

## TYPHON — A WEAPON SYSTEM AHEAD OF ITS TIME

*“Without Typhon, there would be no Aegis.”*

—Rear Admiral Wayne E. Meyer, USN (Retired)

In the late 1950s, Typhon was conceived by APL as an integrated weapon system to defeat the air threats of the 1970s. It comprised (1) a single radar system for search, acquisition, tracking, and missile guidance with multiple beams and instantaneous beam switching, able to operate effectively in the presence of heavy countermeasures; (2) a single Weapon Direction System to handle two complementary missile types, capable of handling multiple intercepts and integrated with the Naval Tactical Data System/Combat Information Center; (3) a long-range and medium-range missile; and (4) launching systems for the missiles. The heart of the system was the multifunction Typhon radar, which represented a quantum jump in beam forming and switching and signal processing techniques. Contract work for the development, fabrication, and test of the Typhon radar and missiles began in 1960 and lasted until 1965. This article recounts those exciting years of the Laboratory's participation in the development of Typhon.

### INTRODUCTION

For the Applied Physics Laboratory, 13 January 1964 was memorable but sad. On that day, the Director of APL, Ralph E. Gibson, announced in a staff memorandum that

The Laboratory has been asked officially by the Navy to terminate as soon as possible all those portions of the TYPHON effort not directly in support of the NORTON SOUND [a missile-test ship for evaluating the TYPHON prototype radar system] Engineering Test Program.<sup>1</sup>

In the early 1960s, more than half of APL's work was dedicated to the Typhon weapon system. The announcement caused a serious redirection of work at APL. Gibson also stated in the same memorandum that the Laboratory knows

the intrinsic worth of the TYPHON concept, the pioneering technical problems that were so ingeniously solved during its development, the outstanding engineering achievements such as the successful production of new travelling wave tubes, and, above all, its demonstrated capacity to provide the Fleet with an anti-air warfare system capable of meeting the modern operational threat more surely than any other system in a comparable state of development.

He concluded his statement by thanking those

who have devoted so much imaginative thought and ingenious skill to the design of the TYPHON system and its reduction to working hardware. The successful flight tests of experimental prototypes of both the Long and Medium Range missiles, including the demonstration in flight of the successful development of a new ramjet engine, command guidance and control systems, together with the demonstra-

tions of entirely new radar techniques and new weapons control systems in the experimental radar laboratory constitute a chapter in its history of which the Laboratory is justifiably proud.

This article will attempt to capture the spirit and innovation of that stimulating period in APL's history, one that is marked with many contributions to the advancement of weapon system technology.

The story began in May 1957 when, in response to the apparent threat to the fleet posed by Soviet nuclear weapons and high-performance aircraft armed with supersonic antiship missiles and using sophisticated jamming techniques, the Navy initiated a major study of fleet air defense. The Navy requested that APL undertake the study because the Laboratory played a major leadership role in the development of Terrier, Tartar, and Talos missiles. Led by Alvin G. Schulz (former Associate Director and now retired), the study was completed in six months and presented the general outline of a system designed to meet the threat. The system, after some review, changes, and elaboration of details, became the fourth T-system known as Typhon.

Although in function and concept Typhon evolved from the earlier Terrier, Tartar, and Talos shipboard surface-to-air missile systems, many of its technical aspects, particularly its radar and guidance techniques, represented a distinct break from the earlier systems. In contrast to earlier missile systems, in which missiles were developed and then shipboard equipments were almost jury-rigged to support them, Typhon was conceived as an

integrated missile weapon system. The Typhon radar was distinguished from earlier radars in that it incorporated complete electronic steering, frequency diversity, and coherent signal processing. These features permitted more rapid reaction to threats and a major increase in the number of targets that could be simultaneously tracked and countered, while providing greater immunity to electronic countermeasures (ECM). The spherical antenna array and feed technique used to achieve these features, however, implied increases in cost, weight, complexity, and power requirements. (As you read this article, it will be helpful to refer to Table 1 on the Typhon program's chronology of events from 1957 through 1965.)

## EARLY YEARS OF THE 3T PROGRAM

During the development period of Terrier, Tartar, and Talos (the 3Ts), many major improvements in missile performance were made even before their missile ships were built. The range of Talos was doubled, and Terrier's range was quadrupled, with a corresponding increase in altitude coverage. The capability of the homing version of Terrier, the HT-3, was extended to encompass effective low-altitude intercepts. Nuclear modes were developed for Talos and Terrier to provide improved performance against aircraft formations and surface targets. Home-on-jam modes were instituted to provide a significantly improved capability against jamming aircraft.

Other equipment of the shipboard missile system had not attained a stage of development comparable to that of the missiles; notably, the Talos and Terrier radars had not kept pace. When the shipbuilding program was under way, the design of all ship systems was frozen because large-scale procurement of equipment was based on current design specifications. This meant that further improvements to the radar systems were limited by space, weight, and, to a lesser extent, power considerations.

By the mid-1950s, it became evident that the performance envelope of the then-current weapons systems, although adequate for the contemporary threat, would have to be drastically expanded to meet the 1970 air threat. For the 3Ts, the time interval from initial target detection to the firing of the first missile could be short, but under adverse conditions the reaction time could increase to several minutes. Even under favorable conditions, the time was too long to successfully counter submarine-launched antiship missiles or a high-density raid by enemy aircraft and missiles. Also, the number of targets that the 3Ts could engage simultaneously were limited by the number of fire control radars installed on the ships. The systems required one fire control radar to engage each separate target, and, because our ships had been fitted with the maximum number of radars they could accommodate, it was not practical to think in terms of increasing firepower by increasing the number of radars. The need for a new concept of tracking and fire control was indicated.

This was the context in which the Navy surveyed systems requirements for anti-air warfare from 1957 to 1967. All estimates of the enemy air threat pointed to an increasing capability, especially in terms of extensive countermeasures and both air-launched and submarine-

launched supersonic missiles. Limitations inherent in the 3T systems reduced their ability to cope adequately with an advanced air threat. Because the missile systems could not be improved significantly in reaction time, firepower, saturation, and operation against advanced ECM, it seemed clear that an entirely new concept was needed—one that would be specifically designed to deal with the most modern missiles and that would be capable of accepting ECM as the normal environment.

The need for defense-in-depth required the development of not one but two missiles: a long-range (LR), ramjet-propelled missile capable of ranges of several hundred nautical miles or more to reduce the number of missile-launching aircraft and standoff jammers, and a medium-range (MR) rocket-propelled missile to meet the demands for high rates of fire. These missiles were designated Typhon LR and MR, respectively, and were sized for both cruisers and destroyer-class ships. In recognition of these facts, the Navy stipulated that Typhon was to represent not an improvement in the 3Ts, but a quantum jump in capability. Figure 1 is a block diagram that shows the integration of the Typhon weapon system equipments.<sup>2</sup>

## TYPHON PROTOTYPE RADAR CONTRACT

When LCDR Milton Gussow, USN, reported to his new duty station at the Bureau of Ordnance (BuOrd) in July 1959, he was assigned to the Typhon Weapon Control Section, where his first task was to review the proposals submitted to BuOrd on the development, fabrication, and test of the Typhon radar from Westinghouse, RCA, and Sperry. Other members of the review board included CDR Bill Coyne, USN, also from BuOrd, and John B. Garrison and Alvin Schulz from APL. Having just completed a tour on a World War II-commissioned radar picket destroyer with two deployments in the Mediterranean, Gussow was amazed by the far reaches of radar and signal processing technology written in the proposals.

The radar antenna used for beam forming was a spherical array with wide bandwidth and frequency and phase diversity for jamming immunity. The radar used a large number of high-power traveling wave tubes (3400 for the prototype system), a Luneberg lens for the transmitter array, and three Luneberg lenses for the receiver array.

After extensive review, the Navy in December 1959 approved contracting with the Westinghouse Corporation for a prototype of the Typhon radar. The Laboratory and Westinghouse then began to finalize the requirements definition and specification. In March 1960, the Bureau of Naval Weapons (BuWeps) contracted with Westinghouse for development of the Typhon radar, with APL acting for BuWeps as Technical Director (TD) of the program. This occasion marked the *first* time APL was assigned the job of TD of a Navy multifunction radar system for search, track, and missile guidance and was the beginning of an era that led APL to gain the total weapon systems engineering experience and competence it has today. The Laboratory's assignment as TD was logical because the radar concept and techniques, along with corroborating experiments, were invented at the Laboratory, particularly by John Garrison. (Technical direction is the engineering and scientific supervision of develop-

**Table 1.** Chronology of the Typhon weapon system program.

1957	The Laboratory completed a study of 1970 threat and fleet air defense requirements. Super Talos (now LR Typhon) and Super Tartar (now MR Typhon) missile names were used. Study presented to Chief of Naval Operations (CNO).
1958	Advanced weapon system concepts defined. Super Talos/Super Tartar programs approved by CNO. Weapon control and missile R&D initiated.
1959	Initial Technical Development Plans (TDPS) for Super Talos and Super Tartar sent to CNO. Super Tartar program deferred. Initial Super Talos configuration established; detailed design in process. Successful aircraft tracking performed using frequency diversity pulse Doppler and random pulse repetition frequency. Angle tracking achieved with 100-element Luneberg lens.
1960	Integrated Typhon program, replacing Super Talos and Super Tartar, approved by CNO. Initial Typhon TDP issued. Westinghouse awarded contract for prototype AN/SPG-59 radar. Navy recommends Typhon cruiser in Shipbuilding and Conversion, Navy (SCN) 1963, thus accelerating the program. Construction of Typhon experimental radar started at APL with integrated search and track system, using spherical phased array antenna. Laboratory system tests of Typhon equipment and radar techniques begun. Start of study for installation of prototype Typhon in a test ship approved by CNO. Definition and laboratory testing of Typhon frequency diversity guidance system completed. Successful ground tests of ramjet engine. Detailed design completed for early Typhon LR flight vehicles; LR Typhon S/N-1 accepted and shipped to White Sands Missile Range. Laboratory is designated by BuOrd as TD of Typhon weapon system. Eaton appointed APL Typhon program supervisor with technical direction responsibility of the overall Typhon program. Garrison designated program supervisor for the Typhon weapon control system including radar. Larson appointed program supervisor for Typhon LR missile, Sheppard for Typhon MR missile. LCDR Gussow appointed section head of Typhon weapon control system in BuOrd. Successful operation of 492-element Luneberg lens for computation of phase and amplitude.
1961	Initial operation of Typhon experimental radar and weapon direction equipment; coherent acquisition system demonstrated. Two Typhon experimental LR propulsion test vehicles and one control test vehicle flown. Bendix/Mishawaka awarded prime contract for Typhon LR. Responsibility for Typhon weapon system technical direction integration assigned to APL in addition to technical direction. Typhon MR development program initiated. Change made to wingless Typhon LR configuration.
1962	General Dynamics/Pomona awarded prime contract for Typhon MR. Typhon cruiser construction program cancelled by CNO. Return of Typhon LR to exploratory development directed by CNO. Closed-loop flyover tests demonstrating Typhon guidance system in conjunction with experimental radar are conducted. Two Typhon LR control test vehicles and two command guidance test vehicles flown. Successful flight test of Typhon LR booster demonstrated.
1963	Beginning of installation of AN/SPG-59 prototype radar on the USS <i>Norton Sound</i> (AVM-1). Typhon MR missile prime contract transferred to Bendix/Mishawaka. Two Typhon LR command guidance test vehicles flown. Typhon MR control test vehicle flown.
1964	BuWeps terminated MR and LR Typhon missile programs but allowed continued installation of Typhon radar system for test and evaluation to June 1965. Laboratory designated as director of missile ship's system engineering, integration, and test by having the responsibility for integrating the various weapon elements of the <i>Norton Sound</i> . The <i>Norton Sound</i> is recommissioned. Luke assigned as project engineer for the engineering test program, Schultheis as test team leader.
1965	The <i>Norton Sound</i> tests of Typhon are terminated. The Typhon program is terminated.

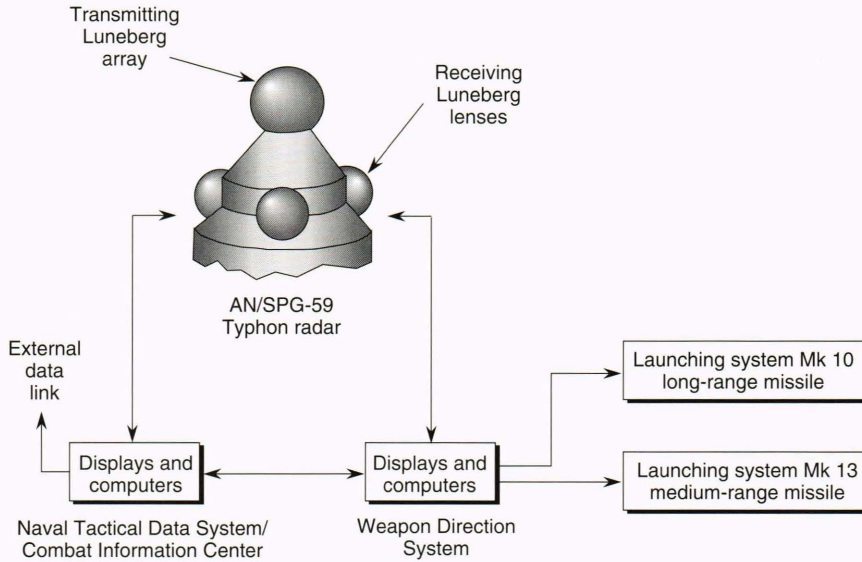


Figure 1. The Typhon weapon system.

ment and design agent activities in a weapons system. The objective of the TD is to conduct the development program through the stage where a production article, subsystem, or system has been demonstrated to the satisfaction of the Bureau and Operations Test and Evaluation Force, and thereafter to provide continuing development support and design assistance as may be necessary throughout the life of the program.)

The Typhon radar was designed to perform many essential functions concurrently. By means of rapid se-

quencing of its electronically steered antenna under computer control, it could scan the hemisphere and (more rapidly) the horizon, maintain high data-rate track on several hundred targets of interest, and transmit guidance commands to missiles intercepting selected targets.

Figure 2 shows how the transmitted radar beam was formed and pointed in space and how the reflected radar beam was received.<sup>2</sup> Figure 2A shows how a spherical dielectric lens brought to a focus an incident plane wave or transmitted a plane wave if a signal were injected into

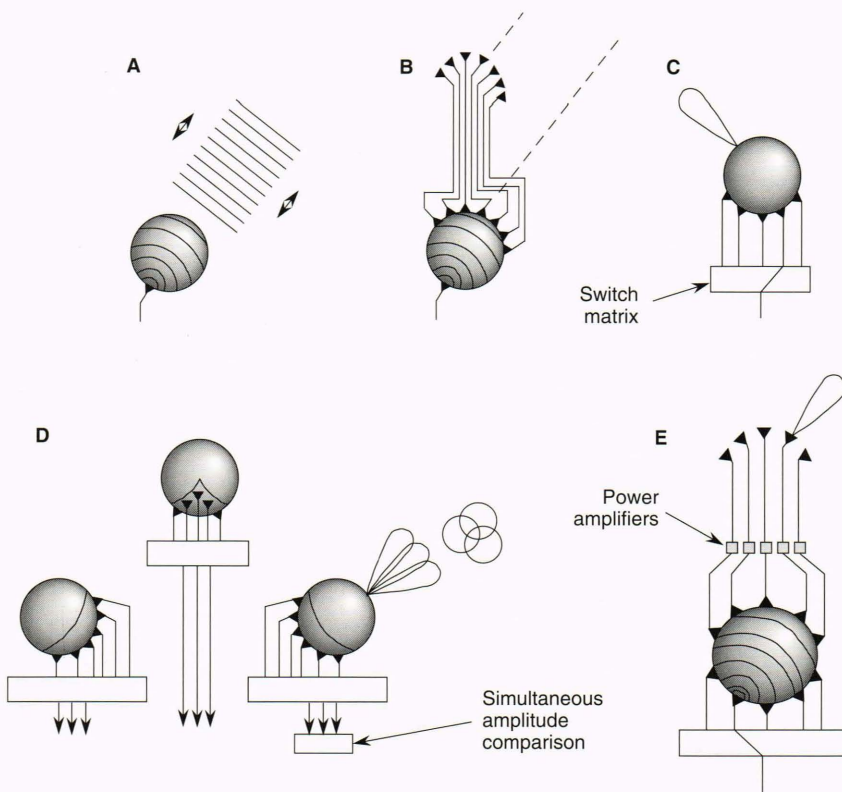


Figure 2. Typhon radar beam forming and beam pointing. **A.** Spherical dielectric lens focuses an incident plane wave or transmits a plane wave if a signal is injected into a feed. **B.** Spherical lens used as a phase computer. **C.** Spherical lens providing high-speed beam switching with multiple feeds and a switch matrix added. **D.** Receiving antenna. **E.** Transmitting antenna.

a feed, with beam direction independent of frequency and beam shape independent of direction. The spherical lens pictured in Figure 2B was used as a phase computer in the phased array system with the addition of multiple pickup elements connected with equal-length lines to the array elements. The spherical lens, as shown in Figure 2C, provided high-speed beam switching with multiple feeds and a switch matrix added. The receiving antennas shown in Figure 2D consisted of three spherical dielectric lenses with multiple feeds, each providing coverage over a third of the hemisphere. Angle tracking was performed by simultaneous amplitude comparison among three adjacent overlapping beams. Figure 2E illustrates the transmitting antenna system, comprising a single phased-array transmitter that provides full hemispherical coverage using a spherical computing lens and a large number of broadband power amplifiers to provide very high peak and average power. Although the array technology later used in Aegis was very different, using several planar arrays to achieve hemispheric coverage, the general concept of a computer-controlled, electronically-steered, multifunction radar as the control element of the weapon system was carried forward into Aegis.

By 1960, Alvin R. Eaton had been appointed Program Supervisor for the integrated Typhon weapon system, including missiles, weapon control, and system integration. Gussow headed the Typhon Weapon Control Section in BuOrd. Garrison was designated Program Supervisor for the Typhon weapon control system, with Roland Larson Program Supervisor for the Typhon LR missile and Tom Sheppard for the Typhon MR missile. The prime contract for the Typhon LR missile had been awarded to Bendix, and an experimental radar system had been placed in operation at APL.

#### APL'S EXPERIMENTAL TYPHON RADAR

Most of the effort during the Typhon development was on the revolutionary new radar. Throughout 1960 and early 1961, Garrison and Gussow both realized that the prototype radar system represented such advanced technology in electronic steering and other radar techniques that a preliminary radar system to the prototype was needed, with scaled-down equipment and performance specifications for test-tracking air targets. The APL experimental Typhon radar system was thus born. BuOrd funded APL for the erection and test of an experimental radar system that would contain a 100-element spherical receiving lens, limited frequency diversity, and 10-kW peak power. A new radar building (now APL's Radar Building 11) was constructed to house the equipment. Shown in Figure 3 is the radar building with a Luneberg lens transmitter and two Luneberg lens receivers on the roof. Also seen is a tracking radar antenna by which the Typhon radar could compare track information. Figure 4 shows the computing Luneberg lens with its many waveguide connectors that lead to the Luneberg lens transmitter on the roof of the radar building. The many microwave connections of waveguides, feedhorns, switches, and other components give the appearance of "microwave spaghetti."



Figure 3. The Laboratory's experimental Typhon radar, 1961.

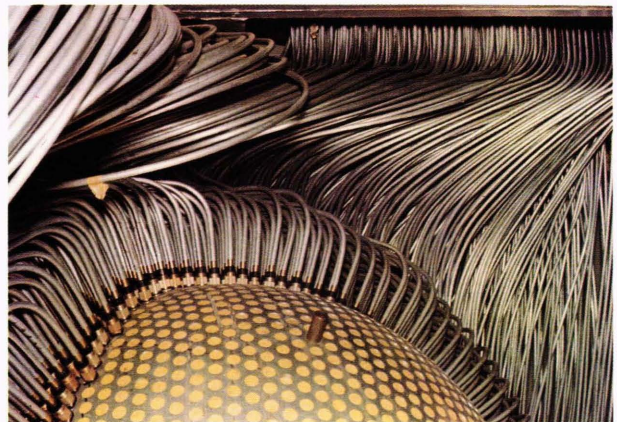


Figure 4. Computing Luneberg lens with waveguide connectors.

In March 1962, the experimental radar at APL successfully tracked simultaneously two augmented helicopter targets in range, angle, and velocity. The design of the radar was driven by the requirement that antenna beam steering and signal processing be highly resistant to enemy countermeasures. Array antennas using phase-steering did not exist. The only known antenna technically meeting the requirement for hemispherical coverage independent of frequency was the Luneberg lens, and this concept became the standard for the new radar. Similarly, the highly sophisticated (by 1960 standards) signal processing techniques required a substantial investment in hardware, but the transistor was still in its infancy, printed circuit boards were just beginning to gain acceptance, and chip circuits had not been invented. General-purpose real-time computers had been introduced into practical use in the Naval Tactical Data System, but the computers at that time were greatly restrained to meet the timing and capacity demands of real-time radar and weapons control. Thus, the groundwork was laid for a technological disappointment, even though the requirements were then valid as subsequent events proved.

## THE TYPHON MISSILES

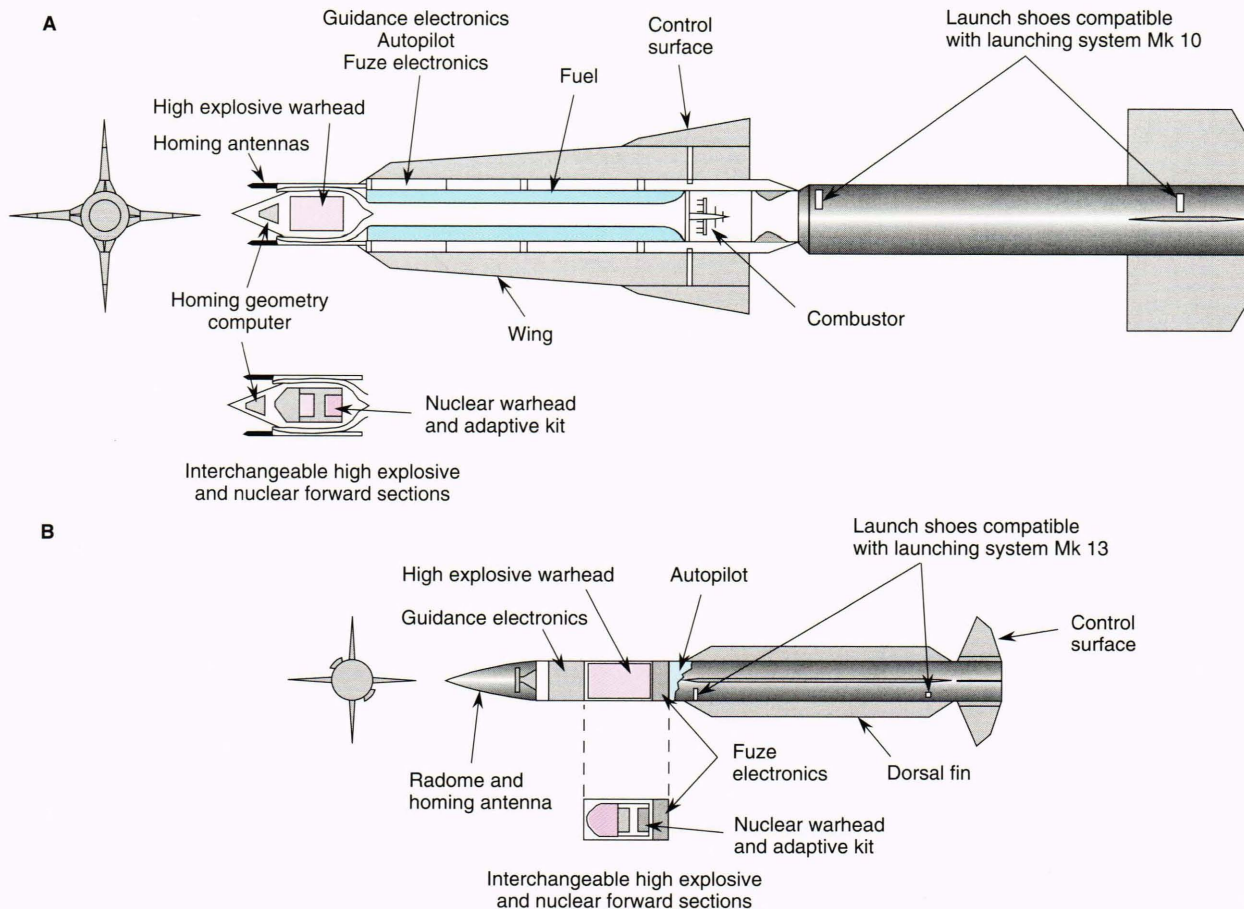
As noted earlier, the two Typhon missiles were to be used together on guided missile cruisers and destroyers. The LR missile was to have the long range (200 nmi) and high altitude (100,000 ft) necessary to counter penetrators at long range, as well as standoff jammers and aircraft carrying antiship missiles. The MR missile was to have less range (40 nmi) and altitude (80,000 ft) coverage but the quick reaction time (10 s) and rapid launch (1 missile/10 s) necessary to counter low-altitude and/or submarine-launched antiship missile mass attacks as well as other penetrators that might come within MR range through the LR coverage. For ships smaller than the guided missile destroyers, the MR missile could be used together with a “small ship” version of the radar and weapon control system to provide a reasonable small-area defense and self-defense capability.

The first concept for the LR missile, as shown in Figure 5A, embodied a ramjet-propelled (with solid rocket boost) body, 16 in. in diameter and 15 ft long, cruciform delta wings with tail flippers, boosted to ramjet operating speed by a solid-propellant rocket that was jettisoned at the end of boost.<sup>2</sup> As the design progressed, the tail flippers and delta wings were replaced by separate tails and very-low-span stubby wings that incorporated air inlets for the ramjet in the leading edges, a design suitably

insensitive to the high angles of attack encountered during intercept. One of the design constraints on LR required it to be usable in the Mk 10 Terrier launching and stowage system with minimum modifications.

The initial concept for the MR missile, as shown in Figure 5B, embodied a solid rocket-propelled body with built-in boost phase thrust, 13.5 in. in diameter and 15 ft long, cruciform stubby (very low aspect ratio) wings, and folding tails.<sup>2</sup> Except for adjustments in the chord length of the stubby wings to satisfy stability and control needs, this configuration was maintained. One of the design constraints on MR required it to be usable in the Mk 13 Tartar launching and stowage system with minimum modifications.

The guidance concept for the two missiles was the same and required that the shipboard radar and weapon control system steer the missile by command during midcourse to a position for homing acquisition, after which the track-via-missile (TVM) homing system, which was conceived at APL, would develop steering commands to achieve the necessary terminal accuracy for target kill. In TVM, the missile is equipped with an antenna to receive the reflected energy from the target. The data are sent to the ship, where target tracking errors are generated and converted to guidance commands by a shipboard computer. Steering commands then are sent from the radar to the missile by uplink. The TVM concept was



**Figure 5.** General configurations of the Typhon missiles. **A.** Long-range missile. **B.** Medium-range missile.

feasible because of the technological advances in the Typhon radar and computer systems. Although the Navy and APL did not pursue the TVM concept after program termination, today's Army/Raytheon Patriot system uses this guidance concept effectively.

A Typhon program goal was to maximize the amount of production missile parts interchangeable between LR and MR, thereby providing substantial savings in production and logistic costs. Naturally, much of the guidance design lent itself very well to this requirement. In addition, the dual-mode fuzing for the continuous-rod and nuclear warheads, the warheads themselves, and the nuclear warhead adaption kits were to be interchangeable.

## SYSTEMS INTEGRATION

Gibson wrote in 1961 that

The TYPHON Program represents the largest Laboratory development effort. The firm allocation of a TYPHON ship in the FY '63 shipbuilding program places great importance on the timely completion of the development. For the first time the Navy has given the Laboratory complete responsibility for weapon system integration, as well as technical direction of nearly all portions of the entire system. The technical challenge inherent in the TYPHON performance objectives, coupled with the magnitude of the job of technical management requires our best efforts. It also requires the unstinting and wholehearted cooperation of all those responsible for portions of the program, working as a team, to insure that the program succeeds.<sup>3</sup>

(Systems integration is the conduct of the necessary engineering and scientific study, development of changes and/or modifications, and test of a surface missile system together with the necessary communications and liaison to ensure the operational workability and compatibility of all elements of the system in a combat environment.)

By November 1962, the Secretary of the Navy, with the concurrence of the Secretary of Defense, had requested and received permission from Congress to cancel the Typhon cruiser in the 1963 shipbuilding program and to reprogram the funds to support the 3T Get Well Program. Pessimism about completing the weapon system on time and the escalating cost of the radar were factors in the decision to slip the date of the first Typhon ship. By 1962, problems inherent in the fragmented design process by which the early 3T weapon systems were developed had become evident, and the Navy formed the Surface Missile Systems Project to assure the functional operability of the 3T systems. The Laboratory was assigned TD for this activity also. Realizing the importance of systems integration, the Navy assigned APL the additional responsibility of TD for Typhon weapon systems integration, another *first* for the Laboratory.

When Edward C. Prettyman joined APL in 1960, he helped design the Typhon weapon direction equipment and demonstrated it in the experimental system at APL. He then became a member of the test team for Typhon radar computer control. Real-time computer programming was an exciting new technology, requiring the utmost in efficient use of the computers then available. This use of computers pioneered concepts of digital engagement scheduling and fire control and was one of the *first*

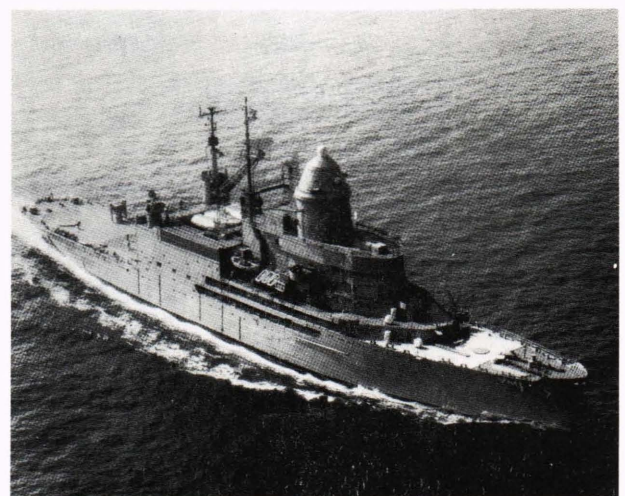
systems to adopt general-purpose operator consoles to the needs of weapon control. The approaches demonstrated in this system later bore fruit in the digitalization of Terrier and Tartar weapon control, as well as in the Aegis weapon system.

## USS NORTON SOUND (AVM-1)

Installation of the prototype Typhon radar and weapon control systems on the test ship USS *Norton Sound* (AVM-1) began in March 1963 at the Maryland Shipbuilding and Drydock Company, Baltimore, Maryland. As development continued through 1963, it became evident that the technical advances being attempted in Typhon were too great. The system was large, complex, and costly. In November 1963, the Typhon program was cancelled, and the *Norton Sound* installation was redirected as the *Norton Sound* Engineering Test Program, the objective being to evaluate the design concept embodied in the radar. The project engineer for this phase of the program was George Luke. Concurrently, the Navy was directed to initiate studies on an advanced missile system that was to be simpler, less expensive, and adaptable to much smaller ships.

In June 1964, the USS *Norton Sound* was recommissioned with CAPT W. A. Arthur, USN, as Commanding Officer. Throughout the remainder of the year, she engaged in experimental exercises at sea with brief stays at New York City, Bermuda, and Miami. The evaluation team composed of Navy, APL, and Westinghouse personnel was aboard at all times. In the spring of 1965, she transited the Panama Canal to home port at Port Hueneme, California. Figure 6 shows the *Norton Sound* under way with its Typhon radar structure. An APL engineering team led by Andreas C. Schultheis took up residence at Port Hueneme to continue the test program.

Evaluation of the radar was conducted from July 1965 through the spring of 1966. Limited testing of search, acquisition, and track of air targets was conducted. Sys-



**Figure 6.** Prototype Typhon radar built by Westinghouse and installed in the USS *Norton Sound* (AVM-1).

tem reliability was poor, and computer programming was difficult to complete with a still-developing and unreliable system. Detection range performance was inadequate.

In December 1965, the Surface Missile Systems Project Director convened a review panel aboard the ship to review the results of the engineering test program. The panel, an advisory group of scientists drawn primarily from industry, concluded that the lessons learned were extremely valuable, but further effort would have little additional value and could be better expended in translating Typhon experience of techniques and equipment to the new Advanced Surface Missile System Study. The need for an advanced system still remained. In June 1966, the Typhon radar was removed from the USS *Norton Sound*, which later hosted the Aegis weapon system engineering development model.

Although Typhon's system design successfully overcame most of the limitations of the 3Ts, it was technologically ahead of its time. The concepts, so brilliantly put forward by the Typhon team, could not be translated successfully into hardware by existing U.S. industries. It was to take another ten years and a new program start before the requisite industrial potential could be exploited. As the last act of the program, the *Norton Sound* engineering team recommended a new and simpler system concept embodying the same basic principles but using phase-phase planar array antennas and large-scale

integration technology. The concepts were later incorporated in the Aegis weapon system.

A historical study of the Aegis weapon system notes that the state-of-the-art technology available then was still too primitive to achieve the performance goals sought within appropriate size and weight requirements or within an acceptable degree of complexity. The Typhon program was one of high risk because of a mismatch between its goals and the technology of the early 1960s.

So ended the saga of Typhon, setting the scene for the birth of Aegis. The Laboratory closed its chapter on Typhon, and with its gained knowledge and invaluable experience was far better prepared to begin the first chapter on Aegis and open a new era on weapon technology. "Without Typhon, there would be no Aegis" is a statement often repeated by Rear Admiral Wayne E. Meyer, USN (Retired), who was the first Aegis and Shipbuilding Program Manager and is considered the "father" of the Aegis weapon system.

#### REFERENCES

- <sup>1</sup>Gibson, R. E., "Reorientation of TYPHON Program," JHU/APL Administrative Memorandum 1087 (13 Jan 1964).
- <sup>2</sup>Eaton, A. R., *JHU/APL TYPHON Weapon System Description* (Dec 1960).
- <sup>3</sup>Gibson, R. E., "Integration of TYPHON Program," JHU/APL Administrative Memorandum 1008 (25 Oct 1961).

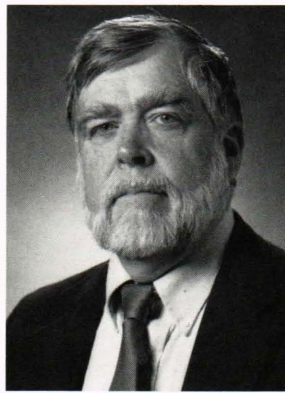
ACKNOWLEDGMENT: The authors appreciate the contribution to the section on Typhon missiles by Ray L. Ely, who now is retired from APL.

#### THE AUTHORS



MILTON GUSSOW is a Principal Professional Staff engineer in APL's Naval Warfare Analysis Department. He is a graduate of the U.S. Naval Academy (1949) and holds a BSEE degree from the Naval Postgraduate School (1956) and an M.S. from MIT (1957). He retired in 1967 as a Commander, U.S. Navy. He was Senior Vice President for Product Development at the McGraw-Hill Continuing Education Center. He joined APL in 1967 for six months and then returned in 1978. Mr. Gussow is the author of the textbook *Basic Electricity*. A past Adjunct Professor at

the George Washington University and the American University, he now teaches a course at the School of Advanced International Studies of The Johns Hopkins University. Mr. Gussow is the Director of the Systems Assessment Group for the NSIA Strike, Surface, and Antiair Warfare Committee. His interests include multiwarfare analysis, wargaming, strategic analysis, and international relations. He is a member of Sigma Xi and a senior member of IEEE.



EDWARD C. PRETTYMAN received a B.S. degree in electrical engineering from the University of South Carolina in 1957. He served an active duty tour with the Navy, and joined APL in 1960. Mr. Prettyman first worked on Typhon weapon system development and subsequently was associated with systems engineering and computer programs development for the Aegis weapon system. He is a member of APL's Principal Professional Staff and is the supervisor of the Warfare Systems Branch of the Fleet Systems Department. He also lectures in systems engineering for

the G.W.C. Whiting School of Engineering.