Air Defense Systems Department: An Overview

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The mission of the Air Defense Systems Department (ADSD) is to advance the readiness and effectiveness of U.S. naval and other military forces, operating singly or in a Joint warfare context, through research, development, engineering, and test and evaluation of current and future air defense and related systems and technologies. The three issues of the *Digest* devoted to ADSD focus primarily on the Department's missile, combat system, and battle force development activities. This article presents an overview of those activities.

INTRODUCTION

From the invention of the VT fuze in World War II to the coordination of Joint battle force operations now under way (Fig. 1), ADSD's activities have focused on enhancing the operational capabilities of naval weapon systems engaged in air and missile defense. In all these activities, whether developing requirements, conceptualizing a solution, evaluating a component, or developing a prototype system, the Department's standard has always been disciplined, thorough, and innovative systems engineering combined with cutting-edge technology.

The ADSD staff provides problem-solving expertise and critical thinking in all facets of air defense technology, including research, development, fabrication and test, and engineering of missile and air defense systems. This expertise includes all facets of missile technology. The Laboratory also maintains a continuing presence at sea to understand first-hand the environment and operational requirements.

ADSD programs focus on area defense, including ballistic missile defense, cruise missile defense, ship self-defense, and battle force operations, primarily within the U.S. Navy but also with Joint and Allied weapon systems. The Department's work in these areas includes guided missiles, fire control radars, search radars, combat systems, and the integration of these elements into ships and battle group weapon systems.

AREA DEFENSE PROGRAMS

Aegis

Today's U.S. Navy Guided Missile Combatant force comprises almost exclusively Aegis cruisers and destroyers. In 1982, the first Aegis ship joined the Fleet. Today, there are more than 50 Aegis combatants. ADSD, as the System Laboratory and Technical Advisor (TA) to the Aegis Shipbuilding Technical Director, has contributed to Aegis development from the start. ADSD developed the prototype of the AN/SYP-1 radar, which was used to investigate the technology that would make the future Aegis Weapon System (AWS) operationally effective. In weapon control, we defined the missile-to-ship uplink/downlink communications concept, design, and equipment. Other early contributions included the

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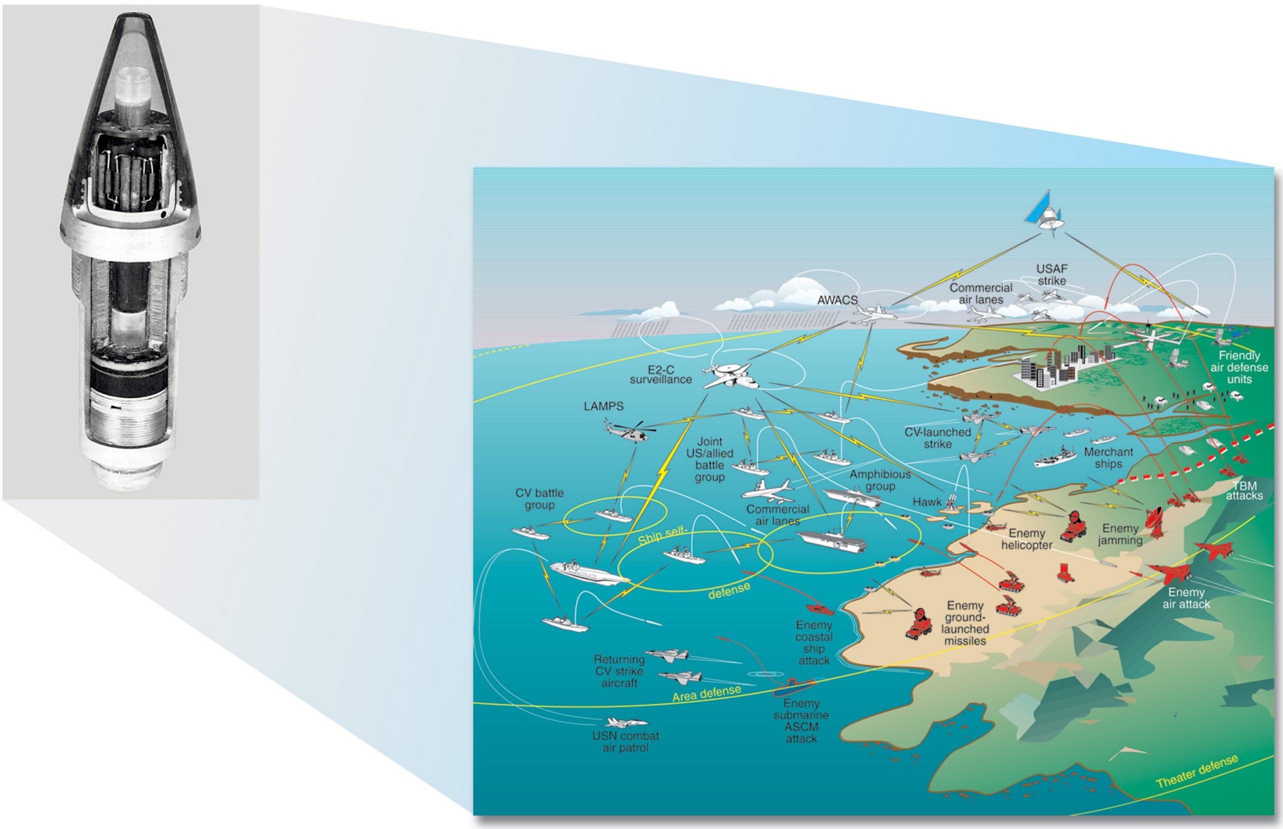

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Figure 1. From the VT fuze to battle force operations.

demonstration and definition of operator and command support systems in the Combat Information Center.

From these beginnings, the Department has maintained a strong technical presence in Aegis detect, control, and engage areas. ADSD led the government effort to define upgrades to the AN/SPY-1A radar, approaches to combat system sensor integration, and approaches to off-board and overhead information integration. Building on its technical role in Standard Missile (SM), ADSD also defined approaches to AWS integration of SM-2 Blocks III and IV that take full advantage of each missile's performance. We continue to conduct critical experiments to validate new technical approaches; examples include the development of a high-performance, distributed, commercial off-the-shelf (COTS)–based Aegis Combat System computer suite and the development and operational evaluation of a fully functional COTS-based Aegis Display System prototype (Fig. 2).

Figure 2. Aegis Display System Mk 6 prototype.

Standard Missile

Standard Missile is the U.S. Navy's premier surface-to-air missile. It is designed to maximize flexibility and growth through the use of interchangeable parts and modules to provide increased capabilities to counter the threat that has evolved over a 30-year period (Fig. 3). Today, SM in its various configurations is used in over 80 U.S. Navy ships and in 12 foreign navies.

ADSD is the Round-level Technical Development Agent for SM, with responsibilities spanning the missile life cycle from concept development through weapon system integration, production, and Fleet operations. The SM mission currently includes defense against manned aircraft, cruise missiles, and endo- and exo-atmospheric ballistic missiles. Advanced versions are also being developed for defense against overland cruise missiles, for strike against land targets, and as air defense test targets. Studies are under way that may lead to additional tasking in the National Missile Defense mission. These capabilities and ADSD's technical approach to bringing technology to bear are described in the articles in this issue of the *Digest*.

Ballistic Missile Defense

Soon after Operation Desert Storm, the Navy initiated two system development programs to provide a tactical ballistic missile defense capability to the U.S. Fleet: the Area and Navy Theater Wide (NTW) programs. These programs are designed to defend against ballistic missiles launched from hundreds to thousands of miles away. The Area System will provide sea-based defense for ports, inland targets, and debarkation areas against short- and medium-range tactical ballistic missiles. The NTW System will provide an exo-atmospheric layer of defense for significantly larger defended areas against medium- to long-range tactical ballistic missiles. Both programs leverage the current infrastructure of the Program Executive Office for Theater Surface Combats, which includes the Aegis Combat System and SM, to develop effective defenses.

ADSD is implementing a systems engineering process in the development of the Area and NTW systems, including definition of the operating environment, threat characterization, requirements development, conceptual development, trade-off analyses, and testing. The Department is defining discrimination concepts for the shipboard AN/SPY-1 radar and the missile seekers and guidance and control algorithms for accurate aimpoint selection and hit-to-kill lethality. In addition, we provide leadership in the establishment of test requirements, ground testing, integration, and preparation for flight tests. As part of the flight test programs, ADSD develops specific flight test scenarios, performs preflight performance predictions, develops test tactical ballistic missile target requirements and associated

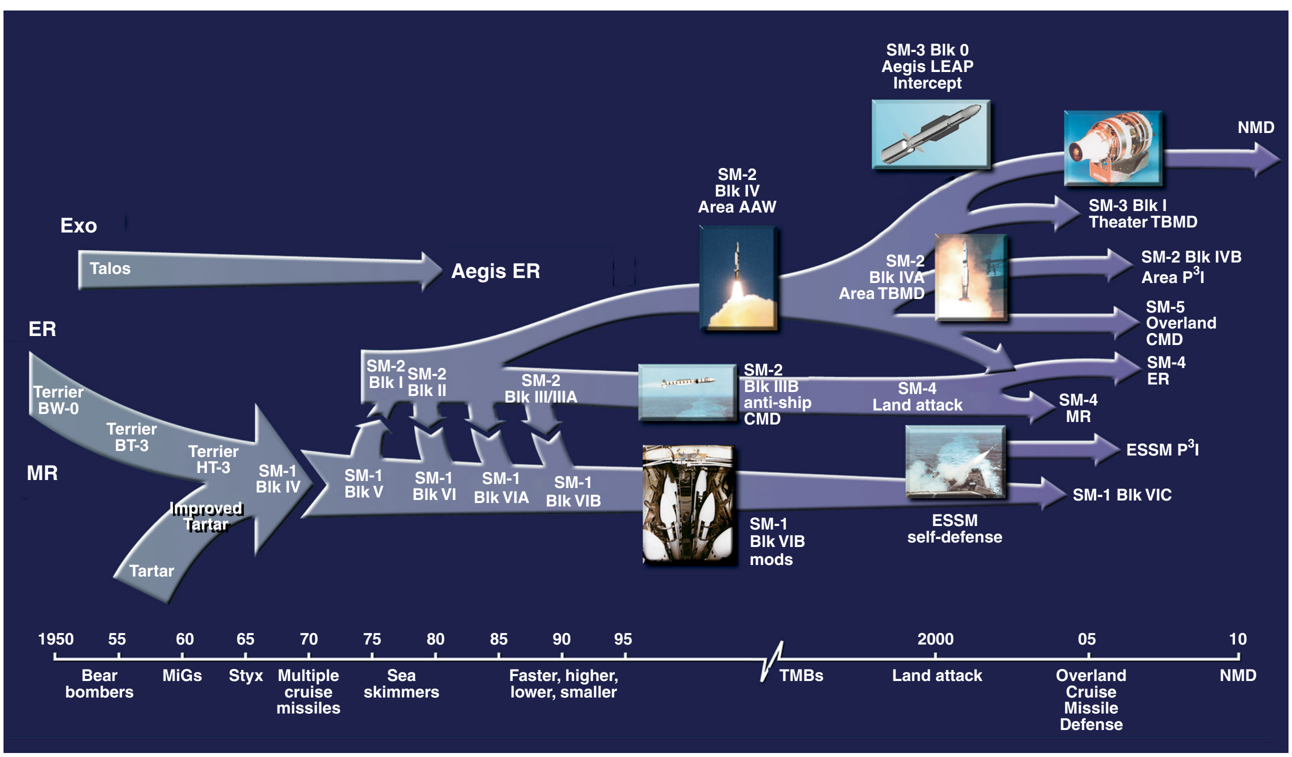

Figure 3. Evolution of the Standard Missile family.

target instrumentation designs, conducts debris analysis for range safety, and participates in the development of flight test plans. Following each flight, ADSD performs postflight reconstructions of the missions and uses the flight data to update and validate the six-degree-of-freedom (6-DOF) performance simulations. The Department is integrating its experience with SM, the Aegis Combat System, and command and control to provide system-level knowledge to this key, new Navy mission. Specific articles on each of these programs are included in this issue.

Figure 4. Hawk Missile launch, a U.S. Navy OCMD Advanced Concept Technology Demonstration.

Overland Cruise Missile Defense

The Overland Cruise Missile Defense (OCMD) Program addresses the threat posed by the development and proliferation of technically advanced land attack cruise missiles. OCMD development confronts critical technical, functional, and operational requirements unique to the engagement of cruise missiles over land (Fig. 4).

ADSD has a primary role in systems engineering efforts for Navy OCMD systems. This role includes defining and analyzing innovative concepts for distributed weapons coordination through the orchestrated actions of networked sensor and weapon systems. Key elements of the distributed weapons coordination concept include real-time data sharing and distributed processes for common threat evaluation, preferred shooter recommendation, and engagement resource allocation.

As with many ADSD programs, OCMD is an inherently Joint operation in which the Department has key responsibilities for identifying system integration issues within the U.S. Navy community of systems and addressing Joint interoperability issues. This work leverages heavily on decades of experience that we have gained in the Cooperative Engagement Capability (CEC) and other developing systems to defend against anti-ship cruise missiles, ranging from developing remote data engagement to integrating air and surface sensor and weapon systems in land–sea operations.

Initial efforts in OCMD focused on the cruise missile defense Advanced Concept Technology Demonstration known as Mountain Top. Mountain Top validated the concept of a ship engaging cruise missiles through the use of airborne sensors that provide detection, track, and illumination for the intercept (Fig. 5). ADSD provided planning, system engineering—including interfaces with the Marine Corps Hawk Missile, Army Patriot Missile, and Air Force Airborne Warning and Control System (AWACS)—test preparation, and data collection for this successful demonstration.

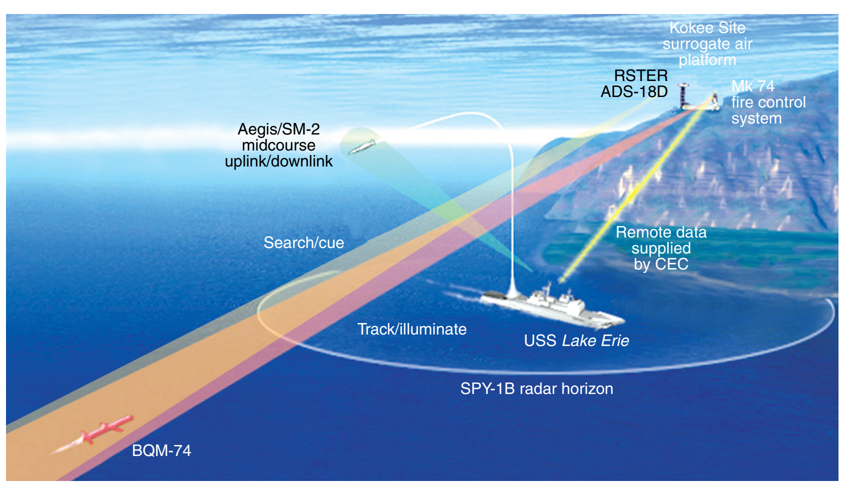

Figure 5. Mountain Top demonstration.

SHIP SELF-DEFENSE PROGRAMS

Ship self-defense activities integrate and automate ship weapon resources (Fig. 6). The Ship Self-Defense System (SSDS) provides a quick-response, multitarget engagement capability against close-in hostile air targets. To do this, SSDS produces a composite track picture using data from the various sensors on the ship. The system then uses the composite track picture as the basis for coordinating target engagements. Additional self-defense programs include the Rolling Airframe Missile (RAM), the NATO Seasparrow Surface Missile System (NSSMS), and related surveillance systems.

ADSD, as Technical Direction Agent (TDA), is responsible for developing technical requirements for SSDS in several ship classes. The Department developed the multisensor integration algorithm for the quick-reaction capability needed against close-in threats as well as the communications infrastructure for the SSDS local area network that connects all of the ship's anti-air warfare (AAW) weapons and sensors. Both active and passive electronic warfare techniques have been integrated into the combat system to further reduce ship vulnerability.

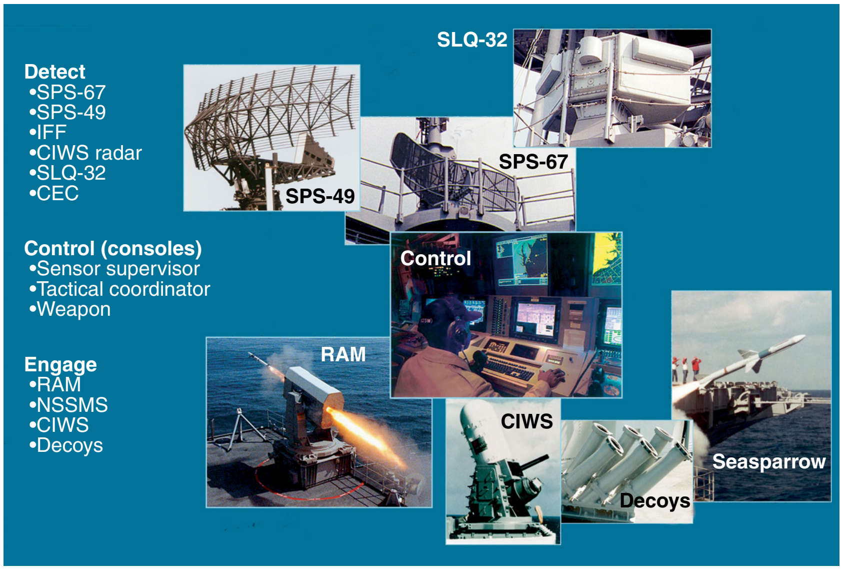

Figure 6. The Ship Self-Defense System features automation and integration of sensors and weapons as well as an open architecture, distributed processing, a fiber-optic local area network, and commercial off-the-shelf hardware. Innovative concepts and advanced developments are listed.

The RAM is the primary weapon for self-defense on many non-Aegis U.S. Navy ships and ships of the German Navy, a co-developer of the missile. ADSD is the TA to the U.S. Navy in RAM-related matters. The TA's responsibilities concern missile development, weapon system integration, and production of emitters for test targets.

The NATO Seasparrow Missile is also a primary self-defense weapon on many U.S. Navy ships. Seasparrow is a Joint development of 13 NATO consortium nations and is installed on ships of many navies. ADSD is TA to the U.S. Navy's NATO Seasparrow Office and has responsibilities in missile development, weapon system integration, and tactics development for the operational use of the Seasparrow Missile System.

Development of the Multi-Sensor Integration and Tracking System (MSITS) followed the decommissioning of the Navy's Terrier Guided Missile cruisers. The AN/SPS-48E high-power, three-dimensional air search radars from the cruisers were installed on amphibious assault ships (LHA class), which had antiquated sensors and a combat system that required manual target tracking operations. ADSD adapted the CEC advanced radar tracking algorithms under development at the Laboratory to provide a designation source from those radars for RAM missiles. This effort provided enhanced air defense capabilities to LHA class ships years ahead of the scheduled installation of modern self-defense systems. The first MSITS was installed on an LHA in less than 12 months. MSITS was later integrated with the highly computerized Advanced Combat Direction System along with the addition of another CEC capability that provides automatic target identification based on operator-entered doctrine and identification, friend or foe (IFF) interrogations.

The need for U.S. Navy ships to operate in littoral regions has stressed the capabilities of Fleet surveillance radars. ADSD engineers have developed advanced techniques for overcoming the effects on radar propagation of the land–sea interface and severe ducting conditions. New operational requirements have emerged for these systems, and APL engineers have provided the technical analysis that underlies many modern radar concepts. The range of engineering work includes the definition of a new volume search radar, concept development and critical experiments with high-frequency surface wave radars, and multisensor integration of in-service radars for synergistic improvements.

BATTLE FORCE PROGRAMS

The Force AAW Coordination Technology (FACT) Program and the CEC Program constitute the core of ADSD's battle force programs. These programs were conceived and developed by ADSD. Critical experiments were conducted, software developed, and prototypes fabricated and tested in the laboratory. The goal was to improve and integrate air defense elements of the Navy and other services into a single, integrated Joint air defense capability. These activities are necessary to counter the evolving area and theater air threats.

FACT

The FACT Program, originally the Battle Group AAW Coordination Program, is an ongoing advanced development effort that develops new concepts in AAW and demonstrates their military worth with prototype systems deployed in U.S. Navy combatants. FACT developments have focused on providing an uncluttered coherent air picture, methods to audit that air picture, and effective controls of AAW resources to coordinate engagements. The concepts and prototypes developed by the FACT Program are the foundations on which many of today's and the future's AAW systems are based. APL is the TDA for this program.

The charter of the FACT Program is to respond to the changing threat and to the changing roles and missions of the U.S. Navy battle group operating in a Joint warfare environment while ensuring that FACT prototypes and other Navy systems are interoperable across all Joint U.S. and Allied forces.

Improvements needed in detect, control, and engage elements of AAW systems have provided a roadmap that the program has followed successfully for more than 25 years (Fig. 7). In the detect element, continuous improvements have been developed in radar and IFF signal and track processing, tactical data link communications, gridlock and track correlation, air track identification, and Joint/Allied interoperability. Systems and capabilities developed in these areas include the Weapons Control Link, the foundation on which the CEC concept is based; SPS-48E Detection Data Converter (DDC); Shipboard Gridlock System with Auto Correlation (SGS/AC); Automatic Identification System (Auto ID); Multifrequency Link-11 (MFL); and Dual Network MFL (DNMFL). In the control element, improvements in situational awareness through the use of advanced display technologies, AAW station planning tools, and threat evaluation and weapons assignment have been developed in the Force Threat Evaluation and Weapons Assignment (FTEWA) prototype. In the engage element, AAW concepts such as Remote Track Launch on Search (RTLOS), Remote Data Engage (RDE), and Remote Magazine Launch have been developed.

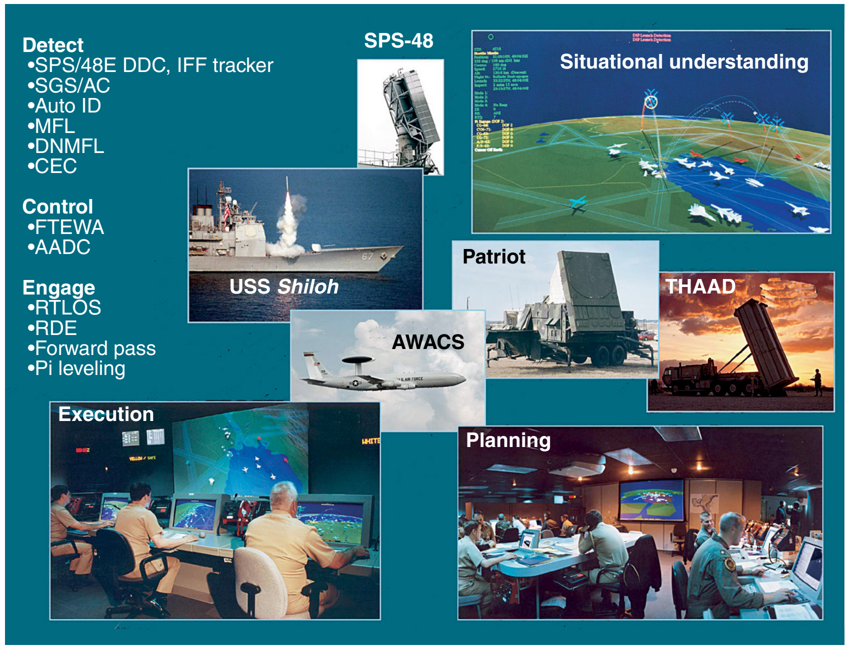

Figure 7. The Force AAW Coordination Technology Program includes innovative concepts and advanced developments.

The features successfully demonstrated in the FTEWA prototype have been carried forward and evolved into the Area Air Defense Commander (AADC) prototype. This prototype will be capable of integrating Navy, Army, Air Force, and Marine Corps air defense elements to produce a coordinated AAW station plan and support the AADC in real-time tactical operations. One AADC prototype has been developed in the APL Combat Systems Evaluation Laboratory, and second and third prototype systems have been installed in an Aegis cruiser and a command ship. The shipboard prototype AADC systems have been demonstrated in numerous at-sea exercises. Lessons learned have been infused and system requirements defined. ADSD has assisted the Navy in transitioning the AADC prototype to industry for engineering and manufacturing development.

Cooperative Engagement Capability

The CEC places the sensors and weapon systems from ships, aircraft, and ground forces into a high-capacity jam-resistant network to allow the air defense systems of all of the services within a theater to operate as a single entity (Fig. 8). This provides inherent performance advantages that accrue from sensor characteristics and diversities in location. CEC is the latest development in ADSD's effort to obtain sensor information from multiple sources simultaneously and to launch missiles from the sites that are in the best position to stop the threat. These performance advantages include major enhancements to track accuracy, continuity, and consistency in identification. Dual tracks are mitigated via automated gridlock; thus, CEC provides a single integrated air picture to all units in the CEC network, increases the battle space, reduces reaction time, and extends engagement ranges through cooperative engagements such as handover of missile control. ADSD's work on CEC has earned APL its second Navy Award of Merit for Group Achievement, the Navy's highest institutional award.

APPLIED SCIENCE AND TECHNOLOGY

ADSD anticipates possible future threats based on emerging technology that the nation's potential adversaries might exploit, as well as ways in which the Navy can counter that technology. To that end, ADSD conducts numerous independent research and development projects focused on the technology needed to counter threat developments. A number of these IR&D projects are described in the three issues of the *Digest* devoted to the Department.

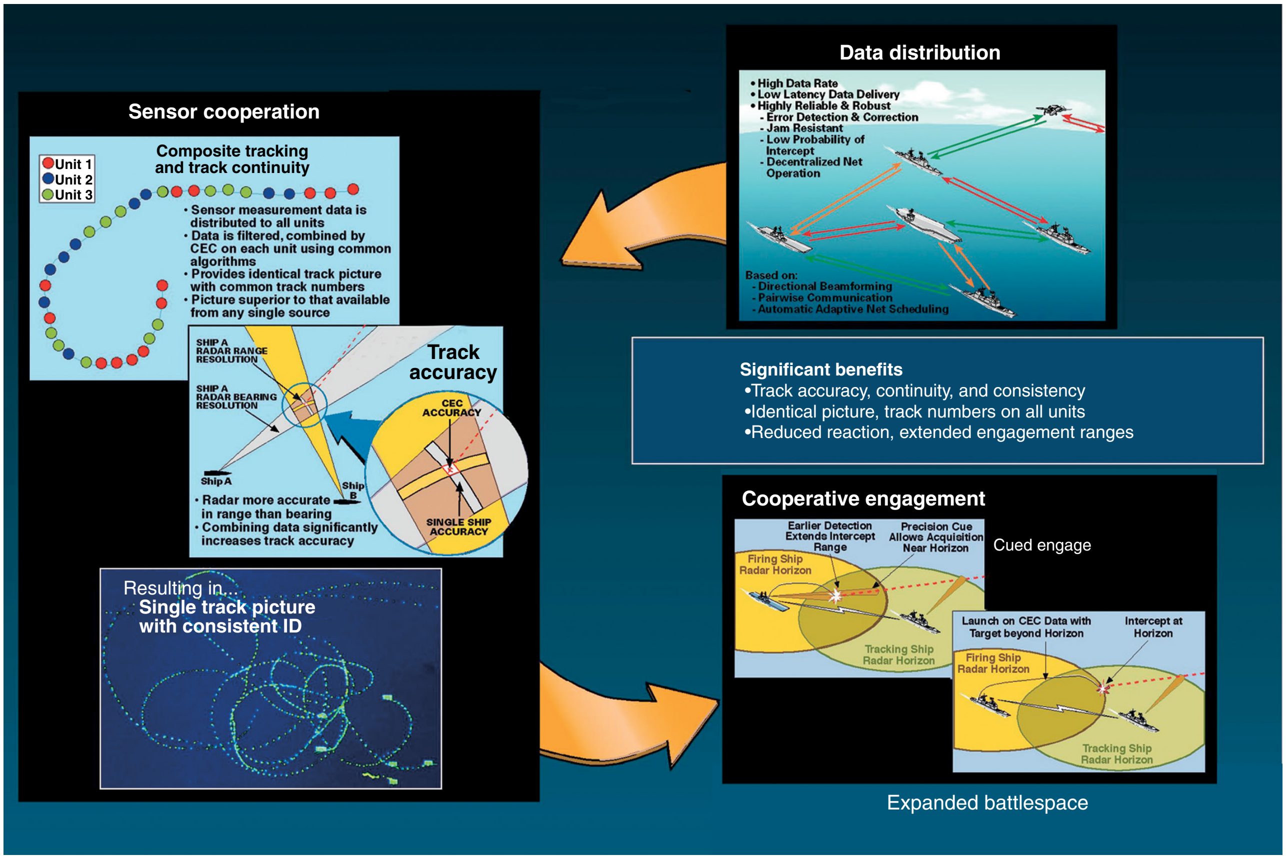

Figure 8. The Cooperative Engagement Capability is not a new sensor or weapon system; rather, it distributes and combines sensor and weapons data from existing systems.

FACILITIES AND TOOLS

The work performed by ADSD's Guidance System Evaluation Laboratory (GSEL) (Fig. 9), the Research and Technology Development Center's Avery Advanced Technology Development Laboratory (AATDL), and other special APL facilities is fundamental to the maintenance and use of the staff's expertise. For example, GSEL is a real-time, multiple guidance mode, hardware-in-the-loop facility that is used to test and evaluate Standard Missile. It is the Department's primary missile hardware and software evaluation tool. The AATDL (Fig. 10) contains supersonic and hypersonic wind tunnels for realistic aerothermal flight simulations at speeds up to Mach 8. These and other ADSD laboratories have been continuously upgraded to support air defense development and testing. The Department also develops and maintains a high-fidelity six-degree-of-freedom missile simulation that is used to verify missile design and predict performance for each SM version, equivalent fidelity models of various surveillance and fire

Figure 9. The Guidance System Evaluation Laboratory.

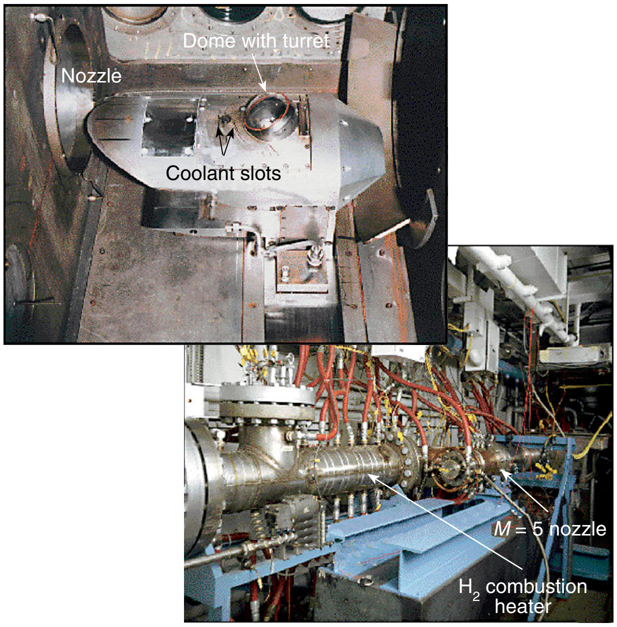

Figure 10. An aerothermal IR test facility is used for realistic aerothermal flight simulations in the AATDL.

control sensors (e.g., the SPY-1 radar), and closed-loop detect-through-engage high-fidelity models of Area and NTW TBMD weapon systems, which are essential to understanding and developing discrimination concepts.

CONCLUSION

Our programs are well positioned to meet the current Air Defense challenges, and our engineering expertise and facilities enable us to translate mission needs into system concepts and lead the technical work to select the best approach from among competing concepts. ADSD's ability to conceptualize is buttressed by its hands-on experience in design and development. The latter provides a solid grounding in terms of what is feasible; the former provides an early appreciation for the technologies that must be developed.

The future challenge will demand enhanced sensor sensitivity to detect targets that are smaller and faster, more maneuverable, and harder to hit and kill; improved tracking and identification precision as attackers suddenly appear in airspace crowded with civilian traffic; impeccable clarity in situational awareness by embarked commanders; and greater selectivity from ordnance fired to prevent targeting decoys and noncombatants. The efficient use of assets and system designs that reflect the lowest cost to the nation for the missions to be performed will be an ADSD objective.

THE AUTHOR

RICHARD W. CONSTANTINE is a member of the Principal Professional Staff and the Laboratory Executive Council. He received a B.S. in aeronautical engineering from Princeton University in 1964, an M.S. in mechanical engineering from Purdue University in 1966, and an M.B.A. from the University of Maryland in 1976. He joined APL in 1966 in the Bumble Bee Propulsion Group of the Aeronautics Department, where he specialized in ramjet engine design, missile composite design, digital flight simulation, and test and evaluation. He moved to the Fleet Systems Department to become Standard Missile Program Manager in 1983 and was appointed Program Area Manager for Surface Combat Systems in 1989. In 1996, he was appointed Head of the newly formed Air Defense Systems Department. He has participated in numerous Navy, OSD, and congressionally appointed studies focused on missile defense. His e-mail address is rick.constantine@jhuapl.edu.