APL's Contributions to Aegis Programs: An Overview

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The Secretary of Defense approved the Aegis Engineering Development Program in 1969. Looking ahead, he saw the end of the service life of the Talos cruisers in the 1980s as well as 10 Dewey class Terrier and 23 Charles F. Adams class Tartar guided missile destroyers in the 1990s. He anticipated that surface ships would continue to be an integral part of our nation's warfighting resources because of their capacity for providing large weapons inventories where needed with significant on-station endurance. The replacement ships would have to be technologically advanced to meet the needs of the nation in an increasingly more complex international environment. The result of planning, development, and system designing came in 1983 when the first Aegis cruiser, USS *Ticonderoga* (CG 47), was deployed. Her revolutionary combat system was based on advanced development work carried out by APL in the mid-1960s.

The adoption of an advanced weapons system employing a high-performance multipurpose phased array weapons control radar was first signaled in the baseline systems established by the Advanced Surface Missile Systems (ASMS) Assessment Group in the mid-1960s. The baseline design required the development of phased array radar capable of surveillance and establishment of tracks with sufficient precision for midcourse guidance and control of intercepting missiles. It also required that those functions be performed, fully automatically, in the presence of electronic countermeasures (ECMs). Not only were there technical challenges to be overcome in the development of a feasible system, but also the engineering challenge of designing a producible, maintainable, multifunction system.

APL reduced the risk associated with the new weapons system with an advanced engineering development program in radar technology (Fig. 1). The Advanced Multi-Function Array Radar (AMFAR) effort, between 1967 and 1970, accomplished two goals. First, it was a means of assuring the maturity of certain key components for support of engineering development. Second, it demonstrated that the resultant radar system could satisfy operational requirements for surveillance, tracking, and missile guidance and communications with strong resistance to ECMs. APL was a key member of the team that developed the robust, ECM-resistant communication link to and from the missile. This new link was engineered to match the AN/SPY-1 radar waveform and to be producible in the

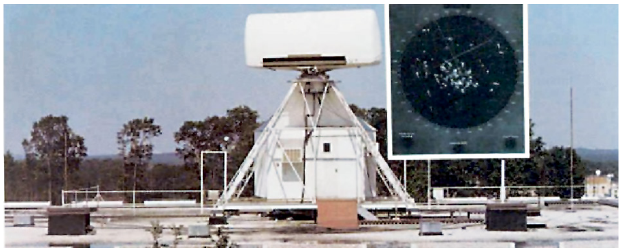

Figure 1. The APL-developed Advanced Multi-Function Array Radar.

Figure 2. Aegis Display System.

confines of the missile. Additional contributions of the Laboratory included the development of models to investigate system operability as a function of equipment reliability, redundancy, and replacement time in the event of failure and to assess the effects of such failure on related ASMS system areas such as Standard Missile.

The Laboratory's role in Aegis since 1969 has been that of Technical Advisor to the Navy program management. The Secretary of Defense directed the Navy to conduct an examination of the Aegis system design to identify means for introducing simplification. The Navy, in turn, tasked APL to conduct that examination. The APL study identified ways to simplify both the transmitter and signal processor designs. The prime contractor's initial Aegis system design required two sets of four transmitters, four phased arrays, two signal processors, and two computer control systems per forward and aft radar systems. APL identified the means to eliminate one transmitter fore and aft through the use of a high-power microwave switch, to combine signal processor functions into a streamlined central unit, and to combine the control functions into a single memory-sharing multiple CPU machine.

APL has continued to serve as Technical Advisor, providing assurance that the contractor's design and its evaluation/improvement satisfies Navy technical requirements, identifying areas of risk, proposing alternative approaches, conducting critical experiments of the alternatives, and transitioning results of investigations and experiments to industry for production.

One of the more significant APL inputs concerned the Aegis Display System (ADS; Fig. 2). The ADS concept originated and was prototyped at the Laboratory in the 1970s. The prototype and experimental work continued in a series of ongoing at-sea experiments that came to be known as the Command Support at Sea Experiments (CS@SE). Beginning in 1987, Phase I of the experiments dealt with the demonstration, evaluation, and subsequent definition of color and advanced graphics for use in large screen displays (LSDs) as they applied to ADS baseline 4 capabilities. Phase II continued the focus on advanced graphics capabilities for future baselines and incorporated technical databases such as commercial air corridors and territorial boundaries to support command decision making. Phase III examined system requirements and design constraints for over-the-horizon/organic data anti-air warfare (AAW) correlation and tracking; added additional technical databases; and enhanced operator interfaces. The human–machine interface was further extended in Phase IV to provide greater flexibility for introducing new display items and to simplify the operator interface for even more complex situations. LSDs were extensively worked in all phases of CS@SE. The design of the second-generation LSD, the PT-563, which is now installed in Aegis cruisers and destroyers, was based on the CS@SE experiences. Experiments conclude this year in Phase V when the Combat Display and Control System (CDCS) is removed from USS *Anzio* (CG 68) and USS *Cape St George* (CG 71). CDCS led the way in implementing commercial-off-the-shelf hardware aboard ship, with ADS application based on a common display kernel.

The Laboratory has developed models and simulations to aid in the design and development of all phases of the Aegis Combat System. "FirmTrack" is the premier high-fidelity SPY radar model. "TEMPER," the Tropospheric Electromagnetic Parabolic Equation Routine, is used throughout the Aegis community for modeling radar propagation in the atmosphere and developing equipment for the measurement of environmental conditions. "AAWSim" provides probability of raid annihilation predictions and combat system depth-of-fire assessment for various ship baseline configurations versus various threat conditions. "ARTEMIS" (Area/Theater Engagement Missile Ship Simulation), which is now in development, will provide a high-fidelity, end-to-end, all-digital simulation capability to generate Monte Carlo statistics on the performance of entire endo-atmospheric Theater Ballistic Missile or AAW engagements, from target launch and target detection through interceptor launch and target intercept.

One other measurement/model/simulation project, the Shipboard Environmental Assessment/Weapons Systems Performance (SEAWASP) tool, must be mentioned since it is being incorporated into a production system and will find its way into almost every U.S. Navy ship. SEAWASP provides environmental and radar performance capability assessments. The SEAWASP environmental assessment subsystem (Fig. 3) will be incorporated into the Shipboard Meteorological and Oceanographic Observing System Replacement (SMOOS(R)).

Figure 3. SEAWASP environmental assessment subsystems include rocketsondes, ship topside environmental sensors, and computer programs to assess radar performance capability.

The High Performance Distributed Computer System (HiPer-D) project is an investigation into the application of computer system architectures and technologies to the broader functional area of the entire Aegis Combat System. It started as a joint Aegis and Defense Advanced Research Projects Agency (DARPA) project, with APL and the Naval Surface Warfare Center/Dahlgren Division (NSWC/DD) collaborating to execute the program. The partners shared engineering efforts with demonstrations at an NSWC/DD site. Concepts and principles explored in HiPer-D have greatly contributed to the confidence to proceed with development of a distributed computing system for Aegis.

The Java Enhanced Distributed System Instrumentation (JEDSI) system was developed to solve the problem of gathering live performance data in a distributed application system such as HiPer-D. It provides a small, flexible application programming interface to instrument a distributed system under test and a set of portable components for data collection, analysis, and display. JEDSI has found its way into the experimental development model and production systems of the Aegis prime contractor, Lockheed Martin Naval Electronic and Surveillance Systems.

What of the future? Military strategy is changing, with emphasis on regional conflicts. Consequently, the fighting environment has changed from the open ocean to the littorals, and soon will include the ionosphere. Multiwarfare capability is stressed to support joint, simultaneous strike, theater air defense, sea control, and ground force insertion operations near land. Threats to Aegis ships present smaller radar cross sections, are faster, fly lower, and weave. Other threats that Aegis must neutralize are hard to sort out from a sky full of potential targets. Operations in the littorals have introduced new challenges—land-based anti-ship missiles, a heavily cluttered environment caused by the land background, terrain masking, and additional classes of threats like small boats, armed helicopters, and mines. And, no matter what is done, it is done under increased media and public scrutiny. With that scrutiny comes a requirement for new levels of precision in the engineering and application of our combat systems. APL will persist in applying scientific and engineering expertise to provide the Navy with the capabilities required to effectively perform assigned peacekeeping and warfighting missions. The challenges are being addressed through the development and innovative application of new technologies which, coupled with sound systems engineering, provide the requisite detection, control, and engagement capabilities.

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