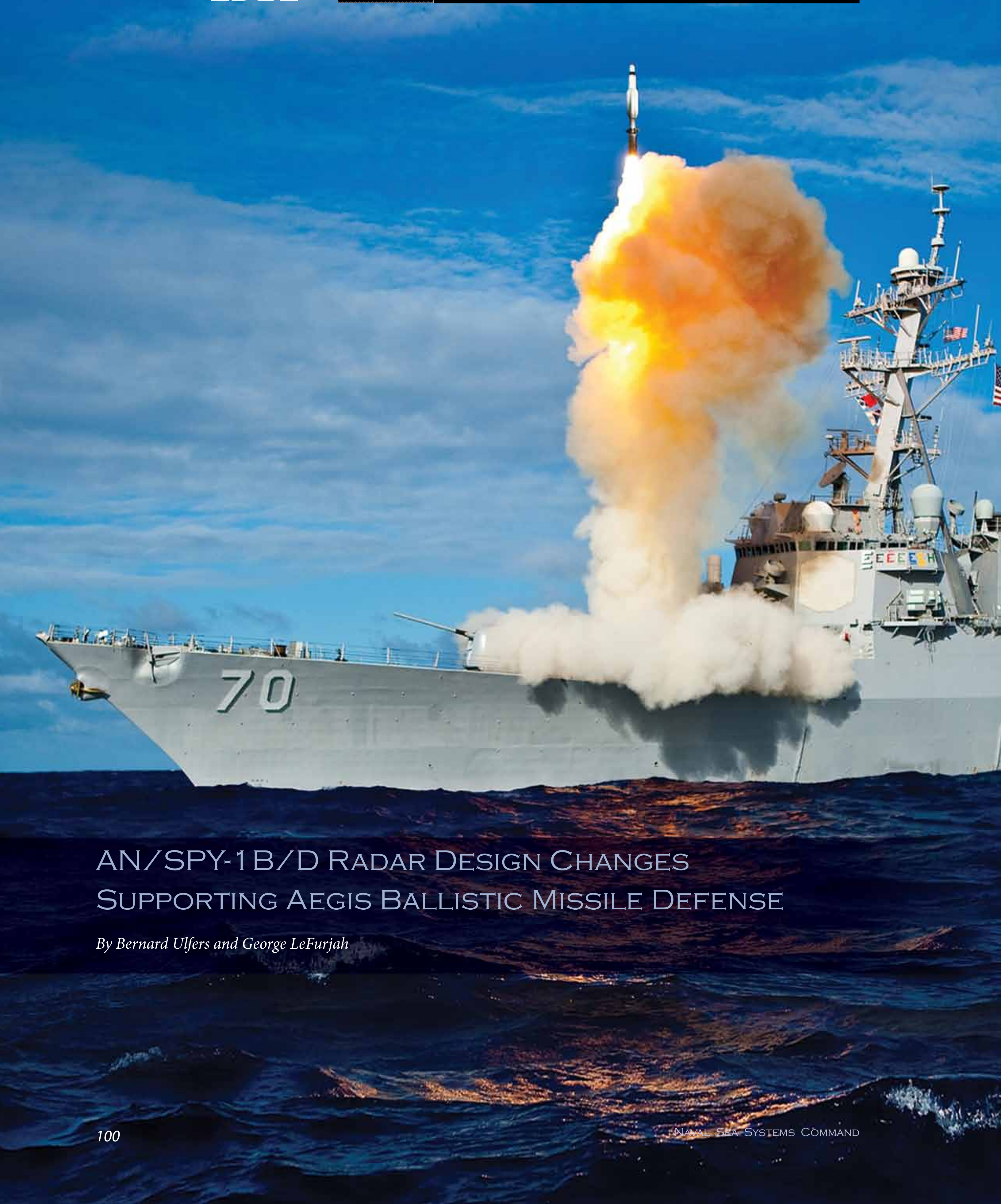


AN/SPY-1B/D Radar Design Changes Supporting Aegis Ballistic Missile Defense

By Bernard Ulfers and George LeFurjah

The Aegis Combat System is an integrated system supporting warfare on several fronts—air, surface, subsurface, and strike—and the Naval Surface Warfare Center, Dahlgren Division (NSWCDD) has been intimately involved in the development, test, certification, and fielding of almost every new baseline of the Aegis Weapon System (AWS) since the 1970s. This involvement continues as the AWS evolves into a critical element of the Ballistic Missile Defense System (BMDS). The Antiair Warfare (AAW) components of the AWS are the AN/SPY-1B-/D radar system, the Command and Decision System, and the Weapons Control System.

BALLISTIC MISSILE DEFENSE SYSTEM (BMDS)

The BMDS is a system of systems employing a layered defense architecture. It consists of several systems (or elements) at each layer, allowing for multiple engagement opportunities against ballistic missiles (BMs) before they reach their intended targets. BMs follow three flight phases: boost (preburnout), midcourse (exoatmospheric), and terminal (post-reentry). Currently, interceptors and associated sensor systems have been deployed to engage BMs in their midcourse and terminal flight phases. For instance, the Ground-Based Midcourse Defense element is deployed in Alaska and California to defend against Intercontinental Ballistic Missiles (ICBM) and long-range BMs during their midcourse phase flight. The AWS sea-based midcourse element is deployed to defend against short- and medium-range BMs during their midcourse flight phase. Detection, tracking, and discrimination of lethal objects by the associated sensors allow the interceptors to utilize hit-to-kill technology against the threat while in the exoatmosphere. The terminal phase is the last opportunity to engage the threat. Two elements providing this terminal capability are the Theater High-Altitude Area Defense (THAAD) and the U.S. Army Patriot Advanced Capability (PAD-3) systems. Figure 1 depicts BM flight phases.

Aegis Ballistic Missile Defense (ABMD) was initially fielded as the 3.6.1 AWS baseline to provide autonomous (search, track, engage, and kill) BM defense against short- and medium-range threats and, to provide surveillance support (search, track, and hand-off) to other elements for a mix of short-, medium-, and some long-range threats. The next upgrade to be deployed, the ABMD 4.0.1 baseline, enhances capability against short- and medium-range threats, from unitary to complex separating. In addition to surveillance support to other elements, ABMD 4.0.1 is also capable of launching

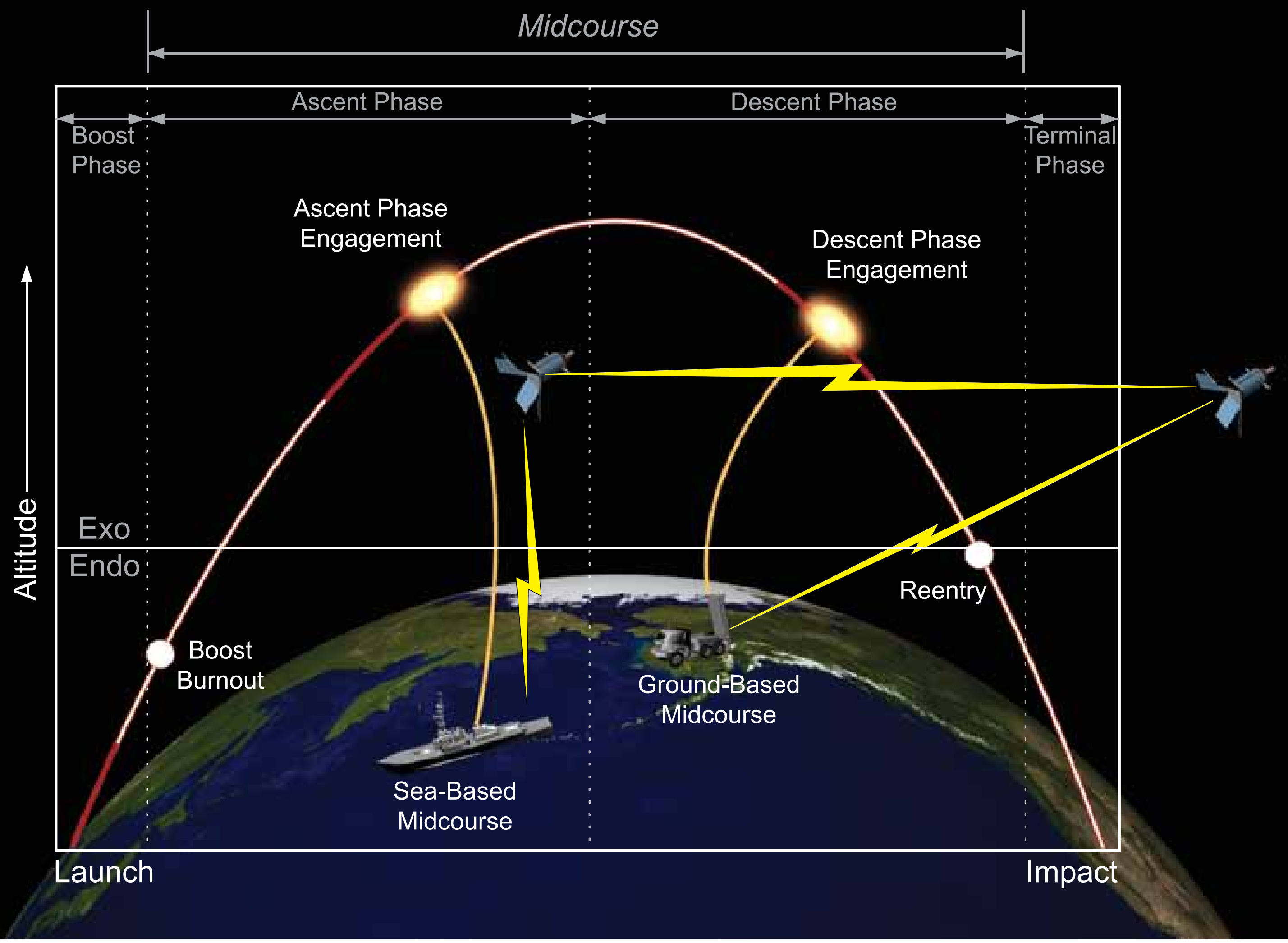


Figure 1. Ballistic Missile Flight Phases

interceptors using external, or remote, BM tracks (launch on remote).

The next ABMD Weapon System (ABMD 5.0) will transition the AAW and ballistic missile defense (BMD) functionality from the older control computers to new commercial off-the-shelf (COTS)-based computers allowing for a single computing system to perform BMD and AAW missions jointly. ABMD 5.0 also brings into play the newly developed Multimission Signal Processor, which combines the receiver and signal processing functions supporting AAW and BMD waveforms together within one set of cabinets.

The AWS was not originally designed with BMs in mind. Designed during the Cold War, it was intended to provide protection from cruise missiles and aircraft for groups of combat vessels in blue-water environments. The system's primary sensor, the AN/SPY-1A radar, provided long-range search and track coverage. As threats evolved and the international scene changed, the AWS evolved as well. In the 1980s, AN/SPY-1B/D radar improvements included higher duty-cycle transmitters, antennas with better sidelobes, increased subclutter visibility, and better environmental controls. This was primarily to counter electronic attack threats and reduce background clutter. In the 1990s, the AN/SPY-1D(V) radar provided substantially more subclutter visibility, increasing detection and track performance against low-flying cruise missiles hidden in sea clutter and near high-clutter littoral environments. Changes were also made to counter more sophisticated electronic attack threats. Since 2000, as part of the BMDS, ABMD capabilities have expanded to include defense against BM threats. The ABMD Baseline 4.0.1 SPY-1 radar introduces new waveforms, signal processing, tracking, and radio-frequency discrimination functionality.

As BM threats become more advanced, the AWS adapts. Complex, separating threats typically break up into numerous objects. Some of these threats may deploy countermeasures. To properly discriminate lethal objects from nonlethal objects associated with the BM launch event, kinetic data obtained from object tracks—as well as data from infrared (IR) images and radio frequency (RF) images—are used. To reduce radar loading, the ABMD 4.0.1 employs single-beam, multi-object tracking. This increases the number of objects that can be tracked simultaneously using only one radar beam (or dwell). ABMD 4.0.1 also adds a new set of radar waveforms, along with advanced digital signal processing. This allows the radar to synthetically combine many pulses in order to construct a synthetic wideband RF image with higher range and higher Doppler resolution than was possible with the previous baseline.

At the heart of the AWS is the AN/SPY-1B/D radar. The radar consists of transmitter, antenna, receiver, signal processor/waveform generator (WFG), and computer control components. In ABMD 4.0.1, these components are augmented with an adjunct signal processor known as the BMD Signal Processor (BSP) (see Figure 2). The BSP comprises a new WFG, receiver, digital signal processor (DSP), and control computer. These new components are integrated into the existing components to provide bursts of the new radar pulses, along with special processing suited for tracking and discriminating BM objects.

Design and development challenges include the careful scheduling and timing of successive radar beams using the new waveform bursts, along with the legacy waveform pulses. Land clutter and electromagnetic interference (EMI) found in the operational environment continue to pose design challenges as well. Another challenge facing ABMD 4.0.1 is determining the period of time that radar system calibration will hold.

Aegis BMD Program Office Support

During the design and development of the adjunct BSP, the ABMD Program Office established a Joint Navy/Lockheed-Martin Radar Integrated Product Team (IPT) comprising organizations including:

- Naval Research Laboratory
- NSWC Port Hueneme Division
- John Hopkins University Applied Physics Laboratory
- Technology Services Corporation
- Massachusetts Institute of Technology (MIT) Lincoln Laboratory
- System Engineering Group

The IPT was intended to cooperatively and jointly explore design solutions, such as the mitigation of EMI effects, mitigation of land-clutter effects, optimization of sidelobe blanking algorithms, and assessment of different RF features as discriminants. NSWCDD provided Navy oversight and expertise in co-leading the IPT. NSWCDD

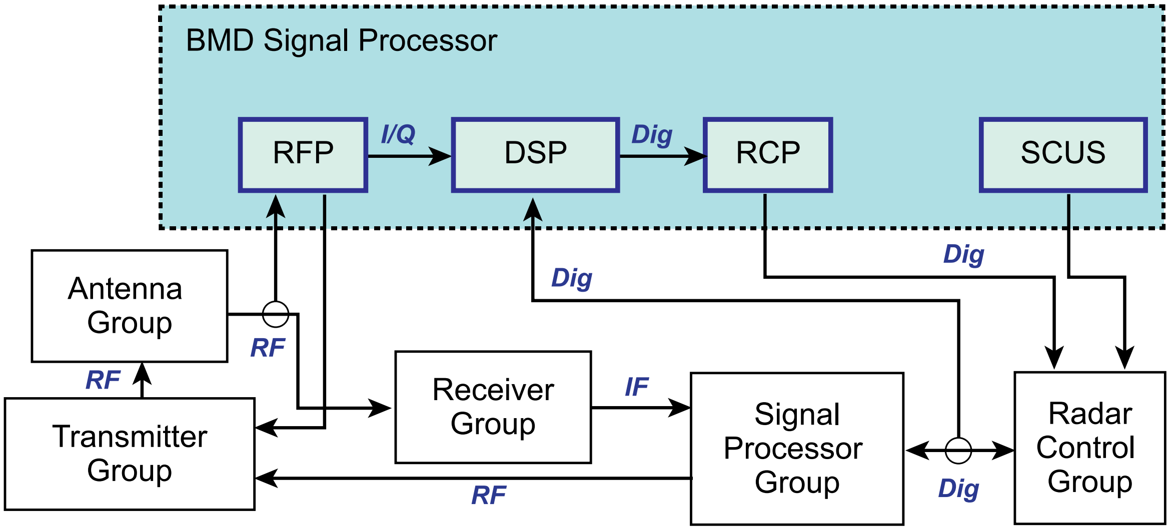


Figure 2. AN/SPY-1B/D Radar System Augmented with the BMD Signal Processor

also provided support to the ABMD Program Office, managing reviews of specifications as part of the design review process. Today, NSWCDD continues to exercise a leadership role in the joint Radar IPT for ABMD 4.0.1 and the follow-on baseline, ABMD 5.0.

NSWC Radar Clutter Modeling

Engineers at NSWCDD are involved in the ABMD 4.0.1 Program radar development process from generation of radar requirements to design to verification to certification. Clutter modeling results produced by the in-house, site-specific radar clutter model—the Littoral Clutter Model (LCM)—were instrumental in driving system requirements for clutter mapping, detection, and mitigation algorithms, as well as sidelobe blanking algorithms. NSWCDD engineers also provided significant technical support in the detailed design and verification of these algorithms.

The LCM is a site-specific simulation of the backscatter from both land and sea for a ship-based radar in a littoral environment, in the presence of ducting. The inputs to the model include:

- Geographic location of the sensor
- Maximum range and angular width of the azimuth sector over which the radar is to transmit
- Radar parameters, such as frequency, antenna height, beamwidth, and elevation angles

In order to evaluate the effect of atmosphere and the sea surface on both propagation and clutter, estimates of the atmospheric refractivity over the region and the sea state are also used as inputs. The principal output from the model is simulated clutter power along each azimuth in the propagation sector, which may be plotted as the Plan Position Indicator (PPI) display of a clutter map.

To simulate the diffraction and shadowing of a clutter patch over variable-height, site-specific terrain, a parabolic wave equation model is executed with terrain contours from Digital Terrain Elevation Data (DTED) files provided by National Geospatial-Intelligence Agency (NGA). The United States Geological Survey (USGS) provides a global land-cover database, Advanced Very High Resolution Radiometer (AVHRR), with 24 terrain type classifications, along with a latitude and longitude worldwide reference. The terrain types are correlated with the DTED data to associate appropriate electrical properties and surface roughness values with each patch of terrain. With the terrain heights, electrical properties, surface roughness, and atmospheric refractivity as inputs, the PWE Model is able to compute a propagation factor for each clutter patch along each propagation path. In order to model backscatter from patches of terrain or ocean surface, the Navy-Standard Georgia Institute of Technology (GIT) sea-clutter model is employed. For land clutter, the Low-Angle Radar Empirical Land Clutter Model designed by J. Barrie Billingsley at MIT Lincoln Laboratory is employed.

NSWC Radar Calibration Test Support

Verification of radar system calibration at the land-based test site in Moorestown, New Jersey, presented system engineers and the ABMD program office with unique challenges. Calibration of the new BSP waveform bursts through the radar equipment must be performed periodically by capturing radar returns from a balloon-borne machined calibration sphere away from sea or land clutter. These returns are then tuned to optimize image-processing performance. To completely capture the responses of the whole radar system is a time-consuming process. It is, therefore, in the best interests of the operational Navy for the designers to reduce the number of these sphere track events to once per 6-month period. Verifying that such a calibration event produces good performance consistently over a long period of time requires a repeatable test with good controls on the test environment. A solution was proposed by NSWCDD engineers to provide and man a tethered aerostat system equipped with a radar sphere target attached to the tether near the land-based test facility, the Combat System Engineering Development Center (CSEDS) in Moorestown, New Jersey. NSWCDD engineers from the Potomac River Test Range Branch have supported similar tests for many years and are currently supporting this effort over a 9-month test period. Figure 3 shows photographs of an Aerostat Test.

As the AN/SPY-1B/D radar evolves to meet ABMD requirements, engineers at the Naval Surface Warfare Center (NSWC) Dahlgren will continue to support the evolution of the ABMD Program. As a result, our Navy and our nation will continually remain well postured to defend against BM threats.

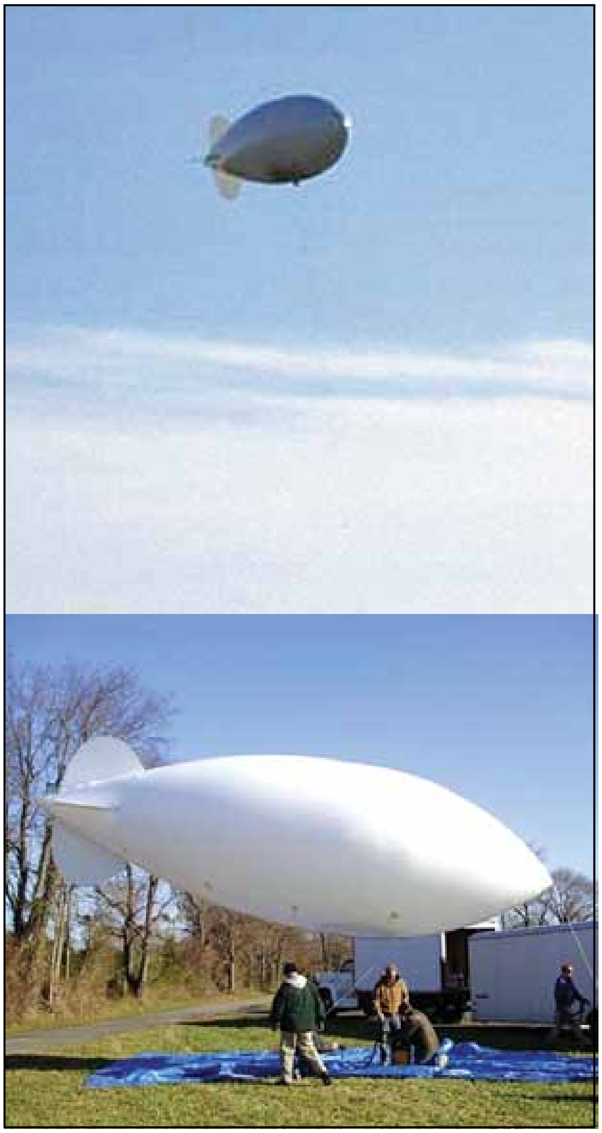


Figure 3. Aerostat Test, Rancocas State Park, New Jersey, 2 December 2008

THE AN/SPS-48G RADAR SYSTEM SUSTAINABILITY UPGRADE

By Daniel Quigley, Lance Walters, Caitlin McInnes, and Christopher Gorby

The AN/SPS-48 radar system provides three-dimensional air surveillance for U.S. Navy aircraft carriers, amphibious assault ships, and amphibious dock landing ships. Its mission is to provide air defense surveillance, support air traffic control, supply accurate target coordinate data for weapon queuing, and support combat air patrol aircraft operations during peacetime and in war. The current version of the AN/SPS-48 radar, the AN/SPS-48E, has been in service in the U.S. Navy since 1987 and is expected to remain in service beyond 2030. In order to ensure that the readiness and rapid-response capabilities of the U.S. Navy remain intact, the SPS-48G Radar Obsolescence Availability Recovery (ROAR) program was initiated. The ROAR program is responding to a need for improvement of declining reliability, maintainability, and supportability issues. This article describes how these issues are addressed via an open architecture (OA)-based system redesign that leverages new technology and by the addition of a new embedded training and system-support methodology.

INTRODUCTION

For over a decade, the AN/SPS-48E radar has experienced a decline in reliability, maintainability, and supportability, which has resulted in diminished operational availability and an increase in life-cycle support costs. Despite attempts to alter this continuous decline with various modifications, the AN/SPS-48E radar continues to operate below acceptable levels. The ROAR program was initiated to reverse this trend and respond to the need for a system redesign that introduces

- A sustainable OA processor
- More reliable and current technologies
- Improved diagnostics
- A performance-based product support strategy

OPEN ARCHITECTURE DESIGN APPROACH

The primary objective of the U.S. Navy OA initiative is to design and build affordable naval warfare systems that support current performance requirements, reduce future potential performance upgrade costs, and achieve portability, modularity, and interoperability throughout their life cycle. To comply with this initiative, the

AN/SPS-48G(V)1 has been designed to meet the U.S. Navy-defined Open Architecture Computing Environment (OACE) Category 3. This designation requires a fully OACE-compliant application implementation and infrastructure, including use of a Portable Operating System Interface for Unix (POSIX)-compliant operating system and Object Management Group (OMG) Data Distribution Service (DDS) publish/subscribe middleware. With the implementation of this standard, a baseline for interoperability among systems with minimal integration effort has been established as illustrated in Figure 1.

Redesign With Current Technology

To address the current and emergent obsolescence issues within the AN/SPS-48E Radar system, and in recognition of system reliability, maintainability, and cost drivers, the AN/SPS-48G program effort follows a practical design approach with several major modifications. The first major item is the introduction of a new solid-state, single-stage amplifier to replace the unreliable and costly AN/SPS-48E microwave tube-based First- and Second-Stage Amplifier. This new unit consists of 180 solid-state, radio-frequency amplifiers (RFA) installed in an architecture that provides redundancy and allows for graceful degradation. This solid-state design was prototyped and tested in the late 1990s and provides a highly reliable and stable output for further amplification in subsequent stages of the transmitter. This new solid-state, single-stage amplifier will substantially increase system availability while significantly reducing transmitter maintenance time.

The second major modification is the new Receiver/Processor unit, which completely replaces three units from the SPS-48E System (the Receiver, Processor, and Auxiliary Detection Processor units). This replacement results in an 87% reduction in unique lowest replaceable units (LRUs), reduces the number of RF cables from over 200 to just 33, and eliminates thousands of backplane

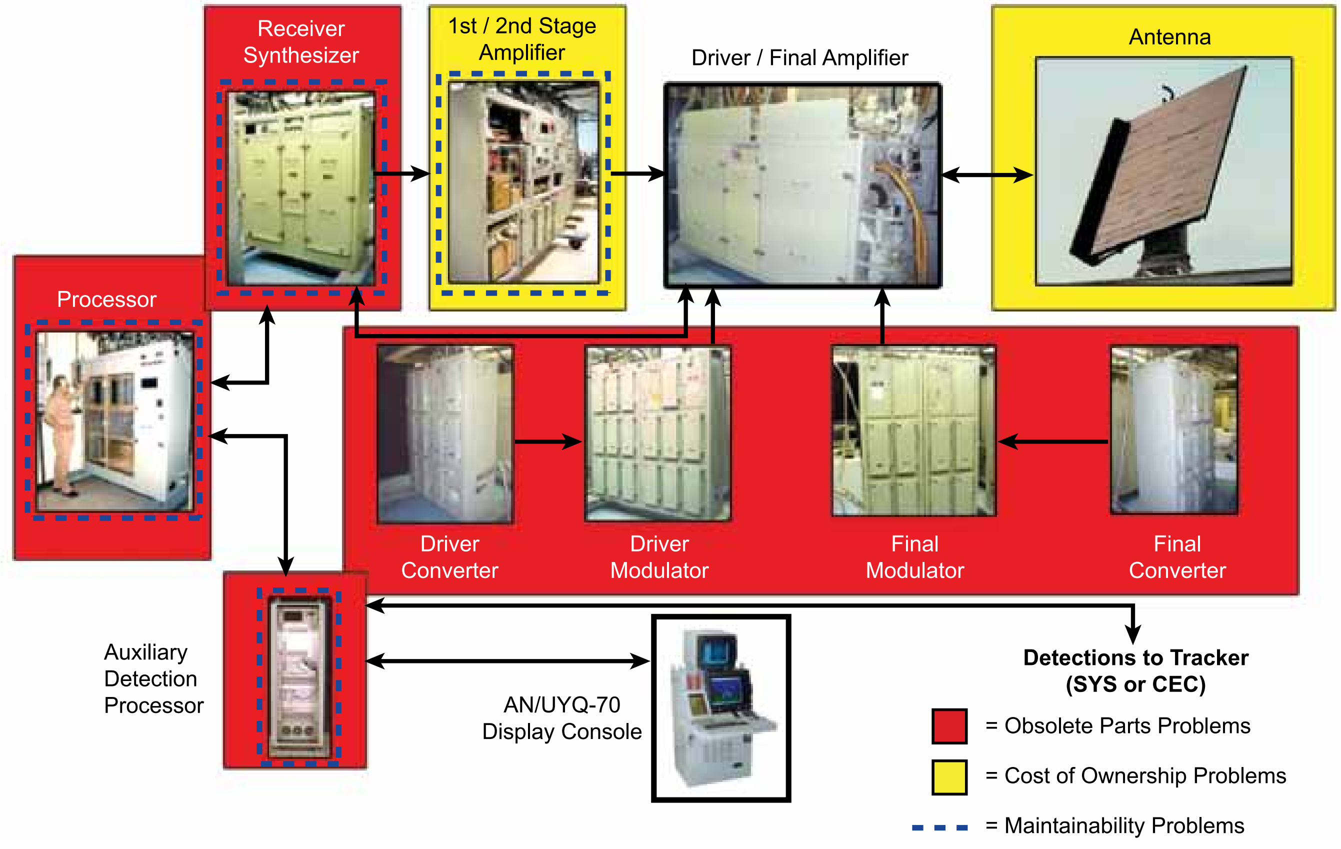


Figure 1. AN/SPS-48E Radar Obsolescence, Cost, and Maintainability Problem Areas

wires, resulting in a marked improvement in system reliability and availability.

Through the use of redundant commercial off-the-shelf (COTS) single-board computers hosted in an VMEBus VITA 41.3 architecture, the OA processor design will ensure the sustainment of the COTS-processor computing environment through a cost-effective tech-refresh program (see Figure 2). Maintainability and supportability improvements result from an improved maintenance system centered on a more comprehensive and intuitive Built-In Test (BIT) function that is fully integrated with embedded technical data, job aids, and training.

Performance-Based Product Support Strategy

Although the AN/SPS-48G(V)1 system is designed to fulfill the AN/SPS-48E top-level performance requirements, the philosophy of supportability is substantially different. For this system to be in service beyond 2030, the program applies new, innovative concepts into the design by developing a product support strategy that synchronizes traditional support elements into a performance-based environment. Responding to policy guidance OPNAVINST 1500.76, the AN/SPS-48G(V)1 radar design reduces the number of organizational-level maintenance tasks and the time required to

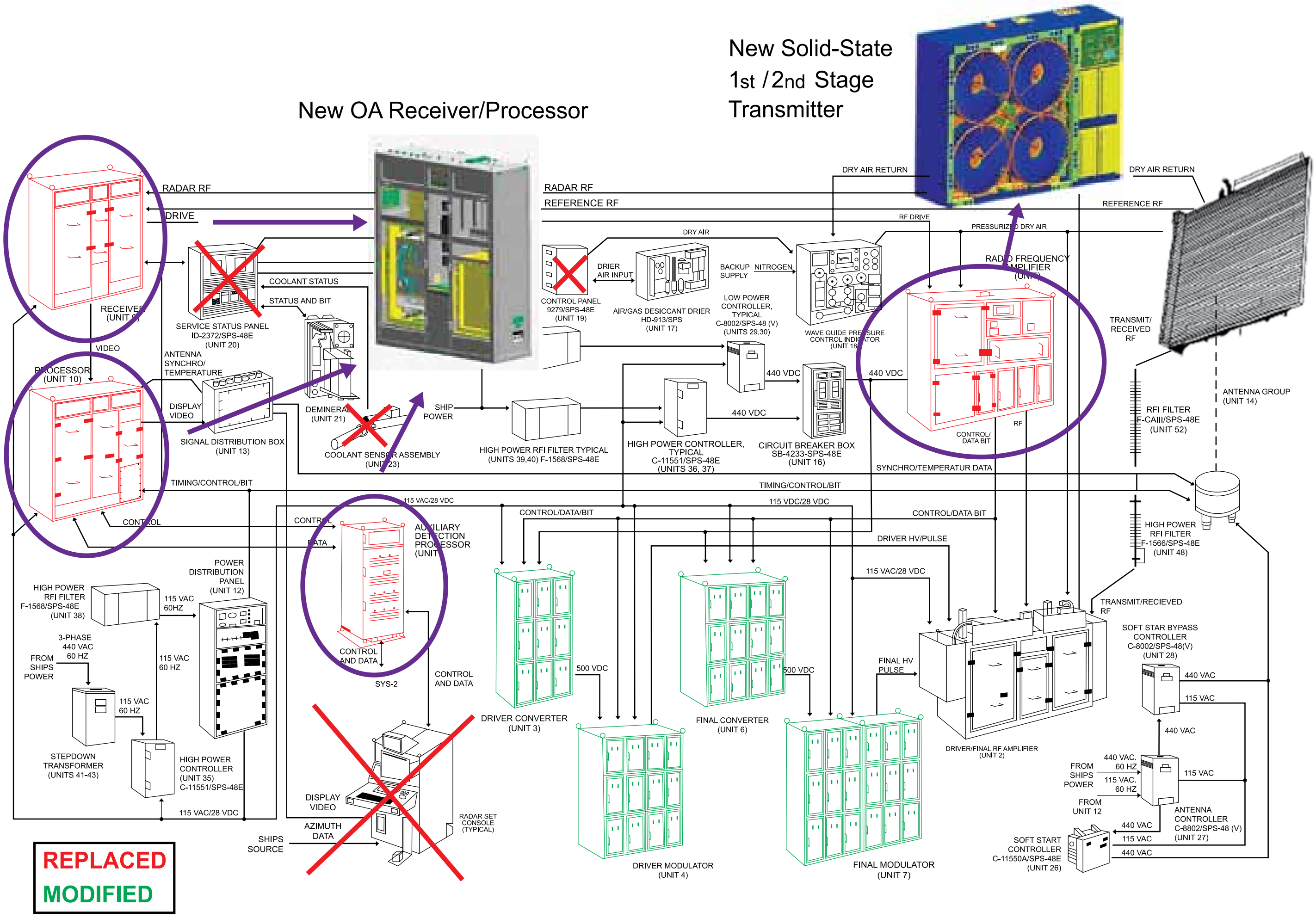


Figure 2. AN/SPS-48G(V)1 Radar System Hardware Modifications

perform these tasks by 62%. The AN/SPS-48G(V)1 employs a new Maintenance System that improves maintenance accuracy, reduces the time and cost to repair, and reduces the knowledge and skill level requirements to effectively perform maintenance.

The Maintenance System consists of an expanded BIT function that includes:

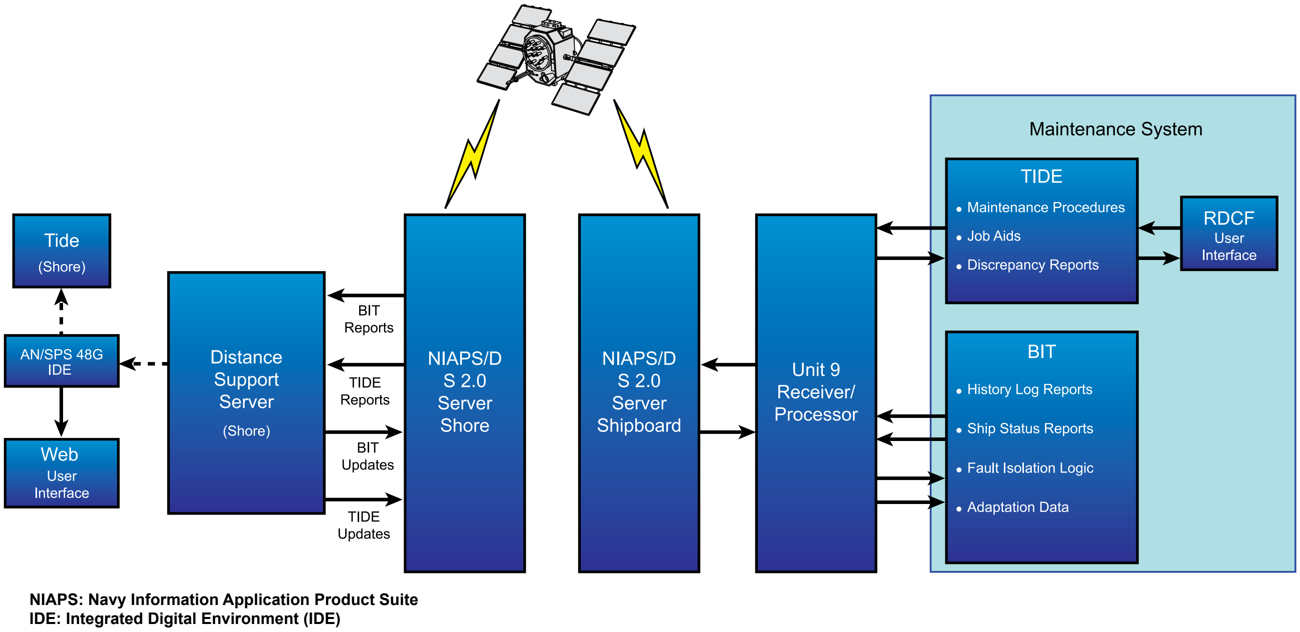
- An embedded Diagnostician package
- An embedded Technical Integrated Digital Environment (TIDE)
- A Radar Display and Control Function (RDCF)

The improved fault-isolation accuracy of BIT, coupled with reduced system complexity, makes it possible to employ a performance-based maintenance strategy. The key paradigm shift to note is that the maintenance methodology focuses the shipboard technician on what, when, and how to perform system maintenance, not on understanding volumes of technical information in order to maintain the system. The integrated maintenance system triad of BIT, TIDE, and RDCF creates, prioritizes, and schedules maintenance sessions to perform all corrective and preventive maintenance actions. All of the procedural and technical information necessary for the technician to perform the maintenance action is intuitively presented at the RDCF when the technician activates a session. Using the established Distance Support network, expert technicians ashore will assist with fault isolation when BIT cannot isolate the fault to one LRU or when the task is beyond the immediate knowledge and skill level of the onboard technician. The maintenance system components are depicted in Figure 3.

This new maintenance strategy also results in a significant reduction in the training requirements for the system. A Job Task Analysis was performed and identified the system-specific knowledge and skill gaps that are not satisfied by the existing apprentice training pipeline and embedded Maintenance System. To compensate for these knowledge and skill gaps, training for the SPS-48G technician includes 3 weeks of hands-on familiarization training to be taught at the Center for Surface Combat Systems facility at Dam Neck, Virginia.

CONCLUSION

Responding to the need for improvements in reliability, maintainability, and supportability, the ROAR program is a unique radar system that offers an OA-based system upgrade that decouples hardware and software to allow for affordable future technology growth. The simplified design has successfully implemented a methodology that reduces the number of maintenance-significant items and organizational-level maintenance tasks, as well as the knowledge, skills, and time required for shipboard maintenance. These changes will drive the system to achieve and sustain an increased operational availability, while at the same time lowering its life-cycle costs.



NIAPS: Navy Information Application Product Suite
IDE: Integrated Digital Environment (IDE)

Figure 3. AN/SPS-48G(V)1 Maintenance System Components

TECHNICAL AUTHORITY AND THE FUTURE OF RADAR

By Roger Kniceley

Radar systems have been critical to the Surface Navy since the initial introduction of the CXAM radar installed on the battleship *California*; the aircraft carrier *Yorktown*; and the heavy cruisers *Pensacola*, *Northampton*, *Chester*, and *Chicago* in 1940. Since that initial introduction, radars have been expected to improve their functionality and performance. Performance has increased from basic detection of ships and aircraft for self-protection and gun fire control to the present requirements to detect and track maneuvering, sea-skimming missiles, as well as the discrimination of lethal objects from ballistic missiles. Radars have also evolved from stand-alone systems with raw video displays to being fully integrated in the fire-control loop and the force-level network of sensors able to provide situational awareness over hundreds of miles. With this increased complexity comes the need for more rigorous systems engineering and coordination to ensure that the "system of systems" is properly integrated, interoperable, and meets the functional and performance requirements.

DEFENSE ACQUISITION SYSTEM DEPARTMENT OF DEFENSE (DOD)

DoD Instruction 5000.2 provides the policies and principles that guide all acquisition programs and defines a Systems Engineering Technical Review (SETR) structure to balance performance and cost while managing risk. Along with this basic systems engineering structure, the Systems Commands (SYSCOM) have been entrusted with execution of the "Technical Authority," which is the authority, responsibility, and accountability to establish, monitor, and approve technical standards, tools, and processes. The goal is to employ consistent, disciplined collaborative engineering processes that provide safe, reliable, effective, integrated, timely, and affordable systems.

TECHNICAL AUTHORITY WARRANT

Virtual SYSCOM Engineering and Technical Authority Policy, VS-JI-22A, defines the engineering and technical authority policy and actions needed to support program managers (PMs) and the fleet in providing best-value engineering and technical products. The instruction defines the Technical Authority roles and responsibilities of the SYSCOM Commanders, the Deputy Warranting Officers, and the Technical Warrant Holders (TWHs). VS-JI-22A lists the following responsibilities of TWHs, organized by the seven competencies critical to being entrusted and empowered as a TWH.

1. Setting Technical Standards—Establish technical policy, standards, tools, requirements, and processes, including certification requirements.
2. Technical Area Expertise—Provide technical advice to the fleet, depot chief engineers, and other DoD customers. Maintain technical expertise and interface with the Science and Technology (S&T) community.
3. Ensuring Safe and Reliable Operations—Ensure that safety and reliability are properly addressed in technical documentation. Ensure that products are in conformance with technical policy, standards and requirements. Where they are not, identify options and ensure that risks are technically acceptable.
4. Systems Engineering Expertise—Ensure engineering and technical products meet Navy needs and requirements, including interoperability. Identify and evaluate technical alternatives, determine which are technically acceptable, and perform risk and value assessments.
5. Judgment in Making Technical Decisions—Provide leadership and accountability for all engineering and technical decision-making. Promote and facilitate communications to ensure that appropriate personnel and organizations are aware of, and are involved in, technical issues and technical decisions.
6. Stewardship of Engineering Capabilities—Ensure that an appropriate engineering and technical authority support network is established for the warranted technical area and provide leadership for the support network.
7. Accountability and Technical Integrity— Exercise integrity and discipline to ensure the soundness of technical decisions. Keep organizational Chain of Command informed of issues and decisions.

NAVSEA has a long history with Hull, Machinery, and Electrical (HM&E)-related TWHs. However, VS-JI-22A defines six types of TWHs, including: Platform Design Managers, Chief Systems Engineers, Cost Engineering Managers, Technical Process Owners, Depot Chief Engineers, and Technical Area Experts (TAE). Within the general category of TAE, there are several different competencies, including marine engineering, human systems, test and evaluation, and warfare systems. SEA05 has designated a number TWHs to support the various warfare system elements, including: guns, missiles, electronic warfare, electro-optics, and radar.

The scope of the Radar TWH includes the RDT&E, acquisition, and in-service support for all Surface Navy radars. To fulfill these roles and responsibilities, the TWH must work with the various radar system PMs in all phases of radar development. This is accomplished by maintaining open lines of communications, participating in the various SETRs, and generally maintaining an awareness of the various radar-system design and support issues. It is important to understand that TWHs in no way change the responsibilities of the Program Executive Offices (PEOs), Major PMs, or individual PMs. The TWH is intended to be a partner and independent source of expertise and review to help provide the best and most cost-effective products to the warfighter.

RADAR TWH ACTIVITIES

It is a very active time for the Surface Navy radar community, with systems in all stages of acquisition. The Radar TWH is not only involved in the development of radar systems, but also in the integration of those systems into combat systems and ships. Primary TWH involvement occurs at the SETRs; however, when properly integrated, there are numerous other opportunities for the radar TWH and PMs to collaborate. The following list will provide some insight into the scope and breadth of the Radar TWH role and support that has been provided:

General Radar Analysis and Concept Definition

- Review of the radar requirements and concepts for CG(X) and Future Surface Combatant
- Review of the Integrated Air and Missile Defense Layered Defense Study
- Assessment and monitoring of solid-state, high-power amplifiers and vacuum tube radio frequency (RF) source development
- Support for continued management of the Surface Navy Radar Roadmap

New Radar System Development

- Review and comment on the Air and Missile Defense Radar (AMDR) Capability Description Document
- Participate in contractual source selection
- Serve as panel member on numerous reviews for Dual-Band Radar (DBR) and SPY-1 Multimission Signal Processor
- Review and evaluate risk-mitigation activities associated with the DBR High-Power Module and radome development

Combat System and Ship Integration

- Review of DDG 1000 Combat System simulation strategy
- Assess and recommend for DBR integration with Battle Force Tactical Trainer for CVN 78
- Review of the improved sensor integration architecture and algorithms for the Amphibious Improvement Program
- Review and recommend for TRS-3D radar performance analysis for the littoral combat ship (LCS)

Deployed System Support

- Investigation and analysis of root cause for Aegis SPY-1 radar adaptation data issues
- Investigation and study of operational radar and commercial system interference

FUTURE RADAR SYSTEM FOCUS AREAS

We are approaching the point where technology is available to design a radar system that can satisfy almost any foreseeable performance requirement: detection of missiles as they come over the horizon; detection, resolution, and identification of threats at hundreds of miles; and accurately tracking and correlating maneuvering threats from multiple sensors to create a complete situational awareness over the entire theater. However, that does not mean that S&T and systems engineering are not required. There are still many critical problems that must be addressed that require broad community attention and coordination.

One of the primary concerns for future systems is procurement cost. Future radar systems are projected to cost hundreds of millions of dollars to develop and an equivalent amount to procure one deployable system. While these costs may be justified for major combatants, the Navy needs lower cost radar systems that can be affordably developed, integrated, and installed on smaller ships. Focus must be maintained on this objective as we develop the future AMDR so that both hardware and software components can be used to quickly and economically develop and build less-capable variants.

Another important aspect of reducing future costs is driven by system efficiency. Historically radar systems have had to deal with significant transmit, receive, and processing losses. To compensate for these losses, radar designers increased transmit power or antenna size. Modern phased-array radar systems have gotten rid of most of these losses but now suffer from low-efficiency, high-power modules. The low module efficiency does not directly impact system performance; however, it does drive the size of the radar power supplies and cooling systems and, therefore, impacts radar system weight, which—for very high-performance radars—can become a significant driver for the overall ship's power generation system.

LEGACY AND RF SYSTEMS

The above focus areas were concerned with new radar systems, but legacy systems also require S&T investment. Many of the radar systems currently in the fleet will still be operational for more than 20 years. Many of the components in these systems are already obsolete and will not be supportable in the future. There must be a coordinated effort to look across these radar systems, and develop replacement systems and support processes that are affordable and supportable for the projected operational life.

Another focus area is applicable to all RF systems, not just radars. The Navy has been a leader in dealing with electromagnetic interference (EMI) and electromagnetic compatibility (EMC) given the close proximity of large numbers of RF systems. In the past, the primary tool was simple spectrum coordination and management. However, with most new major radar systems being developed at either 3 or 10 GHz, it will be difficult to solve EMI/EMC issues using this technique. With the exponential growth in demand and reliance on wireless telecommunications, the RF spectrum is becoming increasingly crowded, especially in developing areas of the world. This is compounded for the Navy since a significant portion of the world's population live in coastal areas. Thus, there is an increasing demand and opportunity for S&T investment in spectral noise reduction, innovative spectrum sharing, and management techniques.

SUMMARY

The future for radar systems presents many challenges. These challenges go beyond the traditional pursuit of increased functionality and performance, and require rigorous systems engineering and technology investments focused on solutions that benefit more than a singular radar system. The Technical Authority and the Radar TWHs play a pivotal role by providing an independent review of individual system developments; establishing and coordinating standards, tools, and processes; and helping identify critical focus areas that will help develop, field, and support the radar systems that the Surface Navy needs.

Sensors

Challenges and Solutions for the 21st Century

LEADING EDGE

Volume 7, Issue No. 2

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NSWCDD/MP-09/32