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TERRIER/TARTAR: NEW THREAT UPGRADE PROGRAM

The New Threat Upgrade Program is the latest in a series of modifications to TERRIER and TARTAR ships to maintain pace with the technological progress of the threats posed against the U.S. surface Navy. Because the complexity and sophistication of the threats have increased since the first guided missile ships became operational three decades ago, the combat systems designed to counter the threats must be upgraded to ensure that the ships can continue to fulfill their mission. APL has assumed a major role in the conception, development, and evolution of the New Threat Upgrade Combat System.

INTRODUCTION

In the mid-1970's, projections of future capabilities of foreign bombers armed with air-to-surface missiles were identified as a serious threat to the U.S. Fleet. The Naval Sea Systems Command directed that a study be performed to determine the capabilities of TERRIER and TARTAR ships against the new threat projection. The study group was also required to produce a plan to increase TERRIER and TARTAR effectiveness as an interim defense prior to the deployment of AEGIS Guided Missile Cruisers.

APL led a team of organizations, including participation by intelligence agencies and Navy contractors and laboratories, that examined the threat's characteristics and assessed TERRIER and TARTAR limitations. The capabilities of the present guided missile cruiser combat system using the STANDARD Missile-2 were evaluated, and limitations were analyzed in detail. The results of this effort were a definition of modifications to the baseline system necessary to overcome the high performance of the new threat projection and a formulation of a plan to upgrade the TERRIER and TARTAR Fleet. The program development plan, submitted in 1976, was followed by approval to proceed.

The New Threat Upgrade Combat System consists of onboard and offboard active and passive sensors as well as air, surface, and subsurface weapon systems directed by the ship's command and control system. The New Threat Upgrade Combat System is built upon the baseline capability of the present system, with modifications introduced specifically to counter new air threats to the Fleet.

APL's role in the New Threat Upgrade Program is representative of its involvement in major Naval programs, with activities ranging from threat assessment through test and evaluation. APL has been designated Technical Direction Agent and System Integration Agent for the combat system. As Technical Direction Agent, the Laboratory has responsibility for the technical development of equipment and system modifications and also for new equipment being designed and fabricated by the various design agents.[1] As System Integration Agent, APL has the responsibility (a) for coordinating changes made to existing equipment and computer programs by the different design agents; (b) for ensuring that new equipment and programs are compatible with the modified baseline elements; (c) for integration, testing, and evaluation of the entire combat system during its development, from individual equipment and program tests at the design agent's facility through testing at the APL Land-Based Test Site; and (d) for formal Technical Evaluation aboard a test ship firing live missiles.

SYSTEM DESCRIPTION

The New Threat Upgrade Combat System consists of three subsystems: Detection, Command and Control, and Engagement. These three subsystems and their major components are shown in Fig. 1. Major modifications to the baseline system were made in the Detection Subsystem and to the STANDARD Missile-2, while supportive changes were made to the remainder of the system.

The Detection Subsystem consists of the AN/SPS-48E three-dimensional and the AN/SPS-49(V)5 two-dimensional search radars, the AN/SYS-2 Integrated Automatic Detection and Tracking System, and the Mk 12 Identification, Friend or Foe equipment. The search radars are equipped with automatic target detection systems that interface with the Integrated Automatic Detection and Tracking System. This system, under the direction of the Command and Control Subsystem, controls the operations of the search radars and provides target data to the Naval Tactical Data System (NTDS) and the Weapon Direction System (WDS).

The Command and Control Subsystem consists of the NTDS computer complex and the command and

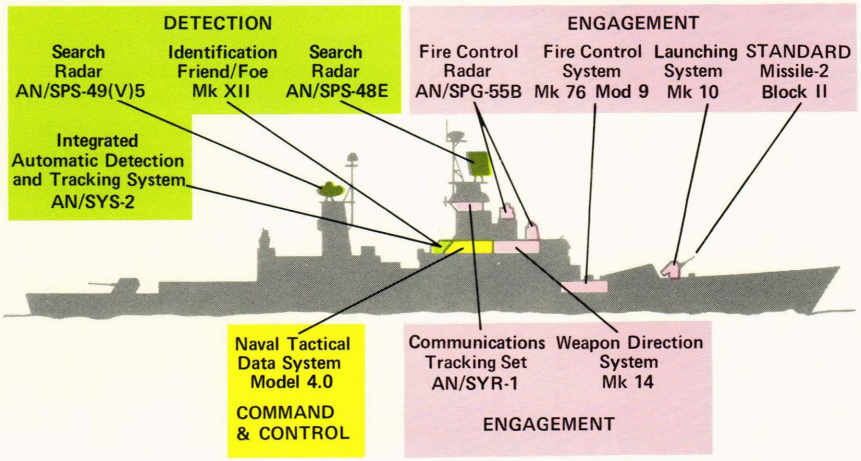

Figure 1 — The elements of the New Threat Upgrade Combat System installed in BELKNAP (CG-26) Class TERRIER Guided Missile Cruiser. This is the latest modification of the TERRIER and TARTAR Combat System to provide increased effectiveness against advanced air-to-surface threats.

control doctrine and procedures that maximize the effectiveness of the combat system in carrying out the assigned mission of the ship. The doctrine and procedures provide recommended responses as a function of the situation the ship is in. This includes the type of weapon that should be employed and considers which ship in a task force should engage the threat. The subsystem is supported by display consoles allowing command and control personnel to direct combat operations through the tactical computer program contained in the NTDS's computer suite.

The Engagement Subsystem consists of the Mk 14 WDS, the Mk 76 Mod 9 Guided Missile Fire Control System, the Mk 68 Gun Weapon Control System, the AN/SYR-1 Communications Tracking Set, the Mk 10 Guided Missile Launching System, and the STANDARD Missile-2 (Extended Range) Block II. The WDS controls Engagement Subsystem equipment that conducts missile and gun engagements against air, surface, and shore targets in response to orders from the Command and Control Subsystem, using target data supplied by the Integrated Automatic Detection and Tracking System.

The three-dimensional and two-dimensional search radars report contact and environmental data to the Integrated Automatic Detection and Tracking System, which (a) modifies radar processing and search volumes on the basis of the environmental data supplied by the radars and operational commands from the NTDS, (b) combines the contact data supplied by the radars into a single track file, and (c) provides track data as requested to the NTDS and WDS. The Mk 12 Identification, Friend or Foe equipment provides track identification directly to the NTDS, which then presents the total combat situation to the ship's officers and passes orders for engagement of tracks to the WDS. On the basis of track data supplied by the Integrated Automatic Detection and Tracking System, the WDS schedules and executes the engagement, using the Guided Missile Fire Control System and AN/SPG-55B Fire Control radar, the Guided Missile Launching System, and the STANDARD Missile-2 (Extended Range) Block II missile. In-flight evaluation of missile performance and kill assessment after scheduled intercept are provided by the Communications Tracking Set, which reports to the WDS.

THE APL ROLE

The many steps necessary for realization of the New Threat Upgrade Combat System may be grouped into conceptual, developmental, and test and evaluation phases. The involvement of APL in each of these phases is detailed below.

Conceptual Phase

The new threat to Naval forces consists of multiple attacks by antiship missiles in severe electronic countermeasures environments. These missiles fly at high altitudes and speeds, have small radar cross sections, and are capable of engagements against a ship at steep dive angles. Despite the performance of TERRIER cruisers equipped with the present combat system, which introduced significant improvements in range and firepower into the Fleet, the studies identified several areas where further improvements were required in the future. The small target and sophisticated electronic countermeasures associated with the newer threat can cause late detection and increase combat system reaction time. Firepower can be severely limited by this environment, and the overall performance of the combat system may not be sufficient to allow the ship to fulfill its mission. In addition, the studies identified areas where the performance of the surface-to-air missile itself had become marginal due to the increased performance of the newer threat.

These conclusions were reached after characterization of the threat and assessment of the present combat system's performance against the threat, using computer simulations of the existing combat system equipped with the STANDARD Missile-2. These simulations, when analyzing attacks by the newer threats, also provided a detailed model for analysis of various combat system modifications proposed to correct the deficiencies previously demonstrated. Three options for upgrading the combat system, complete with per-

formance trade-offs, were summarized in the form of a Technical Development Plan, with additional technical backup material provided.

The major changes recommended by APL decreased combat system reaction time and improved search radar detection of small, fast targets in the presence of severe electronic countermeasures. APL also proposed improvements in missile kinematic, fuze, and warhead performance that would result in a faster missile capable of intercepting and destroying small cruise missiles. During the conceptual phase, APL provided a definition of the danger faced by the Fleet from the newer threats, an analysis and evaluation of the modifications necessary to meet the threat, and a Technical Development Plan for placing the New Threat Upgrade Combat System in the Fleet.

Developmental Phase

During the developmental phase of the combat system, APL had dual designation as both Combat System Technical Direction Agent and System Integration Agent. In addition to these responsibilities, APL was the Detection Subsystem Integration Agent in the early design phases of the program and also served as the Navy's procuring agent for the Fire Control System radar modifications, the Communications Tracking Set, and the Message Interface Unit (an element of the launching system). These assignments ensured APL's presence in all phases and aspects of the development sequence, from setting requirements for equipment or computer program performance to participation in final acceptance testing of the equipment or computer program at the designer's facilities. Control of equipment and computer program configuration and system architecture was maintained through requirements and specifications documents prepared for or by APL and issued by the Naval Sea Systems Command. In addition, direct technical assistance was provided as required to the various design agents and Navy laboratories during the design, development, and fabrication of combat system components.

After approval of the APL Technical Development Plan, the equipment designers began detailed study programs to determine the feasibility and the means of modifying their equipment to achieve the performance goals of the New Threat Upgrade Combat System. These requirements were identified in the New Threat Upgrade System Level Requirements and System Level Specifications. Both documents were written by APL in Navy specification format, approved by the Naval Sea Systems Command, and subsequently made available to the technical community for guidance. From these documents, specifications were developed in detail for each piece of equipment and each computer program. For example, top-level requirements for improvement of detection range were translated into requirements for (a) radar detection range against the threat in an electronic countermeasures environment with a given probability of detection and a maximum false alarm rate, (b) maximum number of targets tracked, and (c) reaction time. These requirements were then formalized in detailed equipment and computer program weapon specifications. The weapon specifications not only guaranteed that each piece of equipment or computer program would perform its allocated function within the combat system, but also provided exact standards for test and evaluation of the system.

APL has also played an integral role in the development of two other major system level documents: the Naval Decision Coordinating Paper and the Navy Test and Evaluation Master Plan. The Naval Decision Coordinating Paper was signed by the Chief of Naval Operations in February 1981. These documents form the basis of the development and test programs and are used at many levels of the Navy and Department of Defense.

Control of Combat System Architecture was maintained by APL through Interface Design Specifications, which define the signals and messages exchanged among equipment and computer programs. The development of these documents was a complex process because the combat system components were sponsored by different offices within the Navy and were designed and developed by a number of designers and Navy laboratories. APL's experience gained during the development of the present combat system provided a method for coordinating definitions of the interface within the technical community and also provided proven concepts and designs necessary for building the interfaces. The Navy sponsors and design agents responsible for the elements on each side of an interface met under APL guidance to discuss each of the signals and messages. These meetings ensured that the information sent over the interface was adequate and would not be misinterpreted and that special requirements, such as timing, would be met. The resultant Interface Design Specification was maintained by APL during development of the combat system, and any proposed change in a combat system element affecting the interface had to be approved by negotiation under APL guidance before implementation. This use of the document not only guarantees control of system architecture but also provides detailed standards for testing the interface to ensure that the interactions between combat system elements are as designed.

Previous leadership in search radar design and automatic detection and tracking systems led naturally to APL's designation as the Detection System Integration Agent. In this role, technical guidance is provided to the designers responsible for the development of the search radars and the Integrated Automatic Detection and Tracking System. APL had played an integral role in the development of the first Integrated Automatic Detection and Tracking System, SYS-1. The New Threat Upgrade version, SYS-2, was a natural refinement and extension of this program. Much detailed design effort was expended to develop the SYS-2 prior to its turnover to the design

agent. The equipment combines the search radars into a Detection Subsystem and is able to perform the multiple functions of search, detection, and tracking. This allows missile guidance up to terminal homing without illumination by the fire control radar; consequently, the fire control radar is able to engage more targets in a given interval. The concepts of multiple function sensors and missile guidance using search radar data have been extensively developed by APL.

In addition to serving as a design consultant for the Detection Subsystem, APL contracted directly with design agents to develop the modifications for the AN/SPG-55B Fire Control Radar, the SYR-1 Communications Tracking Set, and the Message Interface Unit of the Guided Missile Launching System. APL exercised direct control over the design and procurement of the modifications required for both Land-Based Test Site and at-sea test and evaluation. These efforts were governed by equipment and computer program specifications prepared in full or in part by APL, as well as by detailed statements of work defining activities, milestones, and deliveries. This effort was a continuation of work started during the development of the baseline combat system in which the Communications Tracking Set and Message Interface Unit were conceived initially by APL and then developed by the design agent under APL guidance.

In addition to its role in combat system development, APL also led in the preparation of a mission reliability, maintainability, and availability assessment plan. This plan establishes system reliability predictions in a manner that allows allocation of the predictions to the subsystem level. The plan also includes a mathematical model that forms the basis for comparison with actual reliability figures after test and evaluation to ensure that reliability is built into the design. The plan and model were also used for a reliability design review by the Naval Material Command in June 1981.

Test and Evaluation Phase

Before a system as complex as New Threat Upgrade can be authorized for production and subsequent Fleet installation, it must be thoroughly tested to ensure that it meets requirements and objectives outlined in all applicable requirement and specification documents. The test and evaluation phase (Fig. 2) also allows for correction of design or production errors before deployment. The testing for New Threat Upgrade will be conducted at two locations; the APL Land-Based Test Site and USS MAHAN. Land-based testing allows easier resolution of the problems expected when a large system is assembled for the first time. It also allows easier access to technical personnel and repair facilities and expedites the test and evaluation process. Land-based testing has been successfully used for the TERRIER engagement system since the early 1960's. The Building 40 test facility at

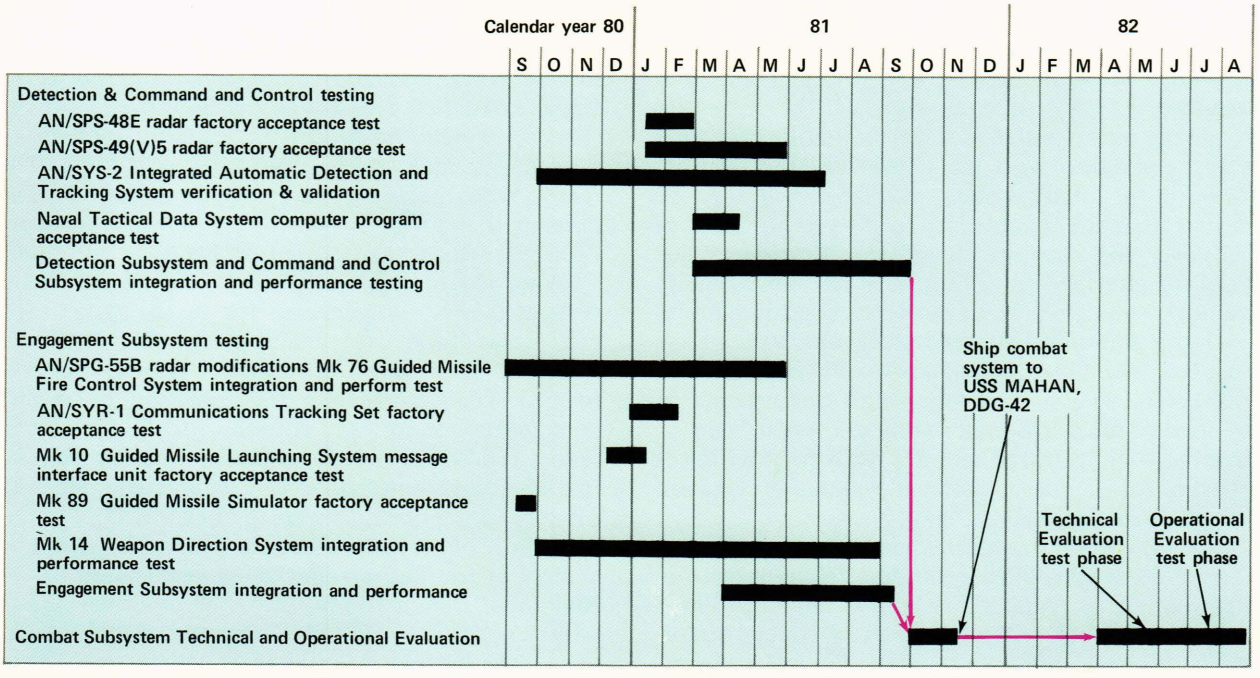

Figure 2 — The test and evaluation sequence for the New Threat Upgrade Combat System. The Detection Subsystem will begin integrated testing at the APL Building 11 Land-Based Test Site after factory acceptance testing. The Command and Control Subsystem's Naval Tactical Data System Model 4 computer program will undergo acceptance testing before it is brought to the Land-Based Test Site. The Engagement Subsystem equipment, after initial factory acceptance testing, will undergo testing at the Building 40 test facility. Detection Subsystem integration testing and integration testing of the three subsystems will then be conducted. After successful completion of these test phases, the combat system will be installed aboard USS MAHAN for live missile firing tests.

APL, now expanded for the New Threat Upgrade Program, is responsible in part for the ever-increasing reliability of the engagement system.

The land-based approach was also used in 1975-1976 to evaluate the baseline combat system prior to its at-sea testing in USS WAINWRIGHT and USS MAHAN. As a result of this effort, Captain L. J. Holloway, then Director of the Long Range Missile Systems Division of the Naval Sea Systems Command, stated: "In this test program, we have experienced the obvious advantages to the Navy of maintaining and utilizing a Land-Based Test Site for initial testing in major programs. The results were achieved with a tremendous savings to the Navy in dollars and manpower compared to the cost of testing in a combatant ship."

In the test and evaluation phase, APL had the responsibility for preparing the Land-Based Test Site, preparing test documentation, and conducting the testing, both at the land-based facility and in USS MAHAN. During both the land-based and at-sea testing, APL serves as overall test conductor and is designated the Naval Sea Systems Command's agent. Test teams, led by APL staff members experienced with the equipment to be tested, will be formed for equipment, computer program, and interface testing.

The majority of the test documentation has been prepared by APL, including the Test and Evaluation Master Plan; Event Plans; Test Requirements, Plans, and Procedures; and finally, the Test Reports for each of the test events. Over 100 documents are required to plan and carry out the test and evaluation.

The test and evaluation methodology was developed by APL and demonstrated during land-based testing of the baseline system. Each computer program or piece of equipment will be tested individually as it is installed to verify that its operation is in accordance with the governing specification. Each of the many system interfaces will then be verified separately according to the requirements of the governing interface design specification. When all of the interfaces have been verified, subsystem integration testing will begin, to verify the compatibility and operation of the subsystem units as a whole. Finally, the three subsystems will be operated together to demonstrate the overall performance of the New Threat Upgrade Combat System and to establish that the test program is ready to move to the test ship for an at-sea technical evaluation. This test philosophy is depicted in Fig. 2.

The test method builds the combat system one element at a time, producing test data for fault or trouble isolation, as required. Testing at the Land-Based Test Site will also provide records of system performance for later comparison with shipboard performance to allow verification of shipboard operating procedures. In addition, intensive training of the USS MAHAN crew who will operate the combat system during Technical and Operational Evaluations will begin at the Land-Based Test Site. Test requirements, plans, and procedures documents for each of the tests are currently being prepared under APL direction in accordance with the overall Test and Evaluation Master Plan and the separate event plans for the various test phases. The Message Interface Unit, the fire control radar and computer modifications, the digital data distribution set (a data bus for distribution of the ship's motion parameters), and the guided missile simulator are currently undergoing or have completed testing at the Land-Based Test Site. Testing of the entire New Threat Upgrade Combat System as a unit began in September 1981, with testing aboard the USS MAHAN to begin in May 1982.

THE APL LAND-BASED TEST SITE

A major APL role in test and evaluation is that of test facility preparation and maintenance. As noted earlier, the Land-Based Test Site already had an engagement system facility housed in Building 40. The major activity in readying for New Threat Upgrade testing was the modification of Building 11 to house the Detection Subsystem; Identification, Friend or Foe equipment; and NTDS equipment as shown in Fig. 3. Building 11 is to house the Detection and Command and Control Subsystems, as well as a data reduction facility, engineering laboratories, and offices. Building 40 is to house the Engagement Subsystem and related test instrumentation, as well as to provide support for the missile van and the data van. Additionally, test support activities in the area of AN/SYS-2 validation are to be conducted in Building 6. The subsystems located in Buildings 11 and 40 are connected by a fiber optic data bus that transmits digital data and provides for voice communication between the test areas. Perhaps the most visible sign of New Threat Upgrade Combat System testing at the Land-Based Test Site will be the Building 11 skyline (Fig. 4), which reproduces the test ship superstructure, masts, and search radar antenna mounts. The search radar antennas have the same relative positions as they have on the ship so that near-field reflections, which have caused problems in automatic tracking programs during previous testing, can be investigated and compensated for in the radar software. In addition, experiments using radar-absorbent materials to reduce reflections will also be performed. The arrangement of the transmitter, receiver, signal processor, and consoles for the two search radars reproduce the floor plan of the test ship so that the same interconnecting cables can be used when the equipment is installed in USS MAHAN. The Identification, Friend or Foe equipment will facilitate control of test aircraft and allow verification of the equipment's compatibility with the modified search radar. A sophisticated radar-frequency signal simulator will be housed in Building 11 to exercise the radars when test aircraft are not available. This device is capable of exercising both search radars simultaneously and of injecting into the radar receiver realistic radar frequency signals that simulate missiles, aircraft, jamming, chaff, and weather. The radar-frequency signal simulator will also be installed aboard

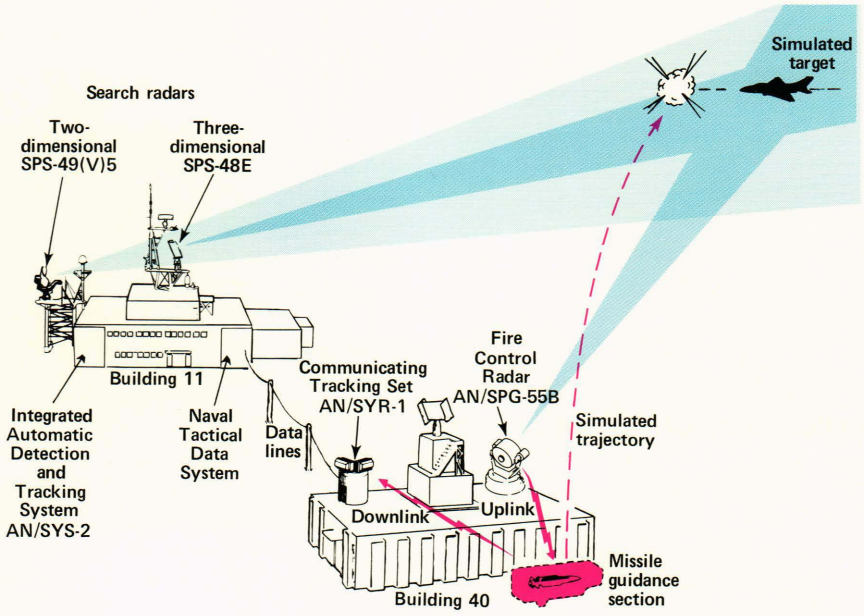

Figure 3 — Relationships between the New Threat Upgrade Combat System and equipment simulations installed at the APL Land-Based Test Site (Buildings 11 and 40). The interfaces between the Weapon Direction System and the Naval Tactical Data System and Integrated Automated Detection and Tracking System (in Building 11) are provided by a data bus using a fiber optic data link.

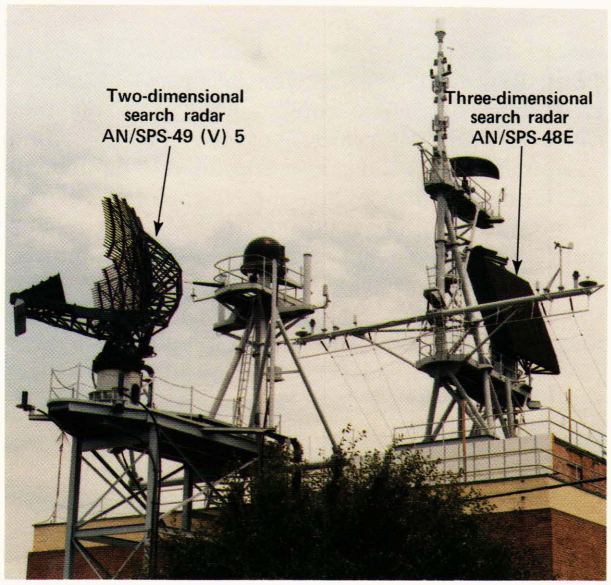

Figure 4 — The skyline of the Land-Based Test Site at Building 11 and the major combat system elements undergoing integration and evaluation testing. In addition to the search radar antennas, the ship's masts and upper superstructure are reproduced to allow near-field reflections to be measured. This arrangement also permits experiments using radar-absorbent materials to be performed. The positions of the transmitter, receiver, signal processor, and consoles for the two search radars also reproduce the arrangement aboard the test ship to allow identical cables to be used when the testing is moved to USS MAHAN.

the USS MAHAN for use in system checkout, crew training, and system performance evaluation.

The data reduction facility, designed by APL, will contain the computers and supporting peripherals to reduce the data gathered during testing. Data analysis will be provided by APL, with assistance as required from the design agent. The APL role in data reduction also includes design and coding of many of the data reduction programs needed to assess system performance. The writing of the data reduction programs to the analyst's specifications is presently under way and will result in an extensive library of programs that can be called upon to produce the desired displays. In addition, the data reduction facility may be called upon to produce specialized data products that may be required during any of the test phases.

The WDS, the Communications Tracking Set, the Guided Missile Fire Control System, and the Message Interface Unit and Guided Missile Launching System simulation were housed in Building 40. In addition, the AN/WSN-5 Inertial Navigation Set, which provides the ship's motion parameters to the combat system, and the Mk 89 Guided Missile Simulator, which simulates the various missile rounds, were installed in Building 40.

Test support equipment includes the evaluation support system, which controls a target simulator in the Fire Control System Radar to allow tracking of a test target in various environments. Use of this test target in conjunction with the radar-frequency signal simulator will permit realistic exercise of the entire operational sequence of the combat system in controlled and repeatable simulations without the presence of test aircraft.

A computer simulation program developed by APL can be used in place of the equipment interfacing with the WDS to allow Engagement Subsystem testing to proceed even if some of the equipment is off line.

A missile van houses a hardware missile simulation to permit verification of uplink and downlink communications, missile response to commands from the combat system, and proper combat system response to changes in missile status.

A data van contains a complete telemetry ground station and supporting data collection and reduction equipment; it will be used to support testing both at the Land-Based Test Site and at the Atlantic Fleet Weapons Training Facility, Puerto Rico, during Technical Evaluation.

Additional test support instrumentation includes standard recording devices, hardware simulations, state-of-the-art electronic-countermeasures transmitters, a radar-frequency simulation tower, and special-purpose test sets.

AT-SEA TESTING

The final phase of the New Threat Upgrade Combat System development effort will be the Technical and Operational Evaluation aboard USS MAHAN. Successful completion will lead to Approval for Service Use and will allow full production to begin for eventual introduction of the New Threat Upgrade capability into the TERRIER Guided Missile Fleet. This at-sea testing is being accomplished under the charter of Chief of Naval Operations Project 547 and is being done concurrently with Project 623, which assesses the performance and operability of the STANDARD Missile-2 (Extended Range) Block II. This evaluation will indicate that engineering is reasonably complete, that significant design problems have been identified and solutions formulated, and that the system functions in a technically acceptable manner. The Laboratory will serve as the test conductor and will support the testing with a team of technical experts who have been involved in all previous phases of testing.

In many respects, at-sea testing will repeat many of the performance, interface, and system level tests previously conducted at the Land-Based Test Site except that artificialities associated with the test site, such as restrictions on tracking exercises and equipment simulations, are eliminated. The at-sea testing also subjects the combat system, for the first time, to shipboard environmental conditions, including the ship's motion and more severe weather. Actual missile firings against unmanned drones will be conducted as the final proof of performance.

SUMMARY

Experience in the previous development of the TERRIER Missile System, search radar design and development, and design of integrated automatic detection and tracking systems allowed APL to play a major role in the development of the New Threat Upgrade Combat System. During the conceptual phase, APL defined the danger to the Fleet presented by the new threat projections and developed a program plan for upgrading shipboard capability to counter it. During the developmental phase, APL translated the program plan into detailed requirements and specifications, which were provided for technical guidance to the designers and Navy laboratories that were building the system equipment and computer programs. Control of system architecture was maintained by APL throughout fabrication and integration of the system. During the test and evaluation phase, APL provided the personnel and facilities for testing, as well as a test method proven in previous research and development programs. The APL Land-Based Test Site, previously used for TERRIER engagement system testing, was expanded to include the entire combat system. A complete range of support services, including data reduction, computer simulations, and special test equipment, has been provided. When the New Threat Upgrade Combat System moves to sea for Technical Evaluation, an APL test team under an APL test conductor will prove the system, using live missiles against threat-representative targets. APL will again provide many support services, including on-site telemetry reception, data reduction, and detailed analysis of results.

NOTE

[1] These design agents include ITT Gilfillan; Raytheon Co.; Norden Systems; Sperry Gyroscope Division; Vitro Laboratories, Automation Industries; Northern Ordnance Division, FMC; and ECI Division, E-Systems.