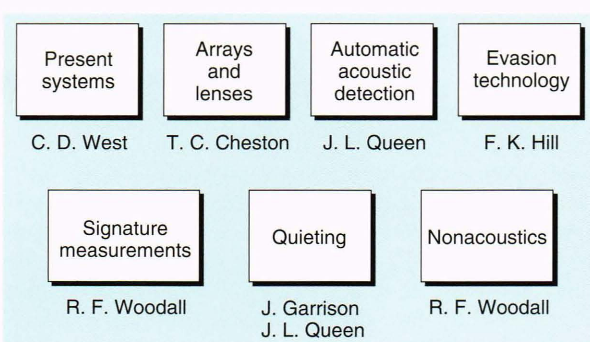

Figure 2. Organization of APL's Strategic Submarine Defense Program. By 1970, APL's SSBN Defense Program had developed as shown, with the majority of the efforts focused on present systems.

SUBMARINE VULNERABILITY INVESTIGATION PROCESS

Among the questions confronting the initial APL management team were the following: Where do we begin? How do we set priorities? How do we uncover new ideas? What technologies exist or what physics can be exploited that could make U.S. submarines detectable and what countermeasures would be required to defeat any such technology? How can we exploit the technical expertise that exists in the U.S. industrial and academic communities? The need to establish priorities for the activities of the program began with its inception and has continued in an evolutionary fashion to the present. As part of this process, the APL team developed a vulnerability investigation procedure (Fig. 4) for each phenomenon, as follows:

1. The project rationale, such as the size of submarine signatures, the nature of submarine operations, the likelihood of a viable threat, the maturity of the relevant technologies, and the systems potential to develop a threat scenario, is examined. Threat concepts are considered that would be of concern either to a single submarine or to the SSBN force as a whole.

2. The technological uncertainties associated with each concept and the issues that need to be addressed to resolve the uncertainties are identified. For example, in the area of passive acoustics, how much sonar receiver gain can be achieved, taking into account the natural variability of the ocean?

3. Research objectives to resolve those technical uncertainties critical to understanding the potential threats to

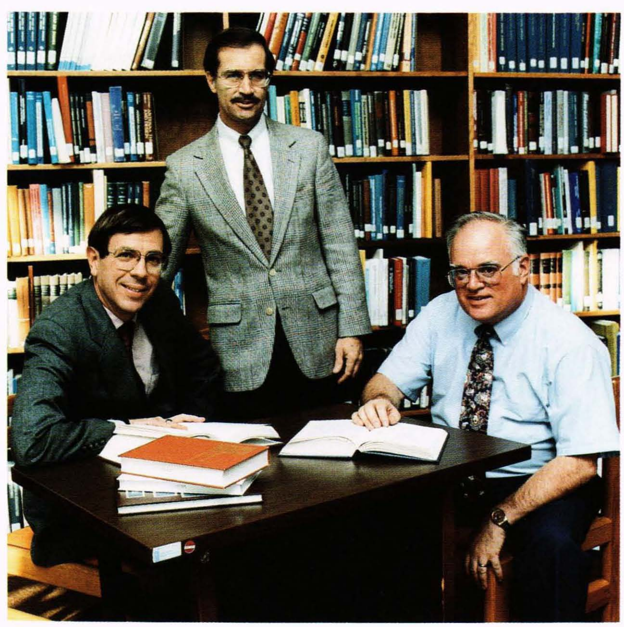

Figure 3. Participants in the original Strategic Submarine Defense program still active in APL's Submarine Technology Department are G. R. Thompson (left), J. W. Petersen (right), and E. A. Chittenden (standing).

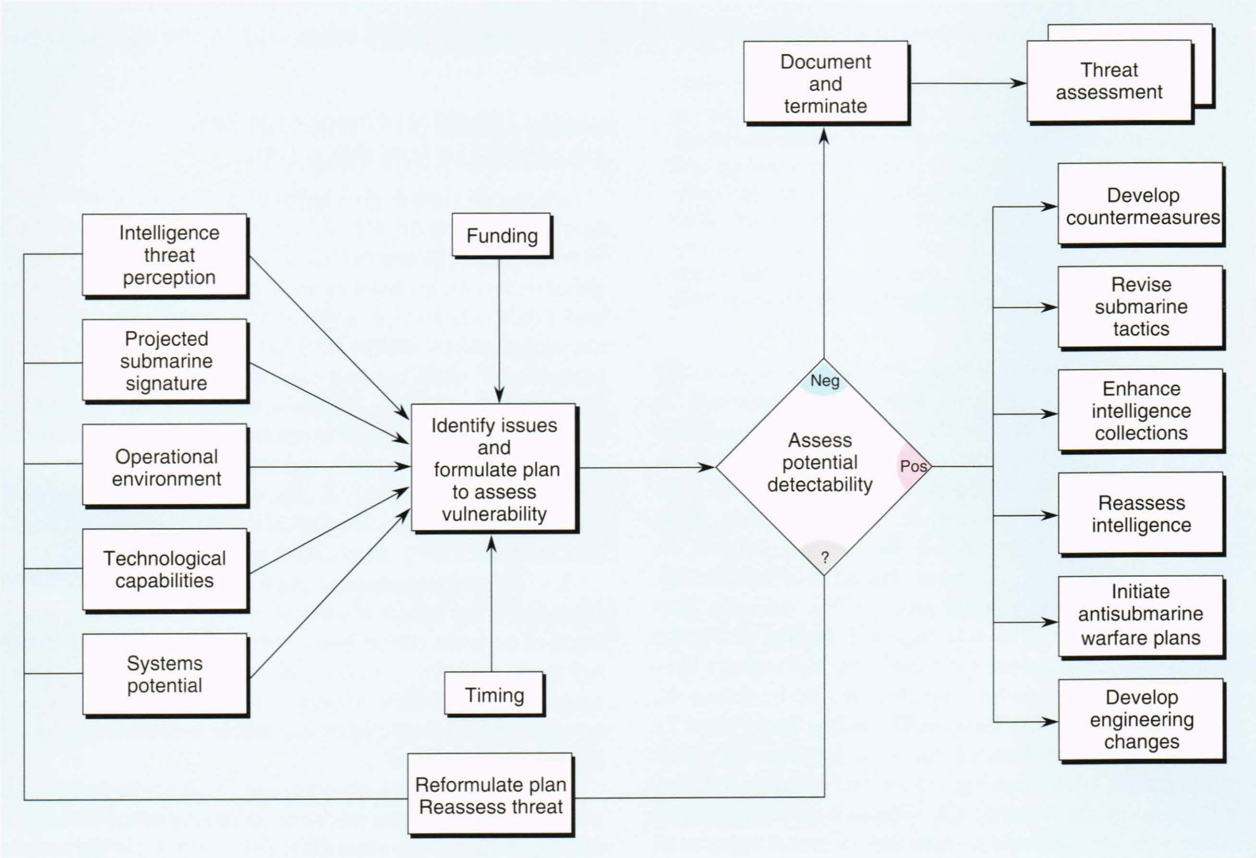

Figure 4. Submarine vulnerability investigation process. Assessment of submarine vulnerability starts with examination of criteria for each technology area and proceeds through development and execution of a plan, which usually requires at-sea testing to obtain an authoritative result. If a feasible threat is identified, several actions, including countermeasure development, are initiated.

the SSBN force are established and theoretical, laboratory, and at-sea research is then conducted. Because submarine detection is based on the signal-to-noise ratio, research objectives must address both submarine signatures and background-related issues. A plan is generated indicating the required resources needed for each technological area and the cooperative activities under way in related government programs.

4. An assessment of the potential threat is conducted. This usually involves model development, simulations, conduct of full-scale at-sea tests, understanding of operational and environmental parameters, and processing and analysis of experimental data. At some point, the basic concept underlying a potential threat becomes sufficiently understood to establish whether a potential threat is feasible, on the basis of current technology. Other concepts may then become more important.

5. Where research continues to indicate that a threat is feasible, the program will identify and evaluate countermeasures, either those of an operational nature or those involving hardware modifications. It may also be necessary to revise the submarine tactics or to develop engineering modifications to reduce submarine vulnerability. In addition, more information about the threat may be warranted, leading to reassessments or collection of further data. In either case, the methodology is product-oriented and leads to overall improvement of the security of the submarine force.

6. As necessary, the program will continually review all concepts, technologies, threat concepts, and technical issues and will realign program priorities accordingly, frequently revisiting previously considered concepts.

The underpinning of this methodology is a technical understanding of what the laws of physics will permit or preclude. Rear Admiral R. H. Wertheim, Director of SSPO during the 1970s, summed it up nicely with a statement that hangs in an APL Building 8 hallway: "In the absence of understanding, any theory is a threat."

AT–SEA TESTING

In the 1970s it was apparent that the knowledge base in the United States was inadequate to address the many technical issues emerging from the SSBN Security Program and that extensive at-sea testing would be required. Thus, APL was destined to go to sea and become a major test organization, developing new and sophisticated instrumentation, deployed at widely scattered ocean locations and under a wide variety of ocean environments (Figs. 5 and 6). The growth of these activities increased steadily and led in early 1974 to the formation of the Submarine Technology Division, headed by James Austin. Over the intervening 18 years, APL has continued to

Figure 5. The supply vessel *State Rebel*, outfitted with vans to provide work space. Extensive measurements of ocean hydrodynamic processes took the Submarine Technology Division to sea in the mid-1970s to mid-1980s. Long-term tests using sophisticated profiling and towed instrumentation to measure conductivity, temperature, and velocity fluctuations made it necessary to outfit large offshore supply vessels with vans for scientists, engineers, and analysts to work in for extended periods of time.

Figure 6. Laboratory staff arriving on submarine. To provide an authoritative assessment of submarine vulnerability, APL staff frequently go to sea and use submarines to make measurements. The close interaction with the fleet is exemplified in this 1977 photo showing the submarine's Commanding Officer greeting (left to right) R. H. Brown, R. Dodd, H. W. Ko, and W. M. Chambers.

develop and utilize sophisticated instrumentation in studies ranging from investigations of various submarine detection phenomena to tactics and operations, and to develop on-board systems.

TECHNOLOGICAL DEVELOPMENT

During the 1970s, APL became a technical leader in the field of passive acoustics, developing an understanding of what the ocean environment would support with respect to propagation, coherence of wave fronts, and noise anisotropy. This work focused on frequencies below 1000 Hz, where reduced attenuation supports long-range propagation. New instrumentation was developed and successfully tested at sea, and advanced processing techniques were successfully applied to the data. During the 1980s, the Laboratory not only supported the SSBN Security Program on acoustic issues, but also began to support the U.S. antisubmarine warfare (ASW) surveillance programs; those efforts have since expanded and matured into the Undersea Surveillance Program Area. The technology associated with low-frequency active acoustics became an increasingly important issue in the 1980s, and APL's SSBN Security Program is leading the way in resolving the major issues.

The Laboratory also became a leader in nonacoustic technologies, including many diverse, and sometimes interrelated, areas such as electromagnetics, hydrodynamics, remote sensing, and optics. These technologies take on greater importance when the potential use of space search platforms is considered, since such platforms could provide high sweep rates and global coverage of the oceans. In many ways, nonacoustics tends to complement acoustic detection means. Among the many novel and complex instruments APL successfully developed and tested at sea were a long-baseline gradiometer employing cryogenically cooled magnetometers (Fig. 7), temperature–conductivity–velocity sensor chains (Figs. 8 and 9), highly sensitive radiometers, and optical systems. System developments are constantly reviewed by the Submarine Technology Department, and new and improved instruments are fabricated and tested to obtain high-quality, reliable data. Today, APL remains the primary source of knowledge about many nonacoustic submarine detection phenomena.

To support its assessments of potential SSBN threats, APL began development of an environmental database in the early 1980s, which incorporates all of the environmental parameters necessary to assess both acoustic and nonacoustic security issues. Recognized by the undersea warfare and oceanographic communities for its global scope, detail, and utility, this database is also used to support the at-sea tests conducted by the Laboratory. The Laboratory's most important asset, however, has been the staff members who have conceived and carried out the technological studies, field tests, and database assembly and analysis. Individuals who have served as leaders in specific technological areas at APL over the years are listed in the boxed insert.

TACTICS AND TACTICAL GUIDANCE

Although the Laboratory's technological investigations have received most of the attention and funding, APL has also made significant contributions to the development of the fleet tactics and tactical guidance necessary to maintain submarine security. The APL staff often embarked on

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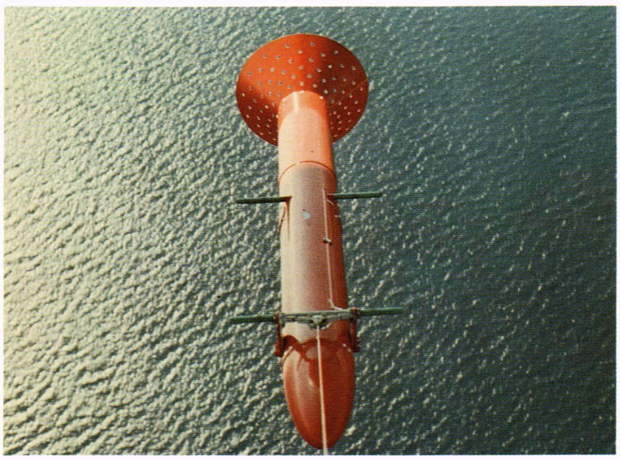
B



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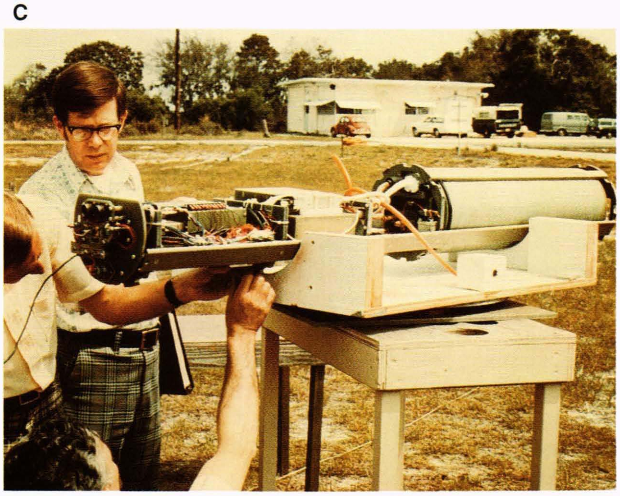

Figure 7. Investigations of magnetic fields in the ocean. **A.** The Submarine Security Program took to the air in 1974, using instruments on a P3 airplane to investigate magnetic fields in the ocean. **B.** Superconducting gradiometer on tow line. **C.** Laboratory staff member Wade Radford explaining the operation of the superconducting gradiometer, which APL was the first to tow. Magnetics-related testing has continued to provide better understanding of the submarine and the Earth's fields.

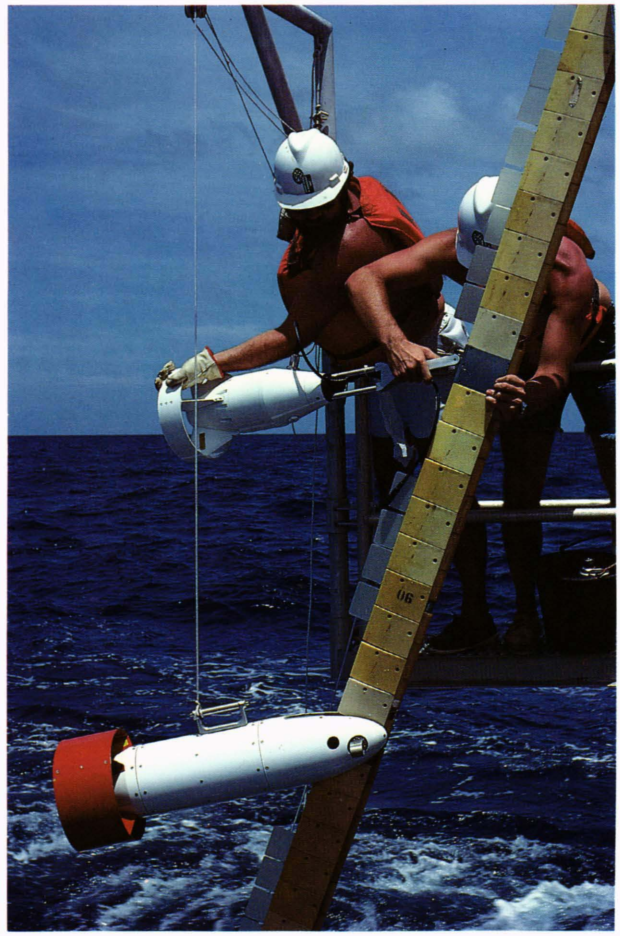

Figure 8. Fluorometer and conductivity sensors being deployed on a towed array. To examine technologies that relate to submarine detection, the SSBN Security Program has developed unique, state-of-the-art instrumentation and sensors under the oversight of Chief Engineer Alan Fraser.

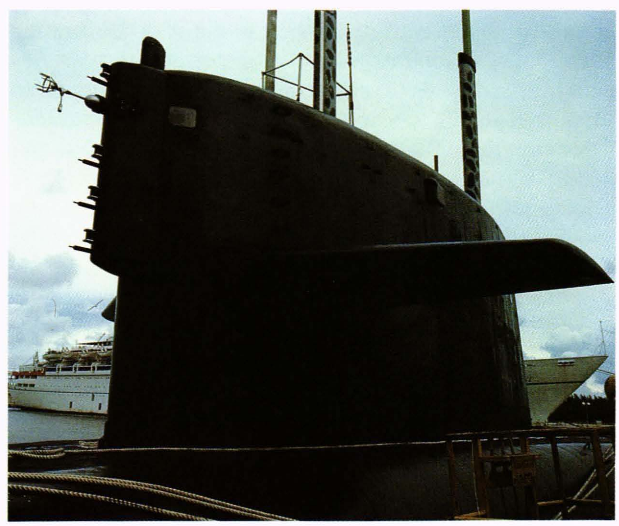

Figure 9. Submarine-mounted sensors. Frequently, oceanographic parameters can best be measured at several depths and over long distances by placing the sensors on submarines. In 1976 this submarine was equipped with probes to measure quantities in the Sargasso Sea off the East Coast of the United States.

SSBN SECURITY PROGRAM TECHNOLOGY LEADERS AT APL

Hydrodynamics	*Acoustics*	*Nonacoustics/Environment*
L. L. Cronvich	J. L. Queen	R. F. Woodall
H. E. Gilreath	T. C. Cheston	G. D. Smith
D. C. Wenstrand	A. M. Chwastyk	C. H. Sinex
L. J. Crawford	E. V. Byron	
G. E. Merritt	E. R. Bohn	

Systems	*Submarine Tactical Development Program*	*Instrumentation/Combat Systems*
J. A. Razmus	G. R. Thompson	D. P. Peletier
A. L. Andreassen	D. M. Restione	F. C. Vaughan
D. A. Blanchard	A. E. Turriff	D. M. Restione
R. A. Fletcher		
M. L. Edwards		
R. E. L. Johnson		
B. E. Raff		

Remote Sensing	*Test/Operations*
R. F. Gasparovic	C. D. West
A. W. Bjerkaas	B. R. Thompson

Figure 10. Dabob Bay deployment of sensor system. The security of U.S. submarines as they enter and leave port has been an ongoing concern of the SSBN Security Program. Through tactical exercises with the Submarine Tactical Development Program and the testing of submarine detection sensor systems deployed near ports, APL is working to assure submarine safety in port regions.

submarines during at-sea exercises, thereby gaining invaluable insight and experience in fleet operations and applications of the various technologies. In 1969, the Navy created the SSBN Tactical Development Program (STDP), to be managed first by the Commander of Submarine Forces, Atlantic (COMSUBLANT) and later by Submarine Development Squadron Twelve, in New London, Connecticut. The Applied Physics Laboratory was designated as the technical agent and has played a vital role in designing, participating in, and evaluating at-sea exercises, and conducting special studies that have led to changes in tactical guidance. This continues to be a major part of the Laboratory's submarine security activity today (Fig. 10).

PATROL HABITS ANALYSIS

In a less visible but evolving role, APL began to examine submarine operations in detail in an effort that was euphemistically called "patrol habits" analysis. Because of the strategic importance of SSBN's to national defense, the Navy monitors and evaluates every aspect of each deterrent patrol. Patrol habits analysis is an effort to collect and analyze operational data pertinent to the evaluation of each SSBN and to assess fleetwide adherence to tactical guidance to ensure absolute security while on patrol. In addition, APL's Strategic Systems Department currently monitors and evaluates the performance of many ship engineering and operational functions that could affect the ship's strategic mission, such as navigation, fire control, and sonar. The Laboratory's Fleet Systems Department also monitors communications and overall shore-to-submarine connectivity assessments.

ADDITIONAL RESPONSIBILITIES

As the Laboratory celebrates its fiftieth anniversary, the SSBN Security Program is celebrating its twenty-second anniversary and, like the Laboratory, is still going strong. In fact, the original SSBN Security Program has been joined by two companion programs—SSBN Survivability and nuclear-powered attack submarine (SSN) Security—in which the Laboratory also has major roles. In 1985, the Navy recognized the need for a special program to develop countermeasures to address issues raised by the SSBN Security Program. This program was named the SSBN Survivability Program, and the Laboratory was invited to participate as the lead organization. This program involves development of advanced, prototype operational hardware to be placed on submarines and tested under operational conditions. Several of these systems are currently making the transition into full-scale engineering development. Today, under the leadership of F. C. Vaughan, APL is developing six systems for shipboard evaluation and is supporting the Defense Advanced Research Projects Agency (DARPA) and other Navy sponsors in similar activities. The Laboratory has also become a leader in the development of submarine systems to improve security. For example, several units of a unique, personal-computer–based acoustic intercept system are now being deployed on operational submarines for extensive testing and evaluation, and the technology is simultaneously being incorporated into the Navy's next-generation acoustic intercept system. The Laboratory's SSN Security Program, led by G. R. Thompson, is applying the technology of the SSBN Security Program to attack submarines, developing tactics and countermeasures to improve SSN mission effectiveness.

CONCERNS FOR THE FUTURE

With the current world situation rapidly changing, where do we go from here? The former Soviet Union had always been considered not only our principal adversary, but also the only adversary with the technology and supporting infrastructure to conceivably threaten a significant fraction of our strategic submarine force. Today, however, three factors in the submarine security equation are changing rapidly:

1. The economic and political problems within the former Soviet Union indicate that a resource-intensive effort to threaten U.S. strategic submarines operating in areas distant from the Soviet homeland is even less likely than before. This situation could continue for the indefinite future.
2. The unilateral force reductions will result in a much smaller U.S. strategic submarine force, and security concerns will shift from guarding against threats to the entire submarine force to preventing the loss of even one or two submarines. Thus, improved security during operations near U.S. ports will likely receive increased attention.
3. Third World threats will increase owing to the ability of these countries to acquire "black-box" technology, such as submarine sensors, towed arrays, diesel submarines, minisubs, sophisticated mines, and weapons. With the U.S. submarine force getting smaller, the Third World factor becomes more significant.

In addition to strategic submarine security concerns, the U.S. attack submarine force will address broader roles, including Third World situations that require operations in restricted areas, shallow-water environments, and near-coastal waters. Thus, new ASW technologies will become more significant. It is likely that the number of U.S. attack submarines will also decrease significantly in the future, increasing the political impact of the loss of even a single submarine in a Third World conflict, which will significantly heighten concerns for the security of U.S. attack submarines.

On the basis of the successful endeavors of the APL Submarine Technology Department and the significant challenges of the future, submarine security will remain as one of the Navy's more critical research and development areas and a major mission of APL's Submarine Technology Department.

THE AUTHORS

ERNEST L. HOLMBOE is a member of the Principal Professional Staff at APL and manager of the Submarine Security Program Area in the Submarine Technology Department. He received a B.S. degree in naval architecture and marine engineering from Webb Institute of Naval Architecture in 1961, and a Ph.D. in mechanical engineering from Carnegie–Mellon University in 1964. From 1984 to 1987, he served as Assistant Technical Director of Operations Security in the SSBN Security Program in the Office of the Chief of Naval Operations. Dr. Holmboe is a specialist in operations analysis and submarine technical program management, and has served as a consultant to the Planning, Steering, and Advisory Committee of the CNO Executive Panel/Technology Subpanel for the past four years.

SAMUEL J. SEYMOUR has particular interest in submarine stealth and detectability, tactics, and intelligence. Since 1973, he has conducted research and managed projects and programs in the Laboratory's SSBN Security Program. A member of APL's Principal Professional Staff, he is currently a program manager for the Submarine Security Program Area in the Submarine Technology Department. Dr. Seymour received a B.S. degree in chemistry from the Rochester Institute of Technology in 1968, and a Ph.D. in physical chemistry from the University of Illinois in 1973. He has taught program management in The Johns Hopkins University G.W.C. Whiting School of Engineering for the past seven years.