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FROM KAMIKAZE TO AEGIS: AN INTRODUCTION

This issue of the *Johns Hopkins APL Technical Digest* discusses one major aspect of the Applied Physics Laboratory's involvement in U.S. Navy Air Defense from World War II to the present. To place this role in perspective, we must examine the development of guided missile technology and the factors that brought it into being.

The Applied Physics Laboratory was founded in 1942 for the purpose of developing, perfecting, and speeding into production a radio proximity fuze to protect the Fleet from air attack. This device was designed to trigger an antiaircraft shell when it came close to its target. In January 1943, the USS HELENA was the first ship to shoot down an enemy aircraft by means of proximity-fuzed projectiles.

Pursuing the technological breakthrough with the highly effective proximity fuze, the Navy's Bureau of Ordnance (BuOrd) requested, in July 1944, that APL make a study of future requirements for U.S. Fleet antiaircraft defense and develop "something brand new" that could maintain an effective counter to enemy air attack. Until that time, no rockets existed with which to launch a missile with a warhead payload large enough to destroy a plane, radar guidance technology was minimal, and the techniques of supersonic flight were virtually unknown. After the problem was studied, "The results of an extensive and intensive investigation by APL and its associated universities, notably the University of Virginia, were reported to BuOrd in November 1944, suggesting that a supersonic, rocket-launched, ramjet-propelled, radar-guided missile was the 'something new' that might solve the emerging operational problems."[1]

At about the same time, the Japanese deployed the Kamikaze — a manned suicide aircraft dedicated to carrying bombs into direct collision with Navy ships. The Kamikaze, in fact, became the first "guided" antiship missile in the Pacific theater of operations.

Early in 1945, BuOrd assigned to APL the broad task of developing guided missiles for shipboard use. The Laboratory turned its attention to the development of the technologies (aerodynamics, propulsion, guidance and control, launchers, structures, test methods, analysis, etc.) needed to develop and produce guided missiles. This program was given the code name BUMBLEBEE. In accordance with the overall objectives of the BUMBLEBEE program, APL and its associated contractors moved to establish a foundation of guided missile technology while simultaneously developing the BUMBLEBEE family of supersonic guided missiles to meet specific tactical requirements. The Laboratory established BUMBLEBEE Technical Panels, embracing each relevant area of technology, to promote an exchange of ideas among government, universities, and industry.

In the early stages of the program, ramjet propulsion was considered to entail somewhat less risk than solid-propellant rocket propulsion for controlled supersonic flight. The ramjet offered greater range and maneuverability — attributes that were considered very desirable for engaging a missile-carrying aircraft before it reached launch range. Priority was therefore given to the development of a long-range ramjet.

By 1948, rapid progress had been made in the development of rocket-powered supersonic flight. One of the early solid-rocket-propelled test vehicles, designed and built to obtain aerodynamic data, had exhibited excellent flight characteristics. After careful review, the Navy decided that this test vehicle could become a useful short-range antiaircraft missile for use on destroyer-size ships.

APL accepted the responsibility for converting this test vehicle into a prototype missile, and the TERRIER Program was officially launched. By the end of 1953, TERRIER Missiles were ready for sea tests from the experimental ship USS NORTON SOUND and the battleship USS MISSISSIPPI. In November 1955, the USS BOSTON was recommissioned as CAG-1 and, carrying TERRIER Missiles, became the first guided missile ship in the world. The event marked the culmination of the first phase of the TERRIER Program.

While TERRIER was being readied for production, parallel development continued on the ramjet missile called TALOS. In 1949, the first full-scale propulsion test vehicle was successfully flown, and in 1952, the first TALOS Missile was successfully flight tested. In 1958, the recommissioning of USS GALVESTON as a guided missile cruiser marked the introduction of the TALOS System into the missile arsenal of the U.S. Navy. The TALOS Weapon System stayed in the Fleet until 1980.

Missile technology continued to evolve at APL with the study of a surface-to-air missile suitable for deployment on smaller ships, such as destroyer escorts. That missile, named TARTAR, was first deployed in USS ADAMS in 1960.

In 1957, APL formulated the basic concepts and techniques for the first integrated missile weapon system based on a radar system with an electronically steered beam of radar energy. The concept included a medium-range missile similar to TARTAR but with Track-Via-Missile (TVM) guidance and an extended range missile that was a small advanced ramjet with command and TVM guidance. This system was named TYPHON. In 1959, APL, Westinghouse, General Dynamics, and Bendix began development of the TYPHON Weapon System and the two versions of the missile. The weapon system was installed in the NORTON SOUND. Successful search and track tests were performed, but no missiles were fired. The missiles were designed and the long-range missile was successfully flight tested at White Sands Missile Range with the command guidance system. The TVM guidance system was successfully demonstrated in aircraft flight tests. Although the designs achieved expected performance, the system could not be produced at an acceptable cost using technology available at that time. Therefore, the program was terminated in 1963.

By 1960, it had become apparent that the TERRIER, TARTAR, and TALOS Systems (the 3T family) faced performance limitations, particularly in view of the expected growth and diversity of air attacks in the next several decades. Those limitations were first perceived to be associated with the shipboard equipment but were later seen to have total system connotations. To improve the effectiveness of the systems then being deployed, the Navy established the Surface Missile Systems (SMS)* Project and, following the recommendations made by a Technical Planning Group (later referred to as TPG), requested that APL initiate a program for upgrading the capabilities of the 3T ships. Concurrently, studies were begun to determine requirements for a new missile system.

In 1963, a formal expression of need was made by the Chief of Naval Operations for an Advanced Surface Missile System (ASMS) suitable for installation on new cruisers and destroyers. (See the article by J. D. Flanagan and W. N. Sweet, "AEGIS: Advanced Surface Missile System," in this issue.) To meet this need, an ASMS Assessment Study Group composed of members from the Navy, APL, Navy laboratories, and industrial organizations was established. This team, under the direction of the (then) Bureau of Weapons and chartered by the Secretary of the Navy, began to formulate the concepts for a new, fully integrated, antiair warfare weapon system.

For the next six years, in a succession of programmatic steps (including concept formulation, contract definition, and advanced development), APL played a vital role in the determination of requirements and in exploratory development of the more complex elements of the system. The Advanced Multi-Function Array Radar (AMFAR), discussed in the article by C. C. Phillips in this issue, is representative of this development. Concurrently, a decision was made by the Navy to standardize the TERRIER and TARTAR Missiles by developing modular components that could be assembled into medium-range and extended-range versions for TARTAR and TERRIER ships, respectively.

During the summer of 1968, the Laboratory was host to a second Navy Technical Planning Group, which recommended that the "standardized" missile, now known as the STANDARD Missile (SM-1), be equipped with a midcourse command guidance mode for use with the TERRIER and TARTAR Systems, as well as with the new Advanced Surface Missile System. The evolution of these developments is discussed in the article, "STANDARD Missile: The Common Denominator," by M. E. Oliver and W. N. Sweet, in this issue. In late 1969, engineering development commenced on the system, now called AEGIS. (This development is presented in the article in this issue by J. D. Flanagan and G. W. Luke, "AEGIS: Newest Line of Navy Defense.") By the early 1970's, the AEGIS Mk 7 Weapon System had emerged conceptually as the embodiment of all the key elements required in an area antiair warfare defense ship. (Area defense, the middle ground between long-range outer defense and short-range self-defense antiair warfare, is discussed in the article, "Battle Group Air Defense Analysis," by R. S. Farris and R. J. Hunt, in this issue.)

Meanwhile, it had become apparent that many changes were needed to upgrade existing ships to keep them competitive until AEGIS could be extensively deployed. In particular, the requirement for greatly improved target detection performance in adverse radar operating environments, and the need to increase the effective range of the TERRIER System to fill the gap left by the retirement of the TALOS cruisers, demanded attention.

Investigation of radar performance at sea during Fleet operations and exercises showed that, although the radars generally detected targets, the operators were unable to deal effectively with the large quantity of detections reported on their displays or to perform the manual operations required to track a target at rates that would cope with the numbers of targets encountered. Combining experience with radar signal processing and the small digital computers just becoming available, APL undertook the development of automatic detection and tracking systems. As discussed in the articles by W. G. Bath and E. A. Frekko in this issue, this effort led to the successful

*See GLOSSARY, page 236

development of the AN/SYS-1 Integrated Automatic Detection and Tracking System.

Progress in inertial reference technology made it possible to modify the STANDARD Missile to employ midcourse guidance. The SM-2 Extended Range Missile, in conjunction with changes to the TERRIER ship weapon control system, provided a mode of operation that greatly extended the missile's effective engagement range and altitude beyond that previously attainable.

The potent threat posed by a new generation of antiship missiles led, in 1975, to the formulation of a program to upgrade the capabilities of the TERRIER and TARTAR ships. The result was the New Threat Upgrade Program, as described in the article by T. R. Betzer in this issue. This program incorporates performance improvements in the STANDARD Missile and the SYS-1 Integrated Automatic Detection and Tracking System, and upgrades in the surveillance radars and weapon control systems.

Throughout the decade of the 1970's, engineering development of the AEGIS Weapon System continued with a succession of highly successful demonstrations at land-based test sites and in at-sea tests from USS NORTON SOUND. Partly as a result of these successful demonstrations, the Navy decided to incorporate the AEGIS Mk 7 Weapon System as the nucleus of a total ship combat system that included antisubmarine and antisurface warfare systems. In 1978, the Navy contracted for the first AEGIS ship to carry this new system. This AEGIS ship, TICONDEROGA (CG-47), has been christened recently. Commissioning is scheduled for early 1983. Follow-on production of AEGIS-armed ships has been authorized.

With the AEGIS ship, U.S. Navy Battle Groups, for the first time, will possess the fundamental elements (AEGIS AN/SPY-1 Radar and Combat Direction System) to provide a coherent air picture and coordinate ships and aircraft weapons to fully utilize their inherent capabilities. Accordingly, the Navy has now embarked on a major program under the technical direction of APL to provide the Fleet with advanced capabilities for Battle Group Anti-Air Warfare Coordination. These capabilities are discussed by several authors in the Battle Group Operations section.

In 1978, the Chief of Naval Operations also requested a study to define and to explore alternatives to a "battle-force-capable" surface ship with AEGIS-like capabilities in order to offset the loss of guided missile ships going out of service and to restore Naval forces to full fighting proficiency. The need for a destroyer to complement the CG-47 AEGIS cruiser is clearly indicated by threat assessments that have shown that, in any major naval engagement in the future, the surface forces will be confronted by heavy saturation attacks, heavy countermeasures, and tactics that require a high degree of Battle Group coordination. Under the cognizance of the Naval Sea Systems Command, the AEGIS ship Combat Systems are being designed to incorporate advanced distributed Combat System Architecture and technology sufficient to sustain this ship class in service into the first quarter of the 21st century.

The TERRIER and TARTAR Weapon Systems, currently installed in U.S. ships and in ships of our allies, and the decommissioned TALOS Weapon System have demonstrated outstanding performance in every encounter — on the test range and in combat action — and have established a highly successful tradition. The AEGIS Combat System, designed for modern cruisers and destroyers, continues this tradition and will be the first ship combat system with "total system" design integrity. In conjunction with upgraded TERRIER and TARTAR Weapon Systems, AEGIS will assure the U.S. Navy mission of sea control well into the future.

In the Foreword, Admiral Meyer speaks of a composite force, which he perceives as a prime requisite in countering the threat. The work going on within the APL Fleet Systems Department is strongly supportive of the Navy's needs for such a force, as underscored by the articles in this *Technical Digest*, which summarize the principal relevant programs within the department.

REFERENCE

[1] R. E. Gibson, "Reflections on the Origin and Early History of the Applied Physics Laboratory," *APL Tech. Dig.* **15**, No. 2, 8 (1976).

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