GEORGE F. EMCH

FLEET AIR DEFENSE AND TECHNOLOGY

The Applied Physics Laboratory was founded during World War II to provide the fleet with an effective defense against aircraft. Today, the Laboratory continues to conduct antiair warfare programs for the Navy for the purpose of maintaining a superior defense against a continually evolving air threat.

INTRODUCTION

The air defense of the surface fleet continues to be a primary focus of APL efforts. Thus, in this 10th anniversary issue of the *Johns Hopkins APL Technical Digest*, it seems appropriate to review APL's ongoing contribution to this vital aspect of national defense. This topic was last addressed in depth in a 1981 issue of the *Digest*,[1] which contained several articles dealing with Aegis, Terrier/Tartar, Standard Missile, and battle group operations and addressed developments from kamikaze to Aegis.

When the last of the Talos missile systems[2] was decommissioned in 1981, the Navy's principal assets for surface antiair warfare comprised 27 cruisers and 33 destroyers armed with Terrier (long-range) or Tartar (medium-range) variants of Standard Missile. At the same time, the Navy was faced with the threat posed by a rapidly growing Soviet navy, backed by extensive submarine forces and long-range, land-based bombers. To deal more effectively with the large numbers and variety of very capable antiship missiles that could be employed by Soviet surface, air, and undersea forces, the Navy initiated, through programs with APL, improvements to the Terrier and Tartar weapon systems (the New Threat Upgrade) and new designs of Standard Missile (Standard Missile 2 Block II, where the Block number designates the stage of the technology), with particular emphasis on countering new antiship missiles flying higher and faster in massive electronic countermeasures environments.

AEGIS PROGRAM

In anticipation of the end of the service life of the converted Talos cruisers in the 1980s, and 10 *Dewey* class Terrier ships and 23 *Charles F. Adams* class Tartar destroyers in the 1990s, the Secretary of Defense approved the Aegis Engineering Development Program late in 1969. By 1981, this program, built on advanced developmental work carried out by APL in the late 1960s, had the first Aegis cruiser fitting out in Pascagoula, Mississippi, and a functioning model of this new, revolutionary combat system at a test site in Moorestown, New Jersey. Acting as technical advisor to the Navy's Program Manager, APL provided assurance that the contractor's design would satisfy the Navy's requirements and initiated the definition and development of upgrades to the system in step with the planned construction of 27 cruisers.

Since 1981, APL has continued to serve as technical advisor to the Aegis Shipbuilding Program Manager. The work at APL has emphasized the definition and engineering development of improvements to the combat systems to keep pace with the threat and to exploit evolving technology. The Laboratory has provided technical assistance in specifying and testing improved versions of the hub of the Aegis system, the AN/SPY-1 radar, leading to the B variant now being installed in new construction cruisers (CG 59-73) and the D variant being supplied to the destroyers. It has also carried out advanced engineering of new developments essential to maintaining Aegis radar superiority. For example, investigators have created a family of overmoded waveguide components that enable efficient transmission of the very high levels of microwave power needed to deal with reduced target observability and increased levels of electronic countermeasures (Fig. 1). This new development eliminates the need to provide liquid cooling, which is currently employed for some Aegis waveguide runs. It also allows significantly greater amounts of power to be handled and provides the option of relocating heavy power-conditioning and transmitting equipment to lower levels of the ship, thereby increasing seaworthiness.[3]

ELECTROMAGNETIC PARABOLIC EQUATION

The threat posed to ships by low-flying aircraft, ever present since World War II, has received widely varying degrees of attention over the years. Researchers have known for many years that the range at which a particular radar can detect a low flyer is very dependent on tropospheric refraction effects, which vary with the time of day, season, and geographical location. Nevertheless, practical means for sensing the refractive environment and accurately predicting radar propagation did not ex-

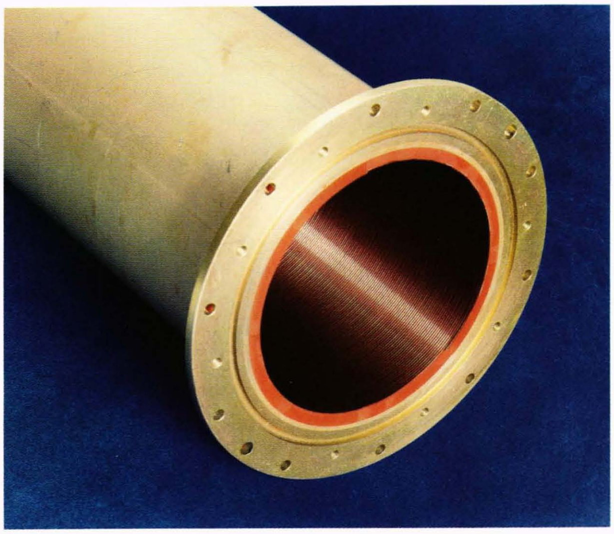

Figure 1. An overmoded waveguide. This type of component enables efficient transmission of the very high levels of microwave power needed to deal with reduced target observability and increased levels of electronic countermeasures.

ist until recently. In the early 1980s, Harvey Ko and colleagues in the APL Submarine Technology Department developed a computer program for modeling radar propagation in the atmosphere. The program was based on the parabolic approximation to the electromagnetic wave equation of Leontovich and Fock and used an efficient numerical method that had been successfully employed in underwater sound applications. Ko's electromagnetic parabolic equation code provided an effective means for modeling anomalous microwave propagation.[4]

Spurred on by the reality of sea-skimming missiles such as the Ottomat Penguin and Exocet, as well as the operational employment of Exocet in the Falkland Islands, Dockery et al.[5] applied the electromagnetic parabolic equation code to predicting the performance of surface ship radars and undertook the demanding task of experimental verification and model refinement. In collaboration with the Fleet Systems Department, Julius Goldhirsh and colleagues in the Space Department showed that the conventional method of making the required atmospheric measurements, which involved using balloon-borne radisondes, was less than satisfactory. To obtain the required fine-grain measurements at low altitude, a procedure for employing a helicopter equipped with modified radiosonde instrumentation was devised. As illustrated in Figure 2, the model provided a reasonably good match to the observed radar performance in shipboard experiments when fine-grain measurements were provided.

SPAR

Recognizing the operational benefits of providing a ship (or battle group) with a reliable indication of its ability to detect low-flying aircraft under prevailing environmental conditions, APL developed a prototype shipboard planning aid called SPAR (System Performance and Response). This decision aid, based on personal computers,

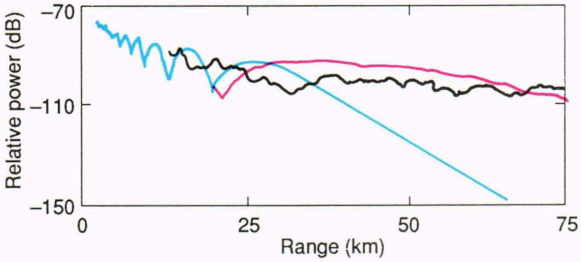

Figure 2. Comparison of the observed signal return from a transponder on a Piper airplane (black curve) with the predictions of the electromagnetic parabolic equation for measured (red curve) and standard (blue curve) environments.

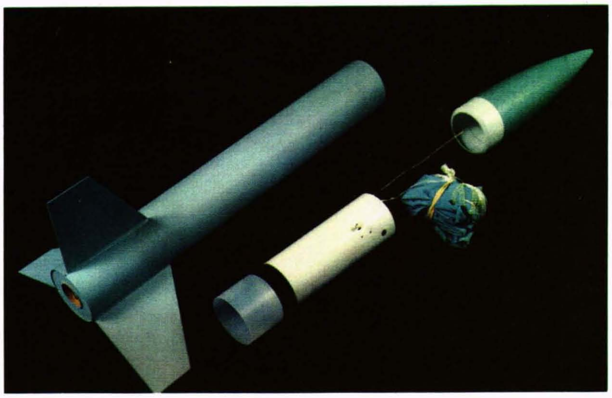

Figure 3. Rocketsonde that employs a hobby shop model rocket to carry it to the required height.

incorporates an improved version of the electromagnetic parabolic equation called TEMPER (tropospheric electromagnetic parabolic equation routine). It also includes radar and combat system models that provide quantitative estimates of detection coverage and engagement capability against specific threats selected by the user. To provide the measurements of environmental conditions required in addition to those supplied by meteorological balloon radiosondes, scientists and engineers in the Space Department devised an inexpensive rocketsonde that employs a hobby shop model rocket (Fig. 3) to carry it to the required height.[6] A prototype SPAR outfit, recently provided to an Aegis cruiser for trial during overseas deployment, has received favorable reports (Fig. 4).

COMMAND SUPPORT AT SEA EXPERIMENTS

To a first-time visitor to the Combat Information Center of an Aegis ship, the most striking feature is the Aegis Display System (Fig. 5). This complex includes computer-driven large-screen displays, automatic status boards, communication facilities, and computer control consoles in conjunction with a cleverly programmed computer having ties to weapons and sensors. It provides the situation display for ship command (and a warfare commander when embarked) to maintain a continual assessment of the operational situation and to effect the split-second control of the combat system, which

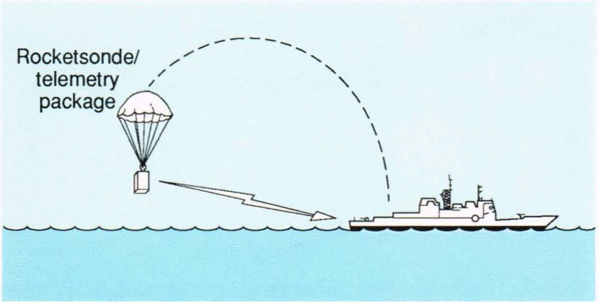

Figure 4. Environmental assessment by a SPAR (System Performance and Response) outfit. Data from the rocketsonde receiver are automatically bussed to a Hewlett-Packard 9020 computer that calculates propagation effects for the SPY-1 radar by using measured atmospheric data, calculates/displays SPY-1 radar detection contours, and calculates/displays the SPY-1 radar detection range for selected threats.

is required to prevail in today's warfare. In addition to assisting the Navy in the functional specification of the basic Aegis Display System, APL has continued a strong developmental program to enhance this command support complex, particularly with respect to the role of Aegis in the battle group. Working with the Naval Sea Systems Command (NAVSEA) (PMS-400) and the Aegis system prime contractor (General Electric), the Laboratory has provided the basic technical design elements for upgrades to the display system in coordination with the shipbuilding program.

This rapid prototyping effort is called the Command Support at Sea Experiments (CS@SE) (Fig. 6). It employs commercial equipment and computer programming facilities to implement necessary or highly desirable features. Following assembly and thorough checkout and testing at the Laboratory, CS@SE equipment is temporarily installed on Aegis cruisers and in other battle group command nodes on non-Aegis ships for experimental use and evaluation at sea.

Phase I of CS@SE, which dealt primarily with the use of large-screen color displays and advanced graphics for improved comprehension, was first demonstrated and evaluated aboard the USS *Ticonderoga* and then aboard the USS *Yorktown* in 1987. In 1988, the utility of supporting decision making by means of a display of area maps was evaluated by using concurrent Phase II CS@SE installations on the USS *Leyte Gulf* and the USS *America*. The displays showed political boundaries and the location of airways (Fig. 6), combined real-time and over-the-horizon tracks, and interoperability with command support systems such as the Flag Data Display System and the Advanced Combat Direction System in aircraft carriers. The results of the experiments are being reflected in the design of future production models of the Aegis Display System, which will introduce large-screen color displays with advanced graphics and map displays on the USS *Chosin* and follow-on construction.

Phase III experiments, currently in progress, are building on the experience gained in Phase II by adding the concurrent display of real-time and over-the-horizon data and also by using a prototype over-the-horizon to real-time track correlator/tracker. These experiments are aimed at demonstrating, testing, and evaluating the ability of the correlator/tracker to provide the command with a current tactical picture by using both own-force (real-time) and theater (over-the-horizon) sensor inputs. These developments are expected to be incorporated in baseline 5 of the Aegis display system to support the

Figure 5. The Aegis Display System. This complex includes computer-driven large-screen displays, automated status boards, communication facilities, and computer control consoles in conjunction with a cleverly programmed computer having ties to weapons and sensors.

Figure 6. Experimental displays of the Command Support at Sea Experiments (CS@SE). This rapid prototyping effort employs commercial equipment and computer programming facilities to implement necessary or highly desirable features.

command in the effective prosecution of antiair warfare at extended ranges to counter new, long-range, air-launched weapon systems.

NEW THREAT UPGRADE

The Navy successfully completed developmental and operational testing of an engineering model of the Terrier New Threat Upgrade on the USS *Mahan* in 1983. Then, with APL as its Technical Direction Agent, the Navy undertook production of the system for installation on Terrier and Tartar cruisers and the 993 class of Tartar destroyers.[7] Both Terrier and Tartar systems use a common design for the highly automated radar detection subsystem and the Advanced Combat Direction System. The Tartar fire control and weapon direction systems have been modified to match their Terrier counterparts, consistent with fundamental differences between the Standard Missile 2 Extended Range (ER) Terrier and Standard Missile 2 Medium Range (MR) Tartar missiles and the Tartar fire control radar. Follow-on testing of the first Terrier system on the USS *Biddle* was completed in 1988, and testing of the first Tartar system on the USS *Scott* is nearly complete. Currently, nine Terrier and one Tartar New Threat Upgrade cruisers are in service, along with one Terrier and two Tartar destroyers; 20 Terrier and 10 Tartar upgrades are planned.

DIGITAL COMPUTER TECHNOLOGY

Digital computer technology was developed at APL to provide automatic radar detection and tracking coverage and threat responsive control of weapons out to hundreds of miles. This technology, now embodied in different forms in the Aegis and New Threat Upgrade systems, enables a few guided missile ships to effect control over hundreds of thousands of cubic miles of the surrounding air space. The Aegis (MR), Tartar (MR), and Terrier (ER) variants of Standard Missile 2 Block II are now in production following successful operational testing of the ER Block II on the USS *Mahan* in 1985. Standard Missile 2 Block II takes advantage of contemporary digital processing techniques and employs advances in rocket propulsion and airframe and ordnance technology to counter the threat posed by manned aircraft and high-speed, high-altitude, antiship missiles in adverse natural and electronic countermeasures environments. In addition to meeting the challenge of advancing threat technology, Block II also provides increased range coverage for all variants, and the ER missile fully fills the role formerly played by Talos.

LOW-FLYING THREATS

Although the principal antiair warfare engineering developmental programs of the 1970s and early 1980s emphasized the new generation of high-flying threats being fielded by the Soviets, NAVSEA and APL did not forget the peril posed by an enemy employing the primeval tactics of "keep low, keep quiet, and make use of natural cover." Although the Navy opted not to develop antiship missiles that fly toward their targets a few meters above the water, several of our NATO allies and other free world countries undertook such efforts. When the world recognized the impact of these weapons after their dramatic employment in the Falkland Islands, the Aegis weapon system was already designed with the quick-reaction, high-fire-power, and radar horizon search attributes required to counter the weapons.

The problem of a radar semiactive homing missile attempting to intercept a small, very low flying target has been studied extensively at the Laboratory. When resources were made available in 1984, the Laboratory, as NAVSEA's Technical Direction Agent for Standard Missile improvement, in concert with the Naval Weapons Center, China Lake, and the Naval Surface Warfare Center, Dahlgren, was able to define and implement rapidly a program to enhance Standard Missile performance against low-flying targets, the Block III/IIIA Low-Altitude Improvement Program. The efficacy of the specified changes was demonstrated in test firings at the Atlantic Fleet Weapon Test Facility in 1988 at the end of the full-scale engineering developmental phase of the program. Production of Block III designs for all three Standard Missile 2 variants is planned, and appropriate portions of the design will be incorporated in Standard Missile 1 Block VIB for use in non-Standard Missile 2 ships.

OUTER AIR BATTLE

The Soviets have continued to field a large number of long-range bomber aircraft and associated antiship missile systems that fully keep pace with technology. This practice requires a continuing effort by the United States to extend the range and capability of its air defense systems so that it can engage aircraft as well as the missiles they deliver. The speed, range, and load-carrying capacity of aircraft have progressed from the Badger, to the Backfire, and now to the Blackjack, and the effective launch range of the antiship missiles carried by the aircraft has increased. Consequently, the difficulty of finding and destroying the airplanes before they can launch a significant number of missiles has increased markedly.

In the early 1980s, the Navy conducted a series of high-level studies to determine the best means for winning the outer air battle. On the basis of these assessments, in which APL participated, the Navy decided to develop a new advanced air-to-air missile (AAAM) and to design Standard Missile 2 Block IV (Aegis ER). The AAAM is intended primarily for the first line of outer air battle defense, whereas Standard Missile 2 Block IV contributes to both the outer air battle and area defense. The Laboratory provided the technical leadership for the specification of requirements for Standard Missile 2 Block IV and assisted NAVSEA in the competitive selection of an industrial contractor for the full-scale engineering development of this vertically launched, two-stage, rocket-propelled, hypersonic missile. The Block IV design successfully passed both a preliminary and a critical design review last year, and construction and testing are now under way.

MISSILE GUIDANCE

The driving force for several investigations and exploratory developmental programs during the past several decades has been the desire to employ means for missile terminal guidance other than semiactive RF homing, which has been used since the original APL design of antiair guided missiles. (The first operational antiair warfare missile, the beam-riding Terrier, does not count because it had to be rushed into service using only the midcourse guidance technique being developed for Talos.) In a semiactive system, the illuminator is located on the ship, whereas in an active system, the missile has its own illuminator. Although most of the other types of guidance considered have been implemented in other antiair warfare missiles with varying degrees of success, the robust constitution of semiactive RF has continued to make it the best single choice for medium- or long-range missiles. In the past, practical limitations on missile size, weight, and configuration have precluded the incorporation of dual-mode homing systems.

Of the several alternatives, passive infrared (IR) homing has been very attractive for some time. Its principal operational handicap is the limited maximum range of visibility of many types of threats in the denser portion of the troposphere. Recent work at the Laboratory indicates that all of the technology required to develop an IR homer for an area antiair warfare missile has advanced to the point that practical development is possible. This conclusion arose not from a technical revelation, but as the product of systematic research that included the development of unique facilities in the Propulsion Research Laboratory for testing IR seeker components under flight conditions (Fig. 7).

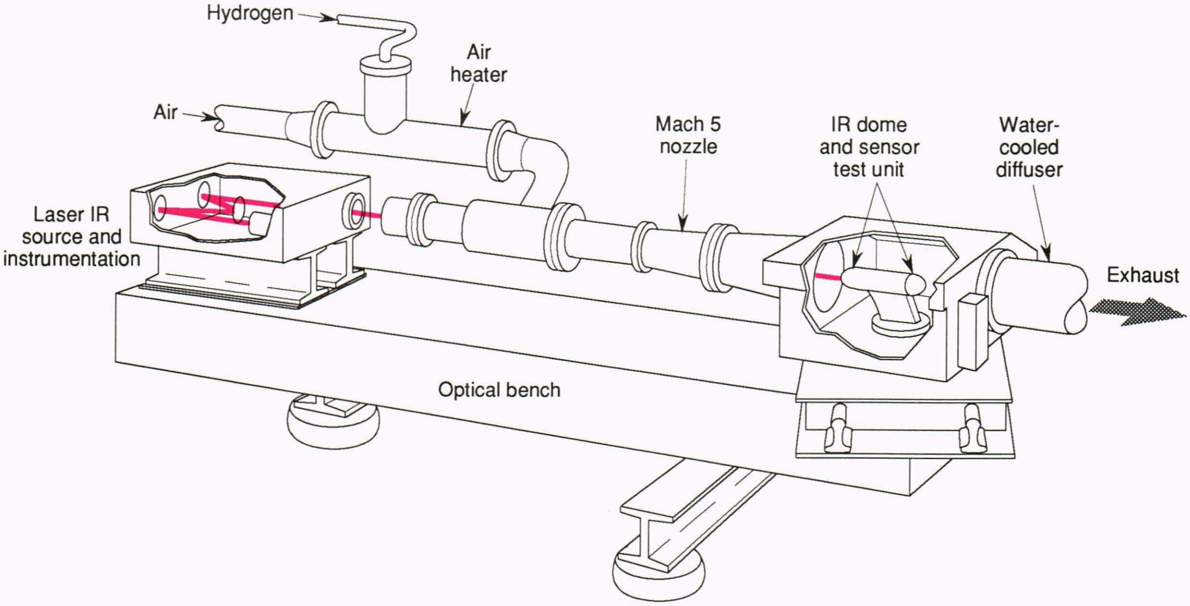

Figure 7. Infrared test setup at the APL Propulsion Research Laboratory.

In 1987, NAVSEA initiated a research and engineering program for the design, development, and demonstration of an IR guidance mode for an advanced, hypersonic area defense missile. The Laboratory successfully completed the concept definition phase of this effort, the High-Performance IR Seeker Program. Theoretical and experimental investigations were conducted to demonstrate the feasibility and expected performance. In preparation for the design verification phase of the program, which will demonstrate the performance of an IR seeker in a missile flight test, the Laboratory engaged three industrial subcontractors to independently develop designs for an advanced demonstration model seeker. Upon completion of these subcontracts, the Navy, with technical advice from APL, selected one of the contractors to build a prototype seeker.

The Laboratory, as NAVSEA's Technical Direction Agent, is continuing investigation in key areas such as characterizing IR window materials, developing analytic models of the IR guidance package for use in computer simulations of missile performance, assessing engineering progress, and working with the contractor to integrate prototype seekers with the missile guidance computer. Meanwhile, exploratory developmental efforts are continuing relative to other forms of guidance and control, and experience gained in the High-Performance IR Seeker Program is being applied to the development of IR seekers for use by Seasparrow and current production models of Standard Missile.

BATTLE GROUP ANTIAIR WARFARE COORDINATION PROGRAM

During the mid-1970s, the NAVSEA Aegis Shipbuilding Program Manager, to ensure the proper integration of the Aegis cruisers with other ships of the battle force so that their benefits would be fully realized, established the Battle Group Antiair Warfare Coordination (BGAAWC) Program at the Laboratory. This program has evolved as an integral part of the Aegis developmental program. Initial emphasis was on the definition and development of the facilities to be provided by the Aegis Display System to support a battle group antiair warfare commander in control of antiair warfare operations, and to provide a force-wide capability to develop and share an accurate, timely picture of the antiair warfare tactical situation (a coherent air picture).

By the beginning of the 1980s, the designs for display and control features to support the antiair warfare commander were being developed, aided by experiments at the Laboratory and at sea on the USS *Norton Sound*.[8,9] Likewise, the steps necessary to achieve a coherent air picture were identified, and a technical approach to demonstrate that capability was selected. Central to this approach was the development of a practical means to allow each ship to continually maintain accurate knowledge of its location on, and orientation with, a common coordinate system, namely, the force tactical reporting grid, a condition known in the fleet as gridlock.

One of the principal difficulties with the practical demonstration of BGAAWC gridlock at sea in the early 1980s was the inability of most naval ships to provide the accurate surveillance radar track information that was required. Despite a determined APL initiative to make available effective means for the automation of naval air search radars, which included successful at-sea demonstrations of an APL prototype system on the USS *Somers* in 1973 and extensive technical and operational tests of an engineering design of the SYS-1 Integrated Automatic Detection and Tracking System on the USS *Towers* in 1978, detection and tracking remained an operator-intensive process. Typically, one operator could, at best, handle only six aircraft tracks, and the video processors and radar automatic target detectors that the Navy had procured to improve the situation were not effective.

To surmount this problem, a piece of radar instrumentation, the Digital Data Collector, and a computer detection and tracking routine based on SYS design experience were combined to provide a temporary replacement for the automatic target detectors of the Navy's primary three-dimensional air search radar, the AN/SPS-48C. This jury-rigged device proved to be highly effective and is now called the Digital Detection Converter. In 1983, it was installed on the USS *Kennedy* as an essential part of an automatic gridlock demonstration system (AGDS). The results obtained with this experimental equipment were so dramatic that the fleet clamored for expedited delivery of the system. Several advanced development models were assembled by APL to provide a pool of equipment that could be rotated between ships to provide the AGDS capability to forward deployed carrier battle groups. Thus, in 1984, when the first Aegis cruiser, the USS *Ticonderoga*, made her maiden deployment to the Mediterranean as a part of the Kennedy battle group, the two carriers and two other guided missile cruisers in this force were equipped with the first rotating-pool AGDS equipment. Operating offshore Beirut in support of Marine Corps operations, Aegis and BGAAWC proved their worth, setting new standards for air surveillance coverage and control.

Upon completion of operational testing of the fully automated Terrier New Threat Upgrade on the USS *Mahan*, and with a second Aegis cruiser (USS *Yorktown*) in the fleet and carriers and cruisers temporarily outfitted with AGDS, sufficient resources were available for ongoing BGAAWC demonstrations and experiments at sea. Engineers at APL continued to extend and improve the fidelity of the force tactical picture through the development and demonstration of computer-based techniques to automate critical processes. In the past, such processes could only be performed imperfectly for short periods through intensive operator attention. Products of these efforts included the demonstration of airborne gridlock (additions and modifications to the E-2 airborne early warning aircraft system to provide automatic gridlock), the introduction of automatic correlation into the fleet rotating pool in 1986 (used by each ship to determine whether or not a track it holds is the same track reported by another), and the demonstration of a track automatic identification system (AUTO ID) on the USS *Forrestal* in 1988 (Fig. 8).

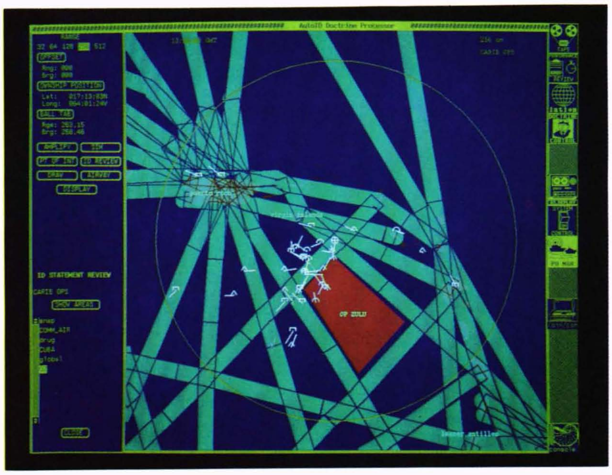

Figure 8. Operator display of the Automatic Identification System.

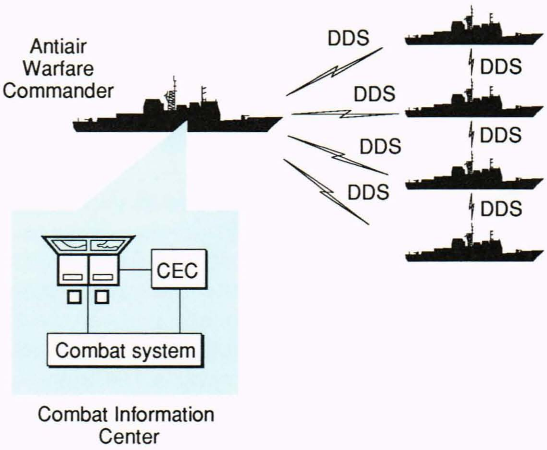

Figure 9. Cooperative Engagement Capability (CEC). The antiair warfare commander enters the cooperative engagement capability doctrine into the Cooperative Engagement Processor, which sends the doctrine to other ships. The Data Distribution System (DDS) is used to exchange digital data between ships in near real time.

In step with these advanced developments, the Laboratory has worked to effect an expeditious transfer of the knowledge and technology to appropriate Navy and industrial activities to enable them to rapidly produce the quantity of systems required by the fleet. These efforts have resulted in 24 cruisers and aircraft carriers on which automatic gridlock with automatic correlation is installed; a digital detection converter field-change kit for the SPS-48C radar being produced by the industrial design agent, with 13 kits already installed; and with this flow of production, the phasing out of the APL AGDS rotating pool. Extension of AUTO ID to include noncooperative target recognition techniques is proceeding, as are extensions to automatic gridlock to employ two-dimensional search radar information (2D gridlock) and electronic support measures data (passive gridlock).

In 1985, as a first small step toward a fundamental BGAAWC goal, cooperative engagement, the USS *Mahan* and USS *Turner* successfully engaged air targets with their Standard Missile 2 by using the air surveillance picture provided by the USS *Yorktown*. In addition to dramatically showing a new dimension of force tactical flexibility made possible by a common coherent air track picture, this demonstration also highlighted the importance of rapidly exchanging large quantities of digital data between units.

Early in the BGAAWC program, the Laboratory developed estimates of the time rate of digital data transfer required for various desired BGAAWC operations and the ability of existing and planned naval data communication links to satisfy the requirements. As expected, the Navy's principal digital tactical data link, Link 11, which was introduced into service in the early 1960s as part of the original design of the Naval Tactical Data System, does not have the capacity to support many BGAAWC functions. Likewise, the Joint Tactical Information Distribution System (JTIDS), which has been under development for several years and is now scheduled for fleet introduction in 1993, cannot dependably deliver the high volume of data required in the severe electronic countermeasures environments anticipated.

Recognizing the unique place that Link 11 occupies in the communications frequency spectrum and the Navy's significant investment in equipment, the Laboratory is developing a Link 11 analyzer and Multifrequency Link 11 to maintain and enhance the operability of this important asset. Similarly, effort is under way to facilitate the introduction of JTIDS and to develop appropriate protocols so that interoperability is assured where Link 11 and JTIDS are both employed.

COOPERATIVE ENGAGEMENT CAPABILITY

On the basis of previous BGAAWC communication studies, the Laboratory developed a design concept for an advanced digital information interchange complex that would embody the characteristics needed to effect advanced BGAAWC ideas such as remote launch (one ship initiating the launch of a missle stored on a second ship and directing the missile to the target) and forward pass (one ship launching a missile and directing it to a selected point in space where a second ship or aircraft can take control and direct the missile to a target that it selects). In 1987, the Navy undertook the development of this concept, known as the Cooperative Engagement Capability (Fig. 9), with APL as the Technical Direction Agent.

The Cooperative Engagement Capability consists of two major pieces of equipment, namely the Data Distribution System and the Cooperative Engagement Processor. The Data Distribution System embodies advanced radio transmitter and receiver technology to provide digital data interchange between units of a battle force; the interchange is very fast, cryptologically secure, and jam resistant. The Cooperative Engagement Processor incorporates multiple digital processors to execute the computer routines required to manage interunit communication; to combine information from all units to provide a common, comprehensive, tactical situation database;

and to effect coordinated direction of force weapons. The computing capacity of a Cooperative Engagement Processor, as measured in millions of instructions per second, is at least twice the combined capacity of all other computers in an Aegis combat system.

Three engineering prototype Data Distribution Systems have been developed and built by the E Systems Division of ECI under APL technical direction. The systems were integrated with three prototype Cooperative Engagement Processors built by APL, and cooperative engagement capability was successfully demonstrated at the Laboratory during the summer of 1989. Cooperative Engagement Capability prototypes are now being prepared for tests at sea near Wallops Island, Virginia (Fig. 10).

SELF-DEFENSE SYSTEMS

Since World War II, the majority of the Navy's research and development efforts pertaining to surface ship antiair warfare have been devoted to area defense guided missiles and their associated combat systems. With the advent of the antiship missile threat in the late 1960s, the Navy recognized its very limited ability to defend itself against that threat by using the antiair armament of most of the fleet, which at that time consisted of guns developed during World War II. Thus, the Navy asked its antiair warfare research and development community to address the self-defense problem. The Laboratory answered the call, and over the ensuing years it has assisted in the development, testing, and evolution of the Seasparrow missile systems, which employ the Sparrow air-to-air missile for ship self-defense; the Phalanx, 20-mm Gatling gun, Close-in Weapon System; and the Rolling Airframe Missile System developed by General Dynamics that employs a dual-mode RF/IR missile derived from an APL conceptual design.

Expanded demands were placed on antiair self-defense systems by the menace of terrorism and the growing sophistication of antiship weapons. This situation prompted the Navy to initiate a new program in 1986 directed at meeting the self/local air defense needs of surface ships in the mid-1990s and beyond. As the Navy's Technical Direction Agent, the Laboratory is leading a consortium of U.S. and NATO national laboratories in the definition of requirements for such systems and the development of conceptual system designs that meet the requirements. In this work, the infusion of Aegis concepts, coupled with the application of evolving technology to short-range defense, shows great promise.

CONCLUSION

In this decade and in the 21st century as well, the Navy, our nation's mobile peacekeeping force, will be undergoing metamorphosis. The ships of the Cold War generation, with their heavy demands for human operator articulation of their electronic nervous systems, are being shed. Emerging from this chrysalis is a smaller body composed of members whose crews oversee the functioning of their sensitive, wide-ranging, sensory organs and direct the motor responses required by the situation in closely coordinated harmony with the action of their fellows. Construction of all 27 Aegis cruisers has been contracted. Fifteen cruisers are in commission, and the last of the class is scheduled for delivery in 1993. The first Aegis destroyer, the USS *Arleigh Burke*, is in the water and will join the fleet in 1991. Seven other ships of this class are under contract.

As evidenced by history, the application of technology by APL to enable the Navy to defeat attacks from the air by either a few nondescripts or a massive national organization will continue to evolve within the broad technical structure of contemporary weapon systems. The Laboratory continues to research systematically other potential avenues for improved defense, however. This past year, a supersonic Vandal (ex Talos) missile was destroyed by a high-energy laser beam that was pointed at the target by a beam director, which the APL Precision Tracking Program helped to develop (Fig. 11). In the glow of our recent national success in maintaining and strengthening the outlook for general peace, we must remind ourselves and our neighbors that history shows that peace stems directly from national stature, and stature can only be assured if the nation and Laboratory continue to dedicate resources to maintaining defense preparedness at a prudent level.

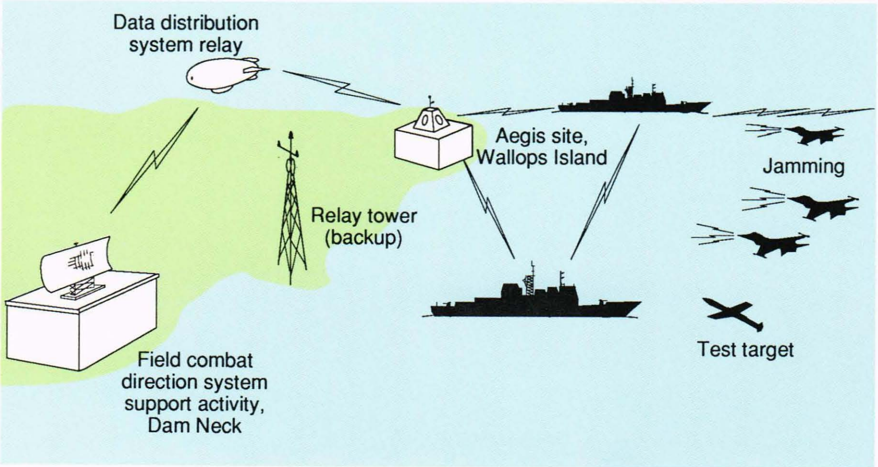

Figure 10. Cooperative Engagement Capability test.

Figure 11. Engagement of a Vandal missile by a high-energy laser experimental test system, White Sands, New Mexico.

REFERENCES

[1] "Fleet Defense Systems and Technology," *Johns Hopkins APL Tech. Dig.* **2**, No. 4 (1981).

[2] "The Talos Missile," *Johns Hopkins APL Tech. Dig.* **3**, No. 2 (1982).

[3] Huting, W. A., Krill, J. A., and Webb, K. J., "New Developments in Circular Overmoded Waveguide," *1988 URSI Radio Science Meeting Programs and Abstracts*, International Union of Radio Science, Syracuse, N.Y., p. 202 (1988).

[4] Ko, H. W., Sari, J. S., and Skura, J. E., "Anomalous Microwave Propagation Through Atmospheric Ducts," *Johns Hopkins APL Tech. Dig.* **4**, 12–21 (1983).

[5] Dockery, G. D., and Konstanzer, G. C., "Recent Advances in Prediction of Tropospheric Propagation Using the Parabolic Equation," *Johns Hopkins APL Tech. Dig.* **8**, 404–417 (1987).

[6] Roland, J. R., and Babin, S. M., "Fine-Scale Measurements of Microwave Refractivity Profiles with Helicopter and Low-Cost Rocket Probes," *Johns Hopkins APL Tech. Dig.* **8**, 413–417 (1987).

[7] Betzer, T. R., "Terrier/Tartar New Threat Upgrade Program," *Johns Hopkins APL Tech. Dig.* **2**, 276–282 (1981).

[8] Phillips, G. C., and Prettyman, E. C., "Battle Group Anti-Air Coordination," *Johns Hopkins APL Tech. Dig.* **2**, 308–313 (1981).

[9] Serpico, D. P., "Combat Systems Evaluation Laboratory," *Johns Hopkins APL Tech. Dig.* **2**, 321–326 (1981).

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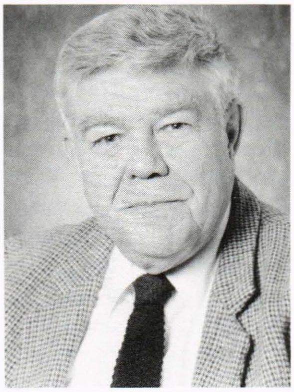

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