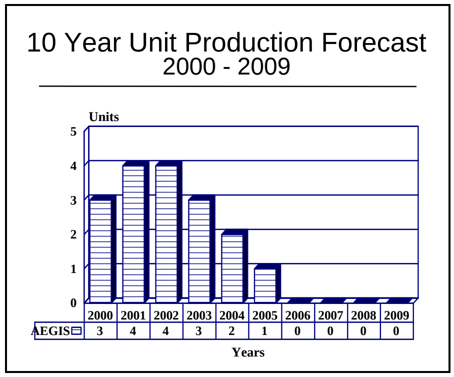
AEGIS - Archived 5/2000

Outlook

- Production supports US DDG-51 construction
- MFR and VSR will support next-generation destroyer
- Taiwan considering AEGIS for missile defense



Orientation

Description. 3D, multi-function, phased-array naval radar system. It is part of the AEGIS Anti-Air Warfare weapons system.

Sponsor

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Contractors

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(SARTIS Recognition System)

Litton Industries
Electron Tube Division
1035 Westminster Dr
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(Double-duty cross-field amplifier tubes)

Raytheon Systems Company
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BAE SYSTEMS – NA
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3050 Hansen Way
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Blohm+Voss GmbH
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Tel: +1 49 40 3119 2414
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(MEKO A-200 Combat System – 25%)

Status. In production, ongoing logistics support and upgrades.

Total Produced. Through 1999, 27 SPY-1A/B and an estimated 47 SPY-1D/F systems had been delivered.

Application. US Navy CG-47 AEGIS class cruisers, DDG-51 AEGIS class destroyers, Japanese DDG-173 Kongo-class destroyers, and Spanish MEKO-class Frigates.

Price Range. Approximately US$20 million (single unit cost as part of a US$57.8 million three-unit purchase of the SPY-1A/1B transmitter group and Mk 99 Mod 1 fire control system).

Cost/price is estimated based on an analysis of contracting data, other available cost information, and a comparison with equivalent items. It represents the best-guess price of a typical system. Individual acquisitions may vary, depending on program factors.

Technical Data

	Metric	US
Dimensions		
Array face:	3.5 x 3.5 m	11.5 x 11.5 ft
Weight (Above Decks)		
SPY-1A:	5,915 kg	13,030 lb
SPY-1B:	3,587 kg	7,900 lb
SPY-1F:	45% reduction	45% reduction
Weight (Below Decks)		
SPY-1A:	59,739 kg	131,584 lb
Characteristics		
Frequency:	3.1 to 3.5 GHz	
Power Out:	4 to 6 MW peak 58 kW average	
Pulse Width:	6.4, 12.7, 25.4, 51 µsec	
Pulse Compression:	128:1	

Characteristics (continued)

Bandwidth:	10 MHz (sustained coherent)	
	40 MHz (instantaneous)	
System Gain:	42 dB	
Antenna Elements:	4,480 per face	
Faces per Ship:	4 (2 fore, 2 aft)	
Coverage:	110° (each face)	
	360° (total)	
Range:	463 km	250+ nm
Track Capacity:	100+	
	Increased in Baseline 4 ships	

Design Features. The AEGIS anti-air weapons system is made up of the SPY-1(V) sensor, a core command and decision element, fire control system, control consoles and large-screen displays, air search and fire control radars, missile launchers, and RIM-66 Standard MR and ER anti-aircraft missiles.

The SPY-1B uses four phased arrays, two mounted fore and two aft. Each antenna is subdivided into 140 array modules, each with 32 radiating elements. There are 4,096 transmitting elements and 4,352 receiving elements. The phase shifters include ultra-precise, temperature-resistant synthetic garnet crystals, and are driven by four-channel driver boards, of which eight are identical ones to ensure redundancy and survivability.

The SPY-1F selected for the Spanish MEKO A-200 uses a smaller array than that of the SPY-1D. The new front-end will provide 360° hemisphere coverage with a 45% array weight reduction.

The SPY-1(V) is connected to the AEGIS weapons system via UYK-7(V) digital computers. These were upgraded with UYK-43/44s in Baseline 4 ships to increase target capacity and processor speed. The UYK-7(V) controls the radar beams for search, detection and tracking. In addition, the UYK-7(V) provides guidance information for the ship's own missiles. The use of parallel redundant transmitter channels results in graceful degradation instead of sudden system failure.

Four UYA-4(V) or UYA-21(V) large screen displays project processed anti-surface, anti-air and anti-submarine warfare information. Two console sets face the LSDs and five Automated Status Boards (ASBs) mounted above the LSDs.

The SPY-1(V) can change frequencies automatically to avoid countermeasures and interference. Advanced digital signal processing techniques suppress jamming, chaff, and sea clutter.

One problem with the system was that the radar data display could not identify a target by its head-on cross-section. The shoot down in the Persian Gulf of the Iranian Airbus in July 1988 by the USS *Vincennes* was partly the result of the inability to get an accurate size ID on the oncoming aircraft. IFF identification was not part of the original SPY-1A, and problems with the operation of an older transponder caused a false-hostile track to be assigned to the Airbus.

Sanders, a Lockheed Martin Company, developed the AIMS antenna system to work with the UPX-29(V) Central Identification System to provide ATC Radar Beacon, IFF, Mk XII combat identification capability. It installs the OE-120/UPX circular array of 64 radiating elements on AEGIS ships to enhance the identification capability of the AAW system. These are being installed on US and Spanish AEGIS ships.

Processing power is the heart of AEGIS, and also its limitation. Efforts continue to capture more computer capability for the system by taking advantage of Moore's Law, which says that the number of integrated circuits that can fit onto a computer chip doubles about every 18 months. Designers are working to incorporate advances in commercial hardware and software for various tasks to increase the overall power of the system. This adjunct processing offers significant promise, but also is a major technological challenge.

Commercial systems can be limited by the MilSpec mainframe architecture with its hard-wired inter-connected design. Such a setup does not come close to running at the speed of which a commercial processor is capable.

Since June 1991, DARPA, the Navy and Johns Hopkins University Applied Physics Lab have been involved in the High-performance Distributed Computing (HiPer-D) program. This system will try to overcome many of the limits to processing operations and take advantage of a supercomputer's speed. It focuses on a variety of approaches, including embedded systems which de-emphasize pure processing power in favor of melding communications hardware and software that tie commercial processors together more effectively and take advantage of the capabilities of commercial computers.

Concentrating on the EDM-5 AEGIS, the more muscled computers (six times the processing power of any AEGIS in existence) proved able to run all current AEGIS computer programs. The new architecture is targeted for the Baseline 7 system planned for DDG-91, the 41st AEGIS ship off the ways. The system will benefit from a distributed architecture and will try to tie together combat functions and other shipboard data processing to take advantage of a ship's overall computer capability. This modular architecture will be easier to upgrade through the introduction of new technology with minimal disruption to the existing system.

A March 1994 test showed that a mainframe-based commercial architecture could not meet AEGIS requirements. During the test, the system could maintain about 50 tracks, far less than the 700 of the existing Mil-Spec processors. In May 1995, a partially distributed HiPer-D processor demonstrated the ability to maintain 700 tracks and run AEGIS programs and maintain tracking equal to Fleet AEGIS systems.

In November 1995, designers demonstrated a distributed architecture that could handle 1,400 tracks, twice what the current systems are capable of. In a December 1996 test, HiPer-D maintained 3,000 simultaneous tracks with no reported problems. The goal is to develop a fully distributed, architecture ready EDM that will be six times more capable than the current HiPer-D EDM-5 AEGIS.

Operational Characteristics. The SPY-1(V) radar is the heart of the AEGIS weapons system for US Navy CG-47 guided missile cruisers and the DDG-51 guided missile destroyer. In a carrier battle group, fighter aircraft provide an outer-layer of defense while the AEGIS system provides the inner layer. AEGIS was designed to protect naval battle groups from aircraft, missile and surface threats. AEGIS employs a number of separate weapons systems, including Harpoon anti-ship missiles, Standard-ER (SM-2) surface-to-air missiles and the Phalanx Close-In Weapons System.

The AEGIS system can track 700 targets simultaneously (ranging from surface to subsurface to airborne) at ranges of over 250 nautical miles. This range limit is specifically set, with the radar receiver unable to accept returns from outside this range limitation since the radar is only able to generate a set number of beams or dwells per second. The AEGIS computer assigns high rates of dwell coverage to new targets until tracks are established. Any signal sent out is immediately digitized and returned so it can be identified.

The information from AEGIS provides many of the inputs for the Navy's Cooperative Engagement Capability which fuses data from multiple sources to provide all ships in a battle group with a comprehensive picture of the naval situation. AEGIS is the main surface sensor, while the E-2C Hawkeye is the key CEC airborne radar. Software and hardware upgrades are in turn upgrading radar performance for the cluttered littoral environment.

The Spanish SPY-1F system is being specifically designed for littoral operations. It will eliminate weather clutter and be able to conduct simultaneous multi-warfare area combat with a track capacity exceeding 100 in multiple engagements. It will also include missile defense capabilities.

Variants/Upgrades

<u>SPY-1A</u>. AEGIS cruisers up to and including CG-58.

<u>SPY-1B</u>. AEGIS cruisers from CG-59 onward. The B model features a new antenna design with lower sidelobes and an improved signal processor. The new transmitter has the same peak power but double the duty cycle.

<u>SPY-1C</u>. Was proposed for use on aircraft carriers, but the program was canceled.

<u>SPY-1D</u>. Developed for DDG-51 AEGIS destroyers. The Arleigh Burke class ships are being built to boost the Navy's guided missile destroyer force. The SPY-1D radars are smaller and lighter than those on the CG-47 guided missile cruisers. The destroyers carry a single radar transmitter instead of two, and three target illuminators on the CG-47 ships in place of four. Use of VLSI technology resulted in a considerable space savings. The ECCM capabilities are enhanced.

It was specifically designed for operating in the high-clutter littoral environment. It features an increased radar sensitivity and sub-clutter visibility, and can maintain a rapid search rate throughout the radar coverage region. It compensates for the increased number of false alarms generated by the more sensitive receivers operating in the cluttered littoral environment.

By replacing the Advanced Signal Processor and SPY-1B/D Low-Power Radio-Frequency Amplifier cabinets with simplified drivers and their power supplies, designers were able to shift from one UYK-43 computer to two, and to commercial off-the-shelf processors when the system was introduced into the Fleet. It retains the SPY-1B/D phased arrays, High-Power RF

Amplifiers and auxiliary/support equipment. The upgraded system will contain 26 new processor module types and feature real-time algorithm downloads.

The system will have higher average power, lower noise, and more pulse-to-pulse, phase and amplitude stability than the SPY-1B/D. A Moving Target Indicator clutter-cancellation system with computer-selectable waveforms of two through seven pulses will provide greater clutter rejection performance. A wider notch filter will reject nuisance tracks (birds, etc.) and enhance the ability to cancel clutter with different relative speeds (land clutter, rain).

An Automatic Adaptive Mode Control will permit the system to automatically select the optimum MTI search waveform for the tactical environment.

Pulse-Doppler acquisition and tracking waveforms of 12 and 16 pulses will provide greater sensitivity and more clutter rejection than MTI in detecting selected targets in heavy clutter and chaff. This will provide operators the ability to track tactically significant targets through regions of dense clutter and chaff clouds. The pulse-Doppler mode also will provide for a cued search capability using inputs from off-board sensors, supporting searching waveforms in regions of dense clutter.

Designers added a dual-beam search capability to make it possible to maintain a rapid search capability in spite of the increased processing time needed to accommodate the changes in the MTI system. The sensor can search two directions at once using opposing array faces, and the returns are processed independently in two channels of the four-channel signal processor. This makes it possible to maintain a high surveillance data rate in a cluttered littoral environment.

Track initiation processing is integrated with the advanced signal processor which has a track-while-scan capability that uses the rapid horizon search rate to screen out low-level targets. Long-duration targets can be passed to the Gun Fire Control System.

These changes are planned to improve the performance of AEGIS in the littoral environment and to make the sensor better able to become part of a Tactical Ballistic Missile Defense system for forces deployed near a shore line. Integrating AEGIS with land-based TBM systems will significantly improve the protection of forces in a theater of operation.

SPY-1E. This was developed from the Littoral Warfare Radar, the engineering model for the EDM 4B. It features an enhanced ability to detect, track and target sea-skimming cruise missiles. The upgrade includes some ballistic missile tracking upgrades. Testing was planned to begin in 1996, with first deployment on DDG-87 sometime in 1999.

The upgraded AEGIS suite includes the Joint Tactical Information Distribution System (JTIDS)/Command and Control Processor (C2P), TADIL J, Combat Direction Finding, Tactical Data Information Exchange System (TADIX B), SLQ-32(V)3 Active Electronic Countermeasures, and Standard Extended Range (ER) Missile.

SPY-1F. This is an international version of the radar being installed on Spanish MEKO F-200 frigates. It will have a smaller, lighter array than the SPY-1D with performance equivalent to that on the SPY-1D on DDG-51 Flight II ships. It provides 360° coverage and incorporate two or three missile directors. MTBF should exceed US Navy requirements. Multiple engagements and a TBMD capability will be included. It will interface with a non-US Combat System.

Baselines. The Navy Baselines refer to improvements to the AEGIS system as a whole.

Baseline 2 - (CG-52 through 58) consists of the vertical launch system, TOMAHAWK weapons system and anti-submarine warfare upgrades.

Baseline 3 - (CG-59 through 64) includes the SPY-1B and UYQ-21 console.

Baseline 4 - (CG-65 through 73) converts programs to the UYK-43/44 computers and supplies increased battle group capability in the AEGIS display suite. It is the base Combat System for DDG-51 through -67.

Baseline 5 - is the version introduced in FY92 ships. It includes the Joint Tactical Information Distribution System (JTIDS) Command and Control Processor, Tactical Data Information Link 16, Combat Direction Finding, Tactical Data Information Exchange System, SLQ-32(V)3 Active Electronic Counter Countermeasures and AEGIS Extended Range (ER) Missile.

Baseline 5 was developed in three phases. Phase I integrated AEGIS ER and supports the missile Initial Operational Capability. Phase II integrated system upgrades including Deceptive Electronic Countermeasures, Track Load Control algorithms and Track Initiation Processors. Phase III integrated JTIDS and the OJ-663 color display Tactical Graphics Capability into the AEGIS Combat System.

Baseline 6 - Baseline 6 was developed in two phases. Phase I was planned for the last ship in FY94 and Phase II for the first ship in FY97. Baseline 6 upgrades include embarked helicopters, Fiber Optics as applied to Data Multiplexing System (DMS), implementation of affordability initiatives, the Radar Set Controller

Environmental Simulator (RSCES) and the Battle Force Tactical Trainer (BFTT). It also has the Advanced Display System, Evolved SEASPARROW Missile (ESSM), Identification (ID) upgrades Phase I, Advanced TOMAHAWK Weapon Control System (ATWCS) Phase II, and Fire Control System upgrades.

Baseline 7 - Baseline 7 will also be developed in two phases. Phase I is planned for the last ship in FY98 and Phase II for the last ship in FY02. Major Baseline 7 upgrades include the SPY-1D(V) radar upgrade, integration of Cooperative Engagement Capability and Tactical Ballistic Missile Defense capability (first forward fit implementation), advanced computer architecture, ID upgrades Phase II, Cueing Sensor, and STANDARD Missile-2 Block IIIB full integration. These ships will also carry the Advanced Integrated Electronic Warfare System (AIEWS) Phase I and II, Light Airborne Multipurpose System (LAMPS) helicopter Mark III Block II, Advanced Tactical Support, Naval Surface Fire Support (NSFS), and Mark 50 torpedo with Periscope Depth Attack.

This project also addresses the Technology Ship Characteristic Improvement Panel (TSCIP) program for advanced computing architecture for SC-21, CVX, LX and other future ship classes.

There is a follow-on baseline planned for integrated land attack and a fully distributed computer architecture. The Cruiser Conversion Program will upgrade cruisers with Theater Ballistic Missile Defense, land-attack, and Area Defense Commander (ADC) capabilities, along with "Smart Ship"-like Integrated Control Systems.

Navy Area Tactical Missile Defense. This program is developing modifications to the AEGIS combat systems and SPY-1(V) radar to make it possible to detect, track, and engage tactical ballistic missiles at low altitude using a modified Standard missile. In late 1998, problems with the AEGIS Baseline 6 Phase III software development caused an 18-month slip of the ten developmental/operational development tests that were scheduled for FY99 and FY00. This caused a six-month delay in initial EMD testing and one-year delay in the First Unit Equipped date.

"Linebacker". These are two AEGIS cruisers (CG 70 and CG 73) modified to be able to perform both AEGIS and Tactical Ballistic Missile Defense missions. They are being used to provide feedback and evaluation of hardware and software to aid in the development of AEGIS modifications. They will be used for at-sea evaluations of both systems and tactics.

Navy Theater Wide Tactical Missile Defense. This is a high altitude, longer range missile defense version of AEGIS. Test problems have delayed the program, and a decision of whether this or the Army's ground-based THAAD missile defense system should be fielded first. This is planned for IOC in 2005.

High-Power Discrimination Radar (HPD). The HPD concept is for an X-band adjunct sensor which will provide long-range detection, tracking, and exo-atmospheric discrimination of advanced theater ballistic missile (TBM) threats. It will also support the STANDARD Missile SM-3 as an interceptor. An initial prototype development contract was awarded to the Raytheon Company in April 1999. It is to leverage technology from the Ballistic missile Defense Office Theater High-Altitude Air Defense (THAAD) radar by using active array technologies and theater missile defense software developed for that program. The program was planned as a hedge and risk-reduction alternative to the Navy Theater Wide Program.

Program Review

Background. In the early 1960s, it became obvious to the Navy that self-defense sensors based on the rotating radar antennas were no longer adequate. Such radars and their fire control systems could not cope with high-speed anti-ship missiles, especially the developing sea-skimmers, or Mach 2 aircraft. Emerging technology was creating the ability to field a phased-array radar that could project a pencil-thin beam out to great distances (250+ nm). By incorporating advanced computer software, also emerging during that period, a phased-array-based weapons system could spot, track and illuminate multiple targets nearly simultaneously for a ship's defensive weapons. In addition, the phased-array design allowed the radar to defeat hostile electronic countermeasures (ECM) by "burning through," – that is, channeling as much power as necessary into pencil-thin beams to overcome jamming. The new beam patterns were not limited by the same power-density considerations as rotating antennas. Advanced in-processing capabilities helped by improving the way radar return data could be analyzed and used.

Following a contract award for the AEGIS weapons system in 1969, RCA began testing an SPY-1A phased-array radar in 1972. In 1973, the SPY-1 was transferred to Long Beach, California, for installation aboard the weapons system test ship, USS *Norton Sound* (AVM-1).

During tests in 1974, the SPY-1 aboard the *Norton Sound* detected and automatically tracked 20 aircraft flying over the Pacific Ocean. At the Navy's Combat

System Engineering Development facility in Moorestown, New Jersey, a series of tests pitted an AEGIS system and similar radar housed in a land-based CG-47 bridge mockup against a host of airborne targets and threats. Navy EA-6B aircraft with their jamming pods at full power could not successfully jam the SPY-1(V) AEGIS radar. A USAF KC-135 outfitted with TREE SHARK, one of the most powerful jammers available at the time (reportedly equivalent to 32 EA-6B aircraft at full jamming power), also could not completely jam the system either. In each case, the radar was able to "burn through" the jammers and simulate the launching of defense missiles.

While hundreds of weapons firings at a variety of targets, including drones, missiles and aircraft using the system, have taken place during tests, few misses were attributed to the performance of the SPY-1(V) radar itself. The misses that did occur tended to be the result of computer problems, missile launcher difficulty or human error.

One notable exception took place during a US$30 million eight-day test of AEGIS off the coast of Puerto Rico in April 1984. Using SM-2 (RIM-67B) Block 1 surface-to-air missiles, the AEGIS system aboard the USS *Ticonderoga* destroyed 10 of 11 target drones. At one point, a drone launched from 70,000 feet, and part of a group of four drones launched simultaneously, managed to elude detection and slip through the AEGIS defense. Two targets during this test were "constructive ships" (one simulating a battleship and one representing an oiler) and were attacked by one drone each from the group, with the *USS Ticonderoga* attacked by the remaining two. The battleship target was 17 miles away from the USS *Ticonderoga* and the oiler nine miles away.

Navy officials said that the one drone that slipped through (targeted for the oiler) was not detected and attacked because it crossed the beams of several jammers and because of the use of heavy chaff. Despite this less-than-perfect score, however, the test was in sharp contrast to an earlier one in which the USS *Ticonderoga* was able to hit only six of 18 targets. Poor crew training was cited in that case.

During 1985, the USS *Yorktown*, the second ship of the class, was subjected to rigorous shock tests. The results were excellent, and there was only minor and temporary damage in spite of the severity of the shocks applied.

An October 1995 *Commerce Business Daily* notice announced that the Navy planned to solicit engineering analyses of the AEGIS Combat System performance in fleet defense, ship self-defense, amphibious operations, and Theater Ballistic Missile Defense missions. The analyses would include evaluating the SPY-1 radar performance, airborne fleet surveillance techniques, associated data fusion, application of the Cooperative Engagement Capability concept, and missile system performance. The effort would include FMS activities. A sole-source base-year plus four nine-year options would be issued to Technology Service Corporation, Silver Spring, Maryland.

On September 11, 1996, two AEGIS cruisers, USS *Anzio* (CG-68) and USS *Cape St. George* (CG-71), took part in the Cooperative Engagement Capability (CEC) Initial Operational Capability final missile firing test. Operating near the AEGIS Combat Systems Center (ACSC), Wallops Island, Virginia, and in the Gulf of Mexico, the ships conducted successful missile firing operations, setting up the final approval of CEC for Fleet operations. The two ships shared SPY-1 data through the CEC system and proved that they were not limited to weapons operations using only own-ship sensors.

Mid-1998 exercises with the EISENHOWER Battle Group uncovered interoperability problems between AEGIS and CEC. Navy memos called attention to funding constraints and how problems were creating a need to look very hard at changes, upgrades, and allocations of fiscal and operational resources. One solution was the idea of developing a common computer language "Sea Athena" to insure that different systems process information the same way. Developments would have to support this common language to be acceptable. A special study group was directed to look at AEGIS Baseline 6 Phase III and Baseline 7 Phase I to determine where these programs could be "frozen" or eliminated and deliver the minimum required neat-term functionality. Study results could have an impact on program funding in upcoming budgets.

In a July 31, 1998, *Commerce Business Daily* the Program Executive Office for Theater Air Defense/ Surface Combatants (PEO(TAD/SC)) announced a pending solicitation for Theater Ballistic Missile Defense (TBMD) prototype active radar concepts to support Navy Theater-Wide risk reduction activities (RRA). The concept, referred to as a High Power Discrimination (HPD) Radar, would be used to support the STANDARD MISSILE SM-3 for exoatmospheric intercepts. Its radar could be an adjunct radar to the SPY-1(V) or a sensitivity upgrade to the SPY-1(V). The HPD will perform the functions of search, detection, tracking and exoatmospheric discrimination. HPD program objectives are to evaluate a prototype radar's suitability in supporting the Navy Theater-Wide TBMD mission by validating shipboard interfaces including weight, moment, power, electromagnetic compatibility and cooling; validating operation in Navy-unique operational environments; validating operation in Navy-unique TBM scenarios such as ascent and mid-course phase tracking and discrimination; providing a hedge against far-term threat developments; and providing a fallback position for the SPY-1(V) Radar high range resolution risk reduction program. The overall Navy Theater-Wide Program will provide a capability starting in 2005.

The announcement went on to note that studies had determined that the AEGIS Weapon System needs additional power and discrimination to counter the far-term TBM threat in accordance with NTW ORD requirements. This need may be met with the addition of a HPD that will provide longer detection, tracking and discrimination ranges than the AEGIS Radar. Funding of US$18 million was available to support the effort, which could include studies, concept design, preliminary design, long lead material acquisition, prototyping and testing. Offerors were encouraged to submit proposals from US$2 million to US$18 million in increments of US$2 million. FY98 funding was identified and could be expended in FY99. No additional funds were identified beyond the FY98 US$18 million.

The Navy would use phased contract milestones to ensure that a useful risk reduction product would be delivered after every funding increment, should outyear funding be unavailable. Contingent on the results of the first contract phase and future budget decisions, outyear funding could be dedicated to HPD risk reduction. The ultimate objectives of this effort are intended to be a ship-based prototype HPD available in 2001.

In November 1998, the Navy tested the first two ships equipped with the initial anti-missile system. In tests off the coast of Hawaii, the USS *Lake Erie* (CG 70) and USS *Port Royal* (CG73) detected, tracked, and engaged two tactical-ballistic-missile targets. The tests did not include an actual missile intercept, but were to validate the detection and tracking performance of the SPY-1(V) radars. On November 18, a modified Standard missile was fired down range. On November 20 a longer range Aries target was fired. The "Linebacker" ships were also interlinked and, to demonstrate interoperability, passed data to Army Patriot and Theater High Altitude Area Defense facilities in Huntsville, Alabama. The tests also were used to gauge the readiness of the battle-management and fire-control computers that would be used for the future anti-missile network.

A November 19, 1998, *Commerce Business Daily* carried a Broad Agency Announcement for short-term concept studies relating to an Area Air Defense Commander (AADC) capability. The Navy was beginning a program to develop and deploy an advanced command and control system that would provide real time battle management to enable the execution of the Theater Ballistic Missile Defense and overall theater air defense missions. As part of the total Navy effort, the Area Air Defense Commander (AADC) capability would be a command and control system element for execution of the Area and Navy Theater Wide TBMD and Joint Warfare programs.

Studies suggested that improved real time battle management within the constructs of network centric warfare is necessary to optimize weapon system performance and operator decision making. Using current state-of-the-market display and computer program technology, the command and control system that was developed for the AADC will provide automated Force Planner and Tactical Operations capabilities to extend the commander's ability to plan, monitor, and execute assigned warfighting functions.

The AADC effort was in the concept development phase of the acquisition process, and the Naval Sea Systems Command was soliciting proposals for short-term concept studies for an AADC capability. The objectives of these studies are to obtain a conceptual design approach for an AADC capability which meets the operational requirements specified in the draft Operational Requirements document (ORD) – a software engineering approach for the conceptual AADC design that identifies the source and effort required to develop the computer programs to satisfy each functional requirement in the System-Subsystem Specification (SSS). The approach should address programming, documentation, quality assurance, configuration management standards, and the process, procedures, and tools to be employed. The approach shall identify, for each functional requirement, the extent of new development that will be necessary. For reuse, it should also identify the source, extent, and description, as well as an estimate for any re-engineering, modification, enhancement or additional documentation required. The software engineering approach should make maximum use of commercial industry standards and COTS tools.

A demonstration of an understanding of an approach to interfacing the conceptual AADC design with other systems (e.g., AEGIS Command and Decision, TBMCS, other potential Joint host command and control systems, and GCCS-M) was required.

On February 19, 1999, the Navy announced a Cooperative Engagement Capability (CEC) Design Agent Services solicitation. The Naval Sea Systems Command was seeking Design Agent (DA) efforts to provide for development, deployment and support of Cooperative Engagement Capability (CEC) functionality for the US Navy. Contracts would be awarded sole source to Raytheon Systems Company, Command, Control and Communications Systems, St. Petersburg, Florida, and Lockheed Martin Corporation, Moorestown, New Jersey, pursuant to 10 U.S.C. 2304(c) (1). Raytheon would continue to provide technical support for CEC baselines 1 and 2 and enhancements to CEC communications capabilities; design, develop, and support CEC baseline 2.1, including the Cooperative Engagement Processor (CEP), all 2.1 software, and CEC integration with SSDS MK 2; and continue the development and delivery of the Data Distribution System (DDS), inclusive of changes necessary for baseline 2.2 CEP design. Raytheon would also continue to provide CEC system level DA services, including cost reduction initiatives, feasibility studies, demonstrations, ECPs, COTS/NDI management, incidental hardware, and advance demonstration support for emerging applications. As previously synopsized, Raytheon will also provide CEC equipment repair and Low Rate Initial Production (LRIP).

Lockheed Martin, as the source responsible for incorporating Theater Ballistic Missile Defense (TBMD) requirements into the AEGIS Weapon System, would lead the implementation of AEGIS area TBMD into CEC as baseline 2.2, by providing CEP DA responsibility for the design, development, and support of the CEC baseline 2.2 CEP computer program. Lockheed Martin will also, in conjunction with Raytheon, interface the CEP with the DDS. Both companies will participate as members of the CEC "Navy Review Team," which will provide government oversight and peer review of new CEC design efforts and assist in the resolution of interoperability problems with other Navy combat systems. The Navy Review Team will also include, as associate members of the team, other DoD prime contractors having responsibility for systems being integrated with CEC. Together, the industry members of the Navy Review Team will serve as an "Industry Council" to advise the Navy on CEC integration and interoperability problems.

Raytheon and Lockheed Martin will also participate on a Navy-led team to assess the top-level requirements for future architectural design paths for CEC in a Battle Force Context. As part of this effort, this team will serve as an advisor for demonstrations, experiments and feasibility studies concerning future applications of CEC; members of the team will participate as designated by the Navy in the definition, conduct & assessment of such initiatives. The Navy has also initiated planning for full and open competition for future CEC work.

On March 5, 1999, Forecast International obtained a pre-publication copy of the Heritage Foundation report *Defending America: A Plan to Meet the Urgent Missile Threat.* A study commission proposed a sea-based system that would be made up of upgraded AEGIS ships linked to SBIRS-Low satellite sensors and become the National Missile Defense protection of the continental US. The study put the cost at US$8 billion and said the capability could be online in four years. The Heritage study emphasized that the sea-based system would be much less costly than the ground-based approach the Pentagon is developing. The report put estimates for the ground system at US$25 billion for the first site, and another US$25 billion to build the multiple sites it said would be necessary to protect the United States. The conservative foundation also criticized leaked Pentagon estimates that a sea-based system would cost US$16 million to US$19 billion.

The report would face a variety of technical and political questions and criticisms; but could force a debate at the Pentagon and on Capitol Hill on the best way to provide missile protection for the nation.

AEGIS Combat System Engineering PE#0604307N. The AEGIS Combat System R&D effort funds a variety of enhancements for the AEGIS system to create a capability to counter the current and expected air, surface and subsurface threats as articulated in Naval Maritime Intelligence Center (NAVMIC) Threat Assessments #012-91 and #018-91 dated September 1991. Since the CG-47 and DDG-51 ships extend into the 21st century, changes in the threat capability and advances in technology such as fiber optics and distributed architecture, local area networks will require corresponding weapons system and combat system changes.

This program provides the combat system engineering and selected weapons development necessary for such a continued increase in the capability of the AEGIS combat system in AEGIS cruisers and destroyers. It will also allow later ships of these classes to take advantage of maturing equipment and weapons systems being developed in other Navy research and development programs.

In addition to developing and integrating improvements to the AEGIS Weapon System, this program integrates combat capabilities developed in other Navy R&D programs into the AEGIS Combat System. Modifications of AEGIS Weapon System computer programs must be made to integrate these capabilities into the AEGIS Combat System so that battle effectiveness and Combat System performance will be retained against the evolving threat. Selected Weapon and Combat System upgrades will be backfitted into CG 47-class and DDG-51-class ships already in the Fleet, providing key warfighting capability while reducing life-cycle maintenance costs.

The Smart Ship Project was incorporated into this program element under Project K2308 starting in FY98. This effort addresses reducing shipboard manning requirements and the integration of Commercial Off-the-Shelf (COTS) equipment. The goal is to reduce life cycle costs for Navy ships.

Project K1447 Surface Combatant Combat Systems Improvements. This project provides AEGIS cruiser and destroyer combat system upgrades to integrate new equipment and systems to keep pace with the threat and to capture advances in technology such as fiber optics and distributed architecture. The ships were upgraded in blocks and the combat system in a series of baselines. (See Baselines in **Variants/Upgrades** section)

This project also addressed the Technology Ship Characteristic Improvement Panel (TSCIP) program for advanced computing architecture for SC-21, CVX, LX and other future ship classes.

The Acquisition Strategy was for Combat System Improvements to be implemented in Baselines as described in the project mission statement. In FY98, Lockheed Martin was awarded a five-year omnibus contract (sole-source) to develop and integrate combat system improvements, which would fund all remaining AEGIS Baseline Upgrade Development efforts. After the baseline had been completed and tested, the computer program and associated equipment would be delivered to the new construction shipbuilders where the program and equipment are installed and tested along with all other elements of the shipboard combat system and associated combat support systems. The computer program is a GFE deliverable to the Production Test Center for equipment test and check out.

FY92 accomplishments were the conduct of SPY-1D Technical and Operational Evaluation (TECHEVAL/OPEVAL) Development Test/Operational Test IIE (DT/OT-IIE) in *Arleigh Burke* (DDG-51). The Navy also performed element test, evaluation, demonstration and qualification of the OJ-663 console variant of the AEGIS display system computer program in Baseline 4 Phase II ships. Program personnel conducted demo and element qualification testing.

The Program Office also conducted a Preliminary Design Review (PDR) II and Critical Design Review (CDR); completed design specifications, and commenced computer program coding, debugging and testing for AEGIS ER integration into the AEGIS weapons system (Baseline 5 Phase I) at the Combat System Engineering Development (CSED) site. It also began developing design specifications to integrate Baseline 5 Phase II (less JTIDS) into the combat system and conducted a PDR.

The Program Office commenced system definition to integrate JTIDS into the AEGIS Combat System (Baseline 5 Phase III), and began system definition to integrate the Evolved SEASPARROW Missile into the AEGIS Combat System (Baseline 6) at the CSED site.

FY93 was funded at US$76.274 million. Engineers completed computer program coding, debugging and testing of AEGIS ER integration into the AEGIS Weapons System Baseline 5 Phase I. Program personnel also demonstrated the system at the CSED Site. These efforts cost US$4.6 million. US$16.5 million was spent to complete design specifications and conduct a Critical Design Review of Baseline II (less JTIDS). The Navy began computer program coding, debugging and testing at the CSED Site for integration into the AEGIS Combat System. Program personnel also completed system definition and conducted a System Design Review (SDR) and Preliminary Design Review, commencing design specifications for Baseline 5 Phase III (with JTIDS) at a cost of US$12.406 million.

Also in FY93, the Navy performed the system definition to integrate Baseline 6 upgrades into the AEGIS Combat System (US$6.4 million). US$8.9 million was provided for the RDT&E share of operations and maintenance at the CSED Site, Program Generation Center, Computer Program Test Site, and Land Based Test Site. US$17.781 million was also provided for the participation of Navy laboratories and field activities to perform the engineering and scientific services necessary to monitor and direct the baseline efforts.

Development of the optical disk upgrade to the UYK-16 memory storage devices began, at a cost of US$3 million. Development of an adjunct processor began, to provide additional computing capacity for future post-baseline 5, Phase III Combat System upgrades, at a cost of US$6.687 million.

In FY94, the Navy resolved problems identified during the CSED Site system demo of Baseline 5 Phase I, spending US$400,000 on the effort. US$12.6 million was spent to complete Baseline 5 Phase II computer program coding along with debugging and testing, and performing the Systems Qualification Test (SQT) at the CSED Site. The Navy conducted the Baseline 5 Phase III CDR and commenced computer program coding, debugging and testing at the CSED Site to integrate Baseline 5 Phase III into the AEGIS Combat System, funding the effort at US$12.2 million. The Program Office spent US$24.116 million conducting the Baseline 6 Phase I System Design Review (SDR). This funding also covered the to re-engineering of the

OJ-663 Tactical Graphics Console display equipment and single cable Local Area Network (LAN) into ruggedized commercial components and standards (Display Simplification). Engineers also began developing the Baseline 6 Phase I design specifications.

Another part of the FY94 plan included US$6 million for the RDT&E share of operations and maintenance of the CSED Site, Program Generation Center, Computer Program Test Site, and Land Based Test Site. US$20.643 million was provided to permit Navy laboratories and field activities to perform the engineering and scientific services necessary to monitor and direct the baseline efforts.

FY95 accomplishments included spending US$19.519 million to complete computer program coding, debugging and testing of Baseline 5 Phase III. Engineers conducted multi-element integration of Baseline 5 Phase III at the CSED Site and conducted System Qualification Test (SQT). The Navy put US$19.50 million into continued development of the Baseline 6 Phase I design specifications, and a Preliminary Design Review (PDR) was conducted. Planners also initiated re-hosting of AEGIS Display System (ADS) and Command and Decision (C&D) display-related computer programs into a Commercial Off-the-Shelf (COTS)-based architecture.

Designers began system engineering and development of the BFTT Phase I/AEGIS Combat Training System (ACTS) re-host. The program offices stopped work on the OJ-663 console with display simplification due to an Assistant Secretary of Navy (Research, Development and Acquisition) decision.

US$2.10 million was used to start system engineering and design to integrate ESSM into Baseline 6 Phase II. US$2.60 million started integration of SPY-1D radar upgrade (SPY-1D(V), formerly known as EDM-4B) into the AEGIS Weapons System and US$1.684 million started Engineering Development Model-5 (EDM-5) for the Advanced Processing in Baseline 7 Phase I. US$1.30 million was budgeted to begin STANDARD Missile-2 (SM-2) Block IIIB and Block IV capability enhancement engineering, and begin technical assessment and feasibility studies for cueing sensor upgrades which will be integrated into Baseline 7 Phase II.

This program continued to provide funding (US$8.70 million) for the RDT&E share of operations and maintenance at the CSED Site, Program Generation Center, Computer Program Test Site, and Land Based Test Site. US$19.678 million was used to continue Navy participation in the engineering and scientific efforts necessary to monitor and direct the baseline efforts.

FY96 accomplishments included completing Baseline 5 Phase III (US$250,000). US$18.965 million to conduct Baseline 6 Phase I Critical Design Review (CDR-1) and CDR-2. Computer program coding, debugging and testing was initiated. A re-hosting of AEGIS Combat Training System (ACTS) computer programs was conducted for BFTT Phase I and development of BFTT/ACTS interface. Re-hosting of ADS, the C&D display, and ID- related computer programs into a COTS-based Advanced Display System architecture continued. Design of the ID upgrade Phase I for Baseline 6 Phase I continued; engineering continued for advanced processing architecture.

The program office budgeted US$14.950 million to conduct system definition and SDR for Baseline 6 Phase II, continued system engineering for ESSM integration efforts. It also spent US$4.9 million to conduct a re-host of the SPY-1D(V) radar upgrade and computer program control loop into COTS-based adjunct processors. The Navy used US$9.216 million to continue system engineering and development of an advanced processing EDM-5 to support implementation of an open system networked architecture in Baseline 7.

US$1.154 million went to continued SM-2 Block IIIB and Block IV capability enhancement engineering, and technical assessment and feasibility studies for cueing sensor upgrades. US$5.7 million was used to continue the RDT&E share of operations and maintenance of the CSED Site, Program Generation Center, Computer Program Test Site, and Land Based Test Site. US$18.047 million provided for the participation of Navy laboratories and field activities in the engineering and scientific efforts necessary to monitor and direct the baseline efforts.

The FY97 plan budgeted US$16.5 million to continue Baseline 6, Phase I computer program coding, debugging and testing. It also funded the continued re-hosting of ACTS computer programs for BFTT, and for C&D- and ID-related computer programs into COTS-based architecture. US$18.537 million was used for conducting a Preliminary Design Review for integration of Baseline 6 Phase II upgrades, including integrating ESSM into the AEGIS Combat System.

Designers used US$16.390 million to complete re-hosting of the SPY-1D(V) radar control loop code into adjunct processors, including interface simulation computer programs. They also began system definition for full integration of SPY-1D(V) into new construction AEGIS Combat System in Baseline 7 Phase I. US$11.290 million was used to conduct system definition and SDR to integrate Baseline 7 Phase I upgrades into the AEGIS Combat System and start system engineering, as well as to continue advance-processing EDM-5 development for open systems networked architecture in Baseline 7 Phase I ships.

It cost US$834,000 to complete engineering SM-2 Block IIIB and Block IV capability enhancements and continue technical assessment and feasibility studies for cueing sensor upgrades which will be integrated into Baseline 7. US$7.20 million was budgeted to continue to provide the RDT&E share of operations and maintenance of the CSED Site, Program Generation Center, Computer Program Test Site, and Land Based Test Site. An additional US$16.770 million was used to continue to provide for the participation of Navy laboratories and field activities in engineering and scientific efforts necessary to monitor and direct the baseline efforts.

FY98 accomplishments included spending US$13.61 million to conduct element test and evaluation (ET&E) and multi-element integration testing (MEIT) for Baseline 6 Phase I, focusing on achieving AWS stability in preparation for CEC OPEVAL and forward-fit baseline development. US$23.1 million was spent to conduct a Baseline 6 Phase III consolidated Preliminary Design Review (PDR)/Critical Design Review (CDR) in accordance with the Baseline Consolidation Plan. Engineers began computer program coding, debugging, and testing. They also completed RSCES EDM Development. US$15.41 million went to completing system definition/design for full integration of the SPY-1D into new construction AEGIS Combat System in Baseline 7 Phase I and starting system design. The Navy conducted a Baseline 7 Phase I System Design Review (SDR) for integration of upgrades into the AEGIS Combat System engineering.

US$6.1 million went to the RDT&E share of operations and maintenance of the CSED Site, Program Generation Center, Computer Program Test Site, and Land Based Test Site. US$14.75 million provided the funds for labs and field activities to support a forward fit baseline upgrade in order to conduct engineering and scientific studies and analysis to minimize the risk in the introduction of increased warfighting capability including TBMD, CEC, ESSM, and AIEWS into the AEGIS Combat System. Studies produced by the Applied Physics Lab and the Naval Surface Warfare Center, Dahlgren Division (NSWC, DD) ensure effective introduction of COTS Technology. NSWC, DD personnel also provided on site technical support at contractor facilities during development, testing, and evaluation of upgrades to the AEGIS Combat System.

The FY99 plan budgeted US$1 million to begin modifications to the AWS computer program to allow incorporation of AAW capability into the SM2 BLK IVA missile. US$42.2 million continued ET&E and MEIT for Baseline 6 Phase I. The program was delivered to the shipyard for first-level testing on new construction destroyers and continued with integration of CEC Baseline 2 functionality into this baseline. The project also provided support for CEC DT/OT and continued preparation for CEC OPEVAL.

US$29.7 million went to continue Baseline 6 Phase III computer program code, debugging, and testing, as well as conducting Critical Design Review (CDR) II. The Program team began extensive ET&E and MEIT at the Combat System Engineering Development Site (CSEDS). US$34.75 million was budgeted for system engineering for full integration of SPY-1D into new construction AEGIS Combat System in Baseline 7 Phase I and conducting Baseline 7 Phase I PDR for integration of upgrades into the AEGIS Combat System. US$17 million was used to start system definition and engineering for the AEGIS Cruiser Conversion Program to incorporate warfighting capabilities including TBMD, AADC, and land attack into Baseline 2, 3, and 4 Cruisers. This included computer program modifications.

US$8 million went to field an AADC User Operational Evaluation System, US$7.2 million to the RDT&E share of operations and maintenance of the CSED Site, Program Generation Center, Computer Program Test Site, and Land Based Test Site, and US$15.52 million for to support the forward fit baseline upgrade in order to conduct engineering and scientific studies and analysis to minimize the risk in the introduction of increased warfighting capability including TBMD, CEC, ESSM, and AIEWS into the AEGIS Combat System. Studies produced by the Applied Physics Lab and the Naval Surface Warfare Center, Dahlgren Division (NSWC, DD) ensured effective introduction of Commercial Off the Shelf Technology (COTS). NSWC, DD personnel also provided on-site technical support at contractor facilities during development, testing, and evaluation of upgrades to the AEGIS Combat System.

US$3.46 million of the extramural program was reserved for Small Business Innovation Research assessment in accordance with 15 USC 638.

In FY00, US$1.2 million was budgeted to continue modifications to the AWS computer program to allow incorporation of AAW capability into the SM2 BLK IVA missile. US$32.5 was set aside to complete ET&E and MEIT and demonstration of Baseline 6 Phase I. Engineers would also continue with system testing of program for certification for fleet-wide use for destroyers, supporting CEC OPEVAL on CGs 66 and 69. US$62.2 million was planed for the Baseline 6 Phase III ET&E and MEIT, with plans to deliver the program to shipyards for AWS testing in new construction ships.

US$43.35 million was budgeted to conduct Critical Design Review (CDR) and begin code, debug and test (CDT) for 7 Phase I computer program and develop a radar handbook and technical manuals associated with introduction of SPY-1D(V) radar. US$28.4 million would be used to begin System Design Review for the Cruiser Conversion Program; US$1 million to finish integrating modifications to the AADC User Operational Evaluation System (UOES); and US$8 million for the RDT&E share of CSED Site, and other support requirements. Program Generation Center, Computer Program Test Site, and Land Based Test Site. US$16.36 million would fund the labs and field activities.

Project K1776 Surface Combatant Weapons System Mods. This program provides for modifications to the AEGIS Weapons System MK-7 to counter the Naval Maritime Intelligence Center (NAVMIC) Threat Assessment #012-91 of September 1991 and Office of Naval Intelligence Threat Assessment ONI TA #046-93. The modifications will be backfitted into CG-47 class and DDG-51 class ships already in the Fleet.

Acquisition Strategy: Lockheed Martin is the sole producer of the AEGIS Weapon System (AWS) except for the SPY-1(V) Radar transmitter and the MK 99 CWI transmitter and illuminator which are produced by Raytheon. It is anticipated that all AWS modifications will be procured from the original equipment manufacturer.

FY92 accomplishments were to complete Phase I development of the Fire Control System (FCS) Stable Master Oscillator (STAMO). The Program Office conducted the STAMO Critical Design Review. It also conducted system design reviews for Operational Readiness Test System (ORTS) upgrade and completed the definition of the Man-Machine Interface (MMI) and prepared preliminary ORTS upgraded specifications.

Planners completed the ORTS Data Terminal Set requirements document, which specifies a full-color work station and its shipboard adaptation. System engineering studies were continued in order to define and develop Electronic (ECCM)/Deceptive Electronic Countermeasures (DECM) design changes relative to the eventual incorporation of these changes into the SPY-1B/B(V)/D radar systems.

Engineers defined the AEGIS Weapons System requirements to support the design effort, and continued to develop computer program algorithms to improve Anti-Air Warfare (AAW) system performance against various DECM threats.

FY93 accomplishments cost a total of US$6.896 million, and included coding, testing and debugging the computer program for ORTS MMI upgrade at US$3.6 million. The Navy continued to develop computer program algorithms to improve Anti-Air Warfare system performance against various DECM threats (US$3.296 million).

In FY94, US$2.15 million was spent to complete ORTS, MMI upgrade equipment fabrication and computer program coding, testing and debugging. US$503,000 was allocated to conducting system testing in preparation for demonstration of ORTS MMI upgrade at the CSED Site in FY95, and SPY-1 radar system analysis support for Cruiser and Destroyer baseline upgrades and the SPY-1B/D radar system upgrades.

In FY95, the Navy spent US$334,000 to conduct an ORTS MMI upgrade CSED Site demonstration. The spending plan included US$3.834 million to develop an ORTS MMI upgrade Ordnance Alteration proof-in kit for land-based integration and test. US$234,000 was used to complete development of computer program algorithms to improve Anti-Air Warfare system performance against various Deceptive Electronic Counter-Countermeasures (DECCM) threats and US$250,000 to continue SPY-1 radar system analysis support for Cruiser and Destroyer baseline upgrades and SPY-1B/D radar system upgrades.

FY96 accomplishments included implementation of the ORTS MMI upgrade, at a cost of US$1.50 million. US$300,000 went into continued SPY-1 radar system analysis support for Cruiser and Destroyer baseline upgrades and SPY-1B/D radar system upgrades. US$2.668 million was budgeted to begin the ORTS upgrade for Baselines 3, 4 and 5.

The FY97 plan budgeted US$300,000 for SPY-1B/D upgrade analysis support and US$1.265 million to continue ORTS upgrades for Baselines 3, 4 and 5 design, development and engineering. US$513,000 was to be used to begin SPY-1B/B(V)/D Moving Target Indicator analysis, design, development and engineering for radar enhancements.

In FY98, SPY-1B/D upgrade analysis support was to be continued, including signal processor overtemperature protection and Track Initiation Processor (TIP) design changes (US$600,000). US$1.239 million was budgeted to continue the Baselines 3, 4 and 5 ORTS upgrade.

The FY99 plan budgeted US$100,000 for SPY-1B/D upgrade analysis support and completing the TIP design changes. US$1.20 million will be used to continue the ORTS upgrades. US$1.10 million is planned for the

SPY-1B/B(V)/D Moving Target Indicator enhancement and US$1.80 million for the SPY-1B/D DECCM upgrades. US$3 million was budgeted to continue design and engineering for SPY-1D(V) RSCES.

Project K1937 Surface Combatant Weapons Development. This program is required to develop selected systems and subsystems for the Arleigh Burke (DDG-51)-class ships. This project funds development of equipment for the AEGIS Combat System, as opposed to the costs of integrating elements into the Combat System which is funded in Project K1447.

Funding provides for development of an upgrade to the current SPY-1D radar (EDM-4B) to enhance its capability against sea-skimming targets in increasingly more severe electronic countermeasures and in near-land clutter environments. The changes are in the transmitter, signal processor and radar control computer program.

This program provides for modifications to the AEGIS Weapon System MK-7 to counter the threat as articulated in ONI System Threat Assessment Report ONI TA #046- 93 dated May 1993, and subsequent updates. The modifications will be introduced into CG 47 Class and DDG 51 Class ships.

Acquisition Strategy. For SPQ-9B Integration, Lockheed Martin (LMCo) is the AEGIS Combat System Engineering Agent and is the sole producer of AEGIS Weapon System (AWS) modifications. It is anticipated that all modifications needed to fully integrate the SPQ-9B into the AWS will be procured from LMCo. As the sole producer of the SPY-1(V) Radar, LMCo is taking the lead in SPY-1(V) Common Signal Processor signal processor TBMD test bed efforts. It will be the prime for the development of the common signal processor with advanced AAW functionality, which will be built off of TBMD common signal processor efforts. Some of the portions of the development may be assigned to laboratories. Procurement of the common signal processor will be with LM.

In FY92, systems engineering was continued to validate performance requirements analyses and definition. Program personnel conducted a System Design Review and a Preliminary Design Review for radar upgrades and continued development of design specifications to determine equipment and firmware requirements. Engineers continued detailed radar frame, module, subassembly and cabinet design and development. The program office continued equipment procurement, and began Engineering Development Model (EDM) fabrication and assembly.

In FY93, US$27.394 million was spent to support the year's activities. A sum of US$3.1 million was spent completing design specifications and conducting a CDR. System engineering continued, and program code generation began. Computer program modifications were debugged and tested (US$5.8 million). US$11.9 million was spent to continue equipment procurement and EDM-4B fabrication and assembly.

In FY94, engineers completed computer program code generation along with debugging and testing, US$6.7 million. US$8.7 million went into completing EDM-4B fabrication and element integration and testing. Engineers installed and performed system level integration at the CSED Site, funded at US$8.585 million.

FY95 plans continued system integration, with US$1.316 million spent on that effort. US$2.524 million was used to conduct Electronic Countermeasures test validation at the CSED Site. US$5.890 million was budgeted to re-host the radar system computer program from two UYK-43 computers to one UYK-43 and one commercial adjunct processor, including testing of microprocessors against AEGIS benchmark requirements, testing commercial operating systems, and computer architecture development.

The FY96 plan budgeted US$5 million to conduct Developmental Test/Operational Test-1 (DT/OT-1) at the CSED Site. The program office set aside US$5.361 million to continue re-hosting the radar system computer program.

FY97 plans called for spending US$3.235 million to complete the radar system program re-hosting from two to one UYK-43 computers and one commercial adjunct processor, including testing microprocessors against AEGIS benchmark requirements, testing commercial operating systems, and computer program architecture development. US$1 million was budgeted to conduct DT/Operational Assessment (OA) of the adjunct processor performance at the CSED Site.

FY98 accomplishments were not applicable.

The FY99 plan budgeted US$2.94 million to initiate expanded common signal processor design for the SPY-1(V) Radar and include advanced AAW functionality and features. The expanded signal processor design would add AAW functionality to and leverage the common signal processor's TBMD functionality design currently being pursued via TBMD funding. The advanced AAW functionality will implement adaptive digital signal processing to improve low altitude clutter rejection performance and Electronic counter- countermeasures (ECCM) capabilities. US$3.76 was planned to initiate the design for the integration of the SPQ-9B Radar (or an advanced variant) into the AEGIS Weapon System. The design would include both AAW and Gun Weapons System (GWS) integration schemes and seek to free-up SPY-1(V) horizon search resources for above horizon search (i.e., TBMD). US$160,000 was reserved for SBIR.

The FY00 plan budgeted US$3.74 million to continue the design of the expanded common signal processor for the SPY-1(V) Radar to include advanced AAW functionality which will improve low altitude clutter rejection and ECCM performance. US$3.5 million was planned to complete the design for the integration of the SPQ-9B into the AEGIS Weapon System.

Project K2308 - Smart Ship Project. The Smart Ship Project (SSP) was initiated by a Chief of Naval Operations directive to examine a variety of means to reduce life-cycle cost of ships, concentrating on the fact that a major portion of ship's life-cycle cost is manpower. The project was chartered to devise and implement technology and policy changes which will reduce the workload for a ship's crew. Reduced workload may result in reduced manning and thereby reduce ship life-cycle costs.

The technology being considered replaces human functions rather than just improving efficiency, and its application requires funding. Policy changes are focused on reducing unnecessary or redundant requirements and do not require funding. Selected technology and policy changes will be tested in an in-service fleet ship, USS *Yorktown* (CG 48). Those changes which prove successful will be considered for implementation in both current in-service ships and future ships to maximize life-cycle cost savings across all Navy ship classes.

The Project will develop, procure, install, train and support test projects for demonstration in the two test ships. Successful projects will be analyzed and packaged for wider application in the Fleet. The effort has special interest to AEGIS designers because of the possibility of expanding the computer processing capabilities to a massively parallel approach or establishing new failure modes which could take advantage of other computers aboard to support radar operations. Although the idea is not likely until the out-years, establishing a better overall computer capability could enable these advances in the future.

This effort was a new start for FY98. The FY98 plan budgeted US$461,000 to assess current technology and equipment available through Department of Defense and industry sources which could be candidates for reducing shipboard manning requirements and individual crew member workloads. Any manning and workload reductions identified will not affect ship and system readiness and performance, crew safety or habitability. US$231,000 was budgeted to conduct ship and system design and engineering studies of what would be necessary to adapt candidate technology and equipment to the shipboard environment and to integrate the equipment into existing ship systems. US$244,000 was budgeted to complete installation and check out of candidate technology and associated equipment on board designated ships and conduct at-sea testing.

FY99 plans set aside US$560,000 to complete installation and checkout of candidate technology and associated equipment aboard designated ships and conduct at-sea testing.

CEC Integration on DDG 51 Ships (K2636) and AEGIS Baseline software development (K2637). Two new efforts started in FY99. One was the development of the AAW requirements and design for a common signal processor (CSP) which builds upon the risk reduction test beds being developed for Navy Theater Wide (NTW) defense under BMDO funding. This NTW CSP is required to provide exo-atmospheric discrimination capability. The common signal processor effort would incorporate AAW functions into the signal processor functions being developed for NTW. The other new effort was integration of the SPQ-9B radar into the AEGIS Weapon System to improve capability against the advanced low-altitude threat.

K2636 was budgeted at US$9.48 million; K2637 at US$19.95 million.

DDG 51 Composite Director Room (K2638). This one-time, FY99 effort was budgeted at US$4.99 million.

Japan. In 1983, the Japanese government announced that it planned to build a class of destroyers equipped with AEGIS. From 1983 through 1987, Japan held discussions with then-contractor RCA to acquire the necessary rights and technology. Design studies of the new class began in 1985, with most of the work being completed by late 1986. An AEGIS technology-transfer request was made in mid-1987 and immediately aroused strenuous objections in Congress.

After a long and protracted struggle, Congress approved the Japanese purchase of AEGIS, to be mounted in what was to be a new class of 6,500-ton destroyers. Even though the DoD approved the purchase in 1986, approval by Congress did not come until mid-1988 for a number of reasons. Probably first and foremost was the fear that the Japanese would "steal" the technology to build their comparable systems.

This question was addressed by ensuring that the AEGIS system would be produced in the US, with no coproduction or licensed manufacture. Some in Congress even wanted the platforms built in the US, but the Japanese balked at this, although they did have to increase the size of the ships since the US Navy felt that the original design was too small (at 5,200 tons) to support AEGIS. As it is, the new destroyers, at 7,250 tons (standard), are larger than the Flight I and II DDG-51, although the new US Flight IIA ships will be heavier than the Japanese counterparts.

The first ship, the *Kongo*, was commissioned in 1993. *Myoko*, Japan's third completed combat system ship, began qualification trials in late 1997. This included 10 successful missile firings against difficult scenarios. The results of the tests were considered to have validated the confidence Japan had in the AEGIS design and proved that the Japanese Self Defense Force could successfully operate its new ships as an effective part of the Fleet.

In early 1999, Japan announced plans to purchase a fifth AEGIS destroyer in the Defense Agency's new program being drawn up for fiscal 2001 to 2005. The destroyer was slated to be deployed after fiscal 2006. The added ship was planned to improve Japan's ability to cooperate with the US Navy and for a role in the theater missile defense (TMD) systems under development. An AEGIS warship deployed by the Maritime Self-Defense Force was responsible for collecting large amounts of data on North Korea's launch of a rocket in August 1998, with the information forming the foundation of a US analysis of the incident. The ship is expected to cost ¥120 billion.

Spain. The Spanish Navy decided to procure a version of the AEGIS SPY-1D for the four MEKO F-200 frigates it planned to build. Spain had been expected to join the Dutch and Germans and develop an active phased array radar that would be used on the Tri-lateral Common Frigate (TCF). In 1995, Spain elected to withdraw from the program to develop the Signaal APAR radar and seek alternative solutions for the air warfare system on its new ships. US officials approached the Spanish in 1994.

The Spanish Navy investigated a downsized version of AEGIS, using the SPY-1F radar and the DANCS combat direction system. In February 1996, this was rejected in favor of a full-size AEGIS system and SPY-1F radar combined with the Mk 41 Vertical launch System. The frigate program was then recast around a modular warship roughly the same size and configuration as the DDG-51. Although the radar featured a smaller, lighter array, it would have the same functionality as the SPY-1D.

The frigate would be made taller to accommodate the arrays, and the Combat Information Center would be enlarged for the Baseline 5 Phase III processors and displays. Germany has expressed some interest in AEGIS as a sensor solution for its planned Type 124 frigate. It is the first time AEGIS has been integrated with an indigenous combat system. These installations were generating other European interest because AEGIS is a proven system. Spain made its decision because of the technological risk in developing its own phased array radar (in partnership with Canada). The system will use SM-2 Block IVA missile and software that will make it TBM-capable. The system performance will be equivalent to the US DDG-51 Flight IIA ships. The reduced-radar cross section MEKO ship (equivalent to that of a Fast Attack Craft) would feature a 75 percent reduction in IR signature, 25 percent displacement reduction, and 20 percent life cycle cost cut.

The effort was budgeted at roughly US$100 million over five years. This was the first European procurement of AEGIS. Planners like the idea that system upgrades will track with ongoing US Navy programs, which are constantly enhancing system performance.

The first AEGIS antenna system was completed in late 1999.

Taiwan decides to seek AEGIS warships. Because it was unable to acquire modern submarines, the Taiwanese navy reportedly decided to purchase four AEGIS warships as a way of improving defenses against mainland China. Taiwan would ask to purchase an unspecified number of the ships. The United States did not say whether it would sell the ships to Taiwan; but the Taiwanese Defense Minister was quoted in the *China Times* as saying he was "very confident" that the sale would go through.

It was noted that two AEGIS warships positioned in the strait at either end of Taiwan could substantially boost the island's ability to detect and shoot down Chinese missiles. According to some reports, China has an estimated 200 ballistic missiles targeted at Taiwan, and is reportedly purchasing Russian Sovremenny-class destroyers carrying SS-22 "Sunburn" cruise missiles that naval experts say pose an even greater threat to Taiwan. If the United States agrees to the sale, the ships would cost about US$800 million each and be delivered between 2006 and 2008.

Taiwan has long sought to bolster its fleet of just two modern submarines with new vessels from abroad, but has not found a seller willing to face China's very strong objections. China retaliated against Holland by downgrading diplomatic relations for three years after it sold the island a pair of conventionally powered Zwaardis-class boats in 1981. Chinese officials have registered very strong objections to any such sale, just as they oppose most arms sales to what they consider a breakaway province of China.

DOT&E Report FY99. The DDG 51 program has been undergoing OT&E since inception. Rigorous at-sea testing of the Flight I ship was conducted during FOT&E from 1992-1996, to verify the correction of previous deficiencies. The ship was found to be generally effective and suitable. A comprehensive Live Fire Testing Program for the Flight I ship, including the a Shock Trial in 1994 and a Total Ship Survivability Trial in 1995, has also been conducted.

FOT&E of a Flight II ship, which was originally scheduled for FY97, slipped to early FY00 because of ship schedules and concerns about the maturity of the AEGIS Baseline 5, Phase 3 computer program. Developmental testing ashore and reports from fleet ships identified performance deficiencies that resulted in an unacceptably high number of Priority 1 and 2 Computer Program Change Requests. Subsequent activity has focused on refinement and additional developmental testing of the computer program in preparation for OT.

The SPY-1D(V) underwent its first phase of OT in FY96. The test, designated OT-IIF1, was conducted at the Aegis land-based test site at Moorestown, NJ. It examined performance of the radar engineering development model against simulated and actual targets in both clear and electronic attack conditions. SPY-1D(V) demonstrated better low altitude detection and performance in clutter than the operational SPY-1D radar. Based on these results, OPTEVFOR found the improved radar potentially operationally effective and suitable and recommended continued development. The Navy authorized LRIP in January 1997, and plans to install SPY-1D(V) in DDG 91 and later ships.

TEST & EVALUATION ACTIVITY

In keeping with the test concept for OT-IIID, OPTEVFOR and DOT&E continued to observe selected Combat System Ship Qualification Trial (CSSQT) and DT events in Flight II ships throughout FY99. These included air defense exercises and SM-2 missile firings conducted in DDG 73 and DDG 76, and electronic warfare testing conducted in DDG 72. Data from the CSSQT and DT events will be considered, along with data collected during DT and OT events scheduled in early FY00, to evaluate the effectiveness and suitability of the Flight II ship and its AEGIS computer program, and verify the correction of deficiencies identified in earlier OT.

The Navy Center for Tactical Systems Interoperability (NCTSI) performed link certification testing of AEGIS Baseline 5.3.7 and Command and Control Processor (C2P) M5R403 computer programs during April and May. Although this testing identified some problem areas, NCTSI certified the computer programs to be interoperable for use in Navy Link 16 and Link 11 operations. No certification was granted for Link 4A operations.

OPTEVFOR and DOT&E observed Distributed Engineering Plant (DEP) testing of AEGIS Baseline 5.3.7 in June. Subsequent DEP testing of the Dwight D. Eisenhower (CVN 69) battle group interoperability performance identified interoperability problems between AEGIS Baseline 5.3.7 and the C2P M5R403 computer program; these affected Link 4A operations and some aspects of Link-16 operations. Special DT events designed to evaluate the interoperability performance of revised versions of the AEGIS and C2P computer programs (Baseline 5.3.7.1 and M5R404) were conducted late in the fiscal year in preparation for OT-IIID. These events linked DDG 75, AEGIS engineering facilities at Wallops Island, VA, the Advanced Combat Direction System engineering facility at Dam Neck, VA, and other units.

DOT&E approved a revision to the TEMP in October 1999 to support OT-IIID, with a requirement for a subsequent update to support OT-IIIE scheduled to occur in FY01. The Test & Evaluation master Plan (TEMP) for SPY-1D requires revision to account for changes in the DDG-51 procurement schedule, and to add a phase of land-based operational testing of SPY-1D(V) as soon as a test article (including Baseline 7 computer programs) is available.

Although Live Fire Test & Evaluation (LFT&E) testing of the for DDG 51 Flight I is complete, the Navy continued its assessment efforts in FY99 by extrapolating DDG 53 Shock Trial results to full design conditions. This work was concluded in October 1999, with the completion and submission to DOT&E of the DDG 51 Flight I Mission Keeping Design Level Assessment. DOT&E will be submitting its independent LFT&E assessment of the DDG 51 Flight I ship in FY 00. As part of the LFT&E survivability assessment for the Flight II and IIA ships, the Navy has completed a susceptibility analysis, an effort that generated thousands of potential hit points from different models and simulations. The Naval Surface Warfare Center, Carderock Division, using the Ship Vulnerability Model (SVM), completed primary damage analysis, the first component of the vulnerability assessment. DOT&E and the Navy worked together to review the primary damage analysis results and select 15 hits for secondary damage (e.g., fire, smoke, flooding) analysis. This vulnerability assessment is expected to continue into FY00.

At the request of the Navy, and endorsed by DOT&E, Congress authorized reprogramming of funds for a Flight IIA Shock Trial. In January 1999, DOT&E approved a Navy request to conduct the shock trial on DDG 81 instead of on DDG 79, the first of the Flight IIA ships. DOT&E concurred that DDG 81 was the better choice since environmental protection prerequisites would not be met until spring 2001, a year after the delivery of DDG 79. DDG 81 is also more representative of the Flight IIA class design and outfitting.

TEST & EVALUATION ASSESSMENT

In 1992, DOT&E assessed the Flight I DDG 51 as operationally effective and suitable but expressed reservations about the ship's ASW effectiveness. The ship's ability to defeat some of the most stressing anti-ship missile (ASM) threats was not tested because the versions of Standard Missile designed to defeat those threats were not yet available. Battle group interoperability testing was not completed and was deferred to OT-IIID. This interoperability testing will be conducted during a Battle Group exercise in 2QFY00. Evaluation of gunnery effectiveness was incomplete because the test ship's Gun Weapon System did not include the Mk 46 Optical Sight and the AN/SPS-67V(3) Automatic Detector Tracker planned for the full installation.

Extensive testing of DDG 51 ASW capabilities during OT-IIIB and gunnery performance during OT-IIIC resolved many of the reservations stemming from the FY92 test. SM-2 Block IIIB testing conducted in FY99 in DDG 73 and DDG 76 demonstrated the ship's capability to defeat additional ASM threats. Unresolved Flight I effectiveness and suitability issues are discussed in the classified version of this report.

These outstanding Flight I issues are also applicable to Flight II ships. Some are being addressed during Flight II testing (OT-IIID), while others will not be examined until Flight IIA testing (OT-IIIE) in FY01. Preliminary results from the developmental testing conducted in FY99 indicate that AEGIS Baseline 5.3.7.1 should prove to be more interoperable and have significantly fewer high severity performance deficiencies than earlier versions of the Baseline 5, Phase 3 computer program.

The Flight I Shock Design Level Mission Keeping Capability Assessment, which extrapolates DDG 53 Shock Trial results to design level shock conditions, was presented to DOT&E in preliminary form in March 1999. This report represents an important milestone in ship LFT&E. This is the first time the Navy has attempted, from a ship-wide perspective, to extrapolate the results of a shock trial to full design level shock conditions; to compare the results of such extrapolations to component shock qualification levels; and assess the results in terms of primary mission readiness. There are areas of weakness in the Navy's assessment related to a lack of shock qualification data for certain vital components and the use of straight-line extrapolation from measured data rather than a more realistic finite element model calibrated to shock trial results.

From an LFT&E perspective, DDG 51 and other ship LFT&E programs are not using the shock trial results to maximum advantage. A method should be developed to use full-ship finite element modeling, calibrated to shock trial results, to assess the damage expected and the resultant impact on primary mission readiness at realistic threat encounter conditions. Realistic threat encounter conditions for conventional underwater proximity weapons typically result in local shock factors in excess of design level plus hull whipping effects. Due to crew safety considerations and the need to limit the potential damage to hull structure and non-shock qualified, non-vital equipment, surface ship shock trials are limited to two-thirds design level shock without hull whipping.

DOT&E considers the shock trial to be the most important ship Live Fire Test the Navy conducts, since it is the only test of the actual ship involving actual threat weapons effects. For Flight IIA, the Navy is conducting a physics-based Shock Trial Simulation Project consisting of finite element modeling of the full ship. This project will help make pre-shock trial predictions to support instrumentation placement for the trial. Other potential applications include post-trial analyses; assessing future Flight IIA design changes; and analyzing Flight IIA ship responses at non-contact, realistic threat encounter levels for selected charge weights and standoff attacks not to exceed design level.

The Flight IIA Shock Trial Simulation Project is making slow but steady progress. Due to modeling and simulation limitations, as well as funding constraints, the Navy has concluded that the Shock Trial Simulation Project will not conduct assessments above the shock design level. The Navy is conducting assessments beyond design level shock using the Ship Vulnerability Model shock algorithm, which is based to a limited extent on empirical data.

Since the shock trial is conducted at less than design level, the Flight IIA (DDG 81) Shock Trial should not be relied upon as the sole basis for shock qualification of major equipment and systems. To address this concern, major equipment and systems should be shock tested separately to full design level. There is no planned or funded component shock qualification program for the new 5 inch, 62-caliber naval gun system being installed in the Flight IIA ships beginning with DDG 81. In January 1999, DOT&E asked the Assistant Secretary of the Navy, Research, Development and Acquisition, to address this concern.

The DDG 51 LFT&E program has incorporated some unique efforts among the existing ship LFT&E programs. From the outset, the DDG 51 Program wanted to include, as a part of LFT&E, an assessment of susceptibility (both hard kill and soft kill) as well as vulnerability. DDG 51 susceptibility analyses have yielded valuable information pinpointing areas of the ship requiring additional radar cross reduction treatments and in helping improve tactics for avoiding active radar-seeking anti-ship missiles and mines. These same studies have developed credible, threat-specific hit distributions for anti-ship missiles, mines, and torpedoes, for use in vulnerability assessments.

Despite an extended holdup resulting from environmental litigation, the Navy conducted the 1994 USS JOHN PAUL JONES (DDG 53) Shock Trial successfully and in an environmentally sound manner. The resultant delay, however, significantly increased DDG 53 Shock Trial costs. The DDG 53 Shock Trial revealed vulnerabilities in some key combat system equipment, the specifics of which are classified. The 1995 Flight I Total Ship Survivability Trial (TSST) of USS LABOON (DDG 58) confirmed significant vulnerabilities in the chilled water system and its documentation (affecting combat system operation), and uncovered vulnerability-related weaknesses in various other systems and their related operating procedures. Ship checks of DDG 53 associated with the TSST revealed significant configuration differences between the ship configuration detailed in the Ship Vulnerability Model, which is used to predict TSST damage, and the as-built ship. The Navy has made significant progress in the vulnerability assessment for the Flight IIA ships. Flight IIA SVM was developed from shipbuilder supplied CAD data and is a significant improvement in fidelity over the Flight I model.

CONCLUSIONS, RECOMMENDATIONS, LESSONS LEARNED

The revelation of serious interoperability problems in the Navy's front-line combatants has sparked several important new initiatives designed to root out, understand, and correct problems in existing systems and those under development. Technical experts associated with AEGIS, CEC, and ACDS programs have labored over the past year to define new measures of interoperability performance, more comprehensive data collection plans, and new analysis tools. These new methods are being used in DEP testing and the DDG 51 DT/OT-IIID interoperability events. Heightened awareness of the need for early, comprehensive interoperability testing of our increasingly complex and interdependent combat systems is also breaking down barriers that have led to "stovepiped" testing in the past. DOT&E fully supports these efforts and has recently issued a new policy statement on interoperability testing.

The long and continuing Operational Test program associated with DDG 51 has been very effective. The AEGIS program office conducts an aggressive program of ship system testing to explore the boundaries of DDG 51 performance, identify deficiencies and develop enhancements to hardware and computer programs. This program office was an early proponent of combined DT/OT and fully supports efforts to achieve efficiencies through combined testing wherever possible.

<u>DD21 Land-Attack Destroyer</u>. The Multi-Function Radar (MFR) will become the advanced solid-state radar suite for the next generation of aircraft carriers and destroyers, CVN-77 and DD-21, as well as other 21st century ship classes, including the next-generation cruiser, the CG-21. A Critical Design review is planned and the first Engineering Development Model (EDM) test unit is to be delivered by FY03 for the start of DT/OT land-based and at-sea testing in FY03 and 04. LRIP is currently planned for mid- to late-FY04. Production estimates are for up to 45 of the new X-band radars.

Navy plans are for the radar to be based on solid state, active array technology, and be able to search, detect, track, and provide weapon control functions with reduced manning and lower life-cycle costs, as compared to maintaining different systems to perform these functions separately.

Plans to incorporate electric drive technology could delay the development by at least a year. Raytheon Systems Co has been selected to develop the Multi-Function-Radar (MFR) to provide search, detection, tracking, and weapons control for these ships. A Volume Search Radar (VSR) will handle medium-range search and cueing. There is no interest in using a variant of AEGIS for these ships.

Funding

US FUNDING

	FY99		FY00		FY01(Req)		FY02(Req)	
	QTY	AMT	QTY	AMT	QTY	AMT	QTY	AMT
RDT&E (USN)								
PE#0604307N								
AEGIS Combat System Engineering								
K1447 Improvements	-	129.4	-	193.0	-	187.0	-	174.4
K1776 Weapon Mods	-	7.2	-	4.2	-	4.3	-	4.3
K1937 DDG Development	-	6.7	-	7.2	-	1.0	-	[a]
K2632 CEC Integration	-	9.5	-	0.0	-	0.0	-	0.0
K2637 Baseline Software	-	19.9	-	0.0	-	0.0	-	0.0
K2638 Composite Director	-	5.0	-	0.0	-	0.0	-	0.0
K2308 Smart Ship	-	1.0	-	0.6	-	[a]	-	[a]
RDT&E Total (PE)	-	178.4	-	204.5	-	192.3	-	178.7

[a]less than US$50,000

Procurement (USN)	FY99		FY00		FY01(Req)		FY02(Req)	
	QTY	AMT	QTY	AMT	QTY	AMT	QTY	AMT
DDG-51	3	-	3	-	3	-	2	-

	FY03(Req)		FY04(Req)		FY05(Req)		FY06(Req)	
	QTY	AMT	QTY	AMT	QTY	AMT	QTY	AMT
K1447	-	138.4	-	109.9	-	91.2	-	TBD
K1776	-	4.4	-	4.5	-	4.6	-	TBD
RDT&E Total (PE)	-	142.8	-	114.5	-	95.3	-	TBD

All US$ are in millions.

Recent Contracts

(Contracts over US$5 million)

Contractor	Award ($ millions)	Date/Description
Condor Systems	6.6	Jan 1998 – Contract for Shipboard Advance Radar target Recognition System for AEGIS. (N00019-98-C-0059)
Lockheed Martin	78.9	Feb 1998 – Modification to a previously awarded contract to exercise an option to provide engineering services in support of DDG-51 class AEGIS Combat System Installation, Integration and Test (DDG 80 through 82). Complete Dec 2001. (N00024-97-C-5173)
Vitro Corp	8.2	Feb 1998 – Modification to a previously awarded contract to exercise an option for engineering and technical services in support of the AEGIS Shipbuilding Program. Completed Feb 1999. (N00024-94-C-6430)
General Dynamics Defense Systems	9.5	Mar 1998 – Exercise an option to a firm fixed price for the procurement of Guided Missile Director Mark 82 Mod 0 with Director Control Mark 200, Mod 0, Maintenance Assist Modules, and Production Test Center Site Support. The Guided Missile Director Mark 82 Mod 0 with Director Control Mark 200, Mod 0 is a vital part of the AEGIS Weapon System and is to be installed in DDG-89, DDG-90, DDG-91, and DDG-92. Complete Jun 2000. (N00024-97-C-5189)

Contractor	Award ($ millions)	Date/Description
Bath Iron Works	2,176.9	Mar 1998 – FPI FY98-FY01 multi-year contract for construction of six AEGIS Destroyers. The ships are distributed as follows: FY98 two, FY99 one, FY00 one, FY01 two. Complete Aug 2006. (N00024-98-C-2306)
Ingalls Shipbuilding	2,523.6	Mar 1998 – FPI FY98-FY01 multi-year contract for construction of six DDG 51 AEGIS Destroyers, with an option for one DDG 51 in FY01. The ships are distributed as follows: FT98 one, FY99 two, FY00 two, FY01 one. Complete Aug 2006. (N00024-98-C-2307)
General Dynamics	9.5	Mar 1998 – FFP option exercise for the procurement of Guided Missile Director Mk 82 Mod 0 with Director Control Mk 200 Mod 0, Maintenance Assist Modules, and Production Test Center Site support. The Mk 82 and Mk 200 are vital parts of the AEGIS Weapon System and will be installed on DD 89 – DD 92. Complete Jun 2000. (N00024-97-C-5189)
Raytheon	113.0	Apr 1998 – Not-to-exceed FFP letter contract for FY98 requirements of four shipsets of AEGIS Weapon System OT-146/SPY-1D, OT-188/SPY-1D(V) transmitter groups, fire control system MK 99 MOD 3 ancillary equipment, site support, data spares, provisioning item order, provisioning technical demonstration, and technical manuals for the US Navy. Complete Jul 2001. (N00024-98-C-5199)
Lockheed Martin	256.1	May 1998 – FPI multi-year contract for production of four AEGIS systems and related production and support services. Contract contains an option for an additional AEGIS Weapon System, which if exercised would bring total cumulative value to US$869.9 million. Complete Oct 2005. (N00024-97-C-5178)
Litton Integrated System	138.6	May 1998 – FFP for design and manufacture of Engineering Control System Equipment and Integrated Bridge Systems (IBSs) for backfit on the CG-47 AEGIS cruisers. Includes a firm requirement for four systems and options for 22 additional systems with pricing agreements for the DDG 51-class of destroyers. Complete Dec 2003. (N00024-98-C-4013)
Lockheed Martin	7.2	Jul 1998 – Mod to previously awarded contract to provide technical and engineering services for FMS to Japan for combat system engineering computer program maintenance, installation and test, and annual inspection planning support of DDG 2316. Complete Dec 1999. (N00024-94-C-5144)
Lockheed Martin	20.0	Nov 1998 – Modification to previously awarded contract to provide for production of UYQ-70(V) advanced display systems equipment to support AEGIS, advanced combat direction, and other associated support services for PMS400. Complete Aug 1999. (N00024-98-D-5202)
General Dynamics	7.3	Dec 1998 – Exercise an option under a previously awarded contract for Guided Missile Directors Mk 82 Mod 0 with Director Control Mk 200 Mod 0, maintenance assist modules, and production test center site support. Part of the AEGIS Weapon System to be installed on DDG 93, 94, and 95. Complete Apr 2001. (N00024-97-C-5189)

Contractor	Award ($ millions)	Date/Description
Raytheon	9.5	Dec 1998 – Modification to previously awarded contract for production special tooling and test equipment to support production of AEGIS Weapon System OT-188/SPY-1D(V) Transmitter Groups and Fire Control System Mk 99 Mod 3 ancillary equipment. Complete Feb 2001. (N00024-98-C-5199)
Lockheed Martin	5.2	Feb 1999 – Mod to previously awarded contact to exercise options for planning and management support of Japanese DDG 173 programs under FMS. Complete Oct 2001. (N00024-97-C-5177)
Lockheed Martin	16.9	Mar 1999 – Mod to previously awarded contract to exercise option for FY99-05 AEGIS combat system baseline upgrades and critical experiments. Covers development and integration of AEGIS combat system baseline computer program hardware and software upgrades for DDG 91 and following ships. Complete Sep 2007. (N00024-98-C-5197)
Raytheon	7.8	May 1999 – CPFF level-of-effort option for 88,018 man-hours of technical production support engineering services for SPY-1D and Mk 99 transmitters. Complete Jun 2000. (N00024-98-C-5103)
Lockheed Martin	34.2	Jun 1999 – CPAF level-of-effort contract for 4,139,530 man-hours of engineering services for AEGIS combat system installation, integration, and testing on DDG 83 and 84. Options could bring cumulative value to US$343,678,065. Complete May 2002. (N00024-99-C-5102)
Lockheed Martin	125.0	Jun 1999 – Cost-sharing agreement for the development, manufacture, and test of a High Power Discrimination (HPD) radar prototype. Complete Dec 2004. (N00024-99-9-5386)
Lockheed Martin	19.2	Jun 1999 – CPAF level-of-effort option exercise for 210,042 man-hours for AEGIS combat system baseline computer program ship integration and validation. Complete May 2001. (N00024-97-C-5197)
Logicon Systems	37.6	Sep 1999 – Mod to previously-awarded contract to exercise option for continuing test and evaluation of the AEGIS combat system and AEGIS weapon system software. This option brings cumulative value of the contract to US$101,952,539. Involves services FMS for Japan and Spain. Complete Sep 2000. (N00178-97-C-2002)
Computer Sciences Corp	22.5	Sep 1999 – Mod to previous contract to exercise an option for continuing performance engineering and technical support for software development. This option brings cumulative value of the contract to US$26,351,511. Involved services FMS to Japan and Spain. Complete Jul 2004. (N00178-99-C-2005)
Lockheed Martin	14.7	Sep 1999 – Mod to exercise an option for continuing AEGIS lifetime support engineering services while modifications are implemented on CG 47 and DDG 51 ships. This option brings cumulative value of the contract to US$51,038,141. Complete Sep 2000. (N00178-98-C-2004)
Planning Consultants	10.8	Sep 1999 – Mod to previous contract for continuing technical and engineering support for AEGIS combat system and future combat systems. Involved FMS to Japan and Spain. This option brings cumulative value of the contract to US$19,861,804. Complete Sep 2000. (N00178-98-C-2006)

Contractor	Award ($ millions)	Date/Description
Marconi Systems	12.9	Nov 1999 – CPAF level-of-effort option for 321,984 man-hours to perform program management support services for AEGIS upgrades in the development phase and for production engineering services directly related to the production, installation, and testing of AEGIS. This option brings cumulative value of the contract to US$61,266,144. Complete Nov 2000. (N00024-97-C-5108)
Lockheed Martin	5.2	Nov 1999 – Mod op previously-awarded contract to exercise an option for 166,330 man-hours to perform combat system activation, operation, maintenance, and engineering services in support of the AEGIS Combat System Center, Wallops Island, Virginia. Provides integration of the new AEGIS combat system baseline with those already installed. Complete Sep 2000. (N00024-94-C-5140)
Ingalls Shipbuilding	660.0	Dec 1999 – Mod to FY98-FY01 DDG 51 multi-year contract for FY00 multi-year ships DDG 97 and DDG 98. This includes approved changes to the FY00 baseline. Complete Oct 2005. (N00024-98-C-2307)
Bath Iron Works	324.1	Dec 1999 – Mod to FY98-FY01 DDG 51 Multi-year contract for FY00 multi-year ship DDG 96. This includes approved changes to the FY00 baseline. Complete Apr 2005. (N00024-98-C-2306)
Raytheon	79.1	Dec 1999 – FFP contract for FY00 requirements of three shipsets of AEGIS OT-188/SPY-1D(V) transmitter groups, Mk 99 MOD 3 ancillary equipment, data, spares, provisioned item order, technical documentation and manuals. For DDG 96, 97, and 98. Complete Feb 2003. (N00024-00-C-5137)
Lockheed Martin	34.2	Jan 2000 – CPAF level-of-effort option for 374,075 man-hours to perform computer program ship integration and validation for AEGIS Combat System Baseline programs. Complete Sep 2000. (N00024-98-C-5197)
Bath Iron Works	74.1	Jan 2000 – CPAF option for lead yard services for DDG 51. Complete Jan 2001. (N00024-96-C-2800)

Timetable

Month	Year	Major Development
	1969	Contract for prototype AEGIS to RCA
	1972	SPY-1 testing begins
	1973	Installation of prototype AEGIS system aboard USS *Norton Sound*
	1974	AEGIS sea trials begin
May	1981	Operational Test IIID of AEGIS
Jan	1983	First AEGIS ship, the USS *Yorktown*, commissioned
	1984	The Japanese Maritime Self-Defense Forces announce that they are seeking to procure the SPY-1D for their new class of destroyers
	FY85	Conducted SPY-1B/D radar development and operational tests at the Combat System Engineering Development Site. Continued development of ORDALTS in the SPY-1A radar system
	1985	Navy announces that it would second-source most elements of the AEGIS system
	FY86	Continue development of SPY-1A ORDALTS and begin production of sub-elements. Initiate system studies to determine the added value to area defense of lower-frequency cueing radars to advanced versions of the SPY-1. Begin efforts to identify critical technologies for radar operation against the threat environment expected in the year 2000.

Month	Year	Major Development
		Begin efforts to develop and demonstrate the following: 1) partial configurations of new technologies required, 2) system integration, 3) track sharing, and 4) achievable capailities of such a system. SPY-1D becomes operational. Installs SPY-1A radar trainer
Oct	1986	Delegation of top US Navy officials calls on NATO countries to persuade them to agree to a major two-year joint effort to design a weapons system using AEGIS technology for fielding of the NATO NFR-90 frigate program
Nov	1986	US approves Japanese purchase of SPY-1D to equip new class of four 6,500-ton destroyers
	FY87	Begin SPY-1 ORDALT designs for the SPY transmitter and signal processor. Conduct SPY-1B/D qualification tests
Apr	1987	SPY-1B/D Qualification Test
	FY88	Continue SPY-1 ORDALT designs for the transmitter and signal processor improvements Conduct SPY-1D DT/OT-IID-2. Complete SPY-1D system engineering
Apr	1988	Unisys and its partner Westinghouse selected as second source for SPY-1D
Jul	1988	Complete and install Radar Supervisor Controller Stress Trainer
	FY89	Complete proof-kit development and fabrication of SPY-1A ORDALTS and test at ACSC. Integrate and test Upgraded AEGIS Display System Doctrine and advanced graphics. Commenced checkout of SPY-1 transmitter and signal processor improvements
Jan	1989	First SPY-1D accepted by Navy
	FY90	Complete testing of SPY-1A signal processor ORDALTS. Continue development of SPY-1D ECCM ORDALTS. Began detailed design of AEGIS Display System force capability and OTH-T upgrades
Apr	1990	Unisys/Westinghouse removed as second sources
Feb	1991	First AEGIS DDG-51 destroyer delivered
	FY91	Began development/design of radar upgrade (EDM-4B) planned for introduction in an FY94 *Arleigh Burke* destroyer. Build and test SPY-1B/D signal processor changes for ECCM. Integrate and test AEGIS Display System force capability and OTH-T upgrades
Dec	1992	Last AEGIS Guided Missile Cruiser (CG-73) *Port Royal* christened
	1992	First AEGIS system for Japan delivered
Mar	1993	First AEGIS-equipped Japanese destroyer *Kongo* commissioned
Feb	1996	Selected by Spain for MEKO-class frigate
	1996	Began fielding of Cooperative Engagement Capability
Mar	1998	Last Japanese AEGIS destroyer commissioned
Nov	1999	DDG-82 USS *Lassen* and USS *Howard* christened, 32nd and 33rd of 51 authorized ships
	2003	SPY-1D(V) Littoral upgrade radar to become operational on DDG-91, new fielding date for Navy Area theater missile defense system
	2005	Possible fielding of Navy Theater-Wide ballistic missile interceptor

Worldwide Distribution

Japan. The Japanese Navy uses the SPY-1D on its AEGIS class destroyer. A total of four are being built and one more is planned for construction.

Spain. Four SPY-1F radar systems and four AEGIS combat direction systems are to be ordered for the A-200 frigates. An additional system may be ordered as a shore training site.

Taiwan. Has expressed interest in four AEGIS ships for missile defense.

The **US** Navy uses the SPY-1A/B on its CG-47 class Guided Missile Cruiser and the SPY-1D on its DDG-51 Guided Missile Destroyer. Twenty-seven cruisers have been built and 34 destroyers approved.

Forecast Rationale

The AEGIS system is the US Navy's wide-area fleet air defense system. It is often the only solution in cases where air cover is not available. Alternatives such as electro-optics are limited by line-of-sight. AEGIS is the key sea-based sensor for the Navy's Cooperative Engagement Capability (CEC) and will work with the E-2C to create "The Big Picture" for the Fleet. CEC testing has proven that the data fusion system works.

The Pentagon is developing ways to fuse AEGIS data with that from E-2C *Hawkeyes*, adding AWACS and JSTARS to an integrated sensor network for the combat theater during operations in the littoral arena. Late 1996 trials of CEC and two AEGIS cruisers validated the operational concept and much of the hardware and software. CG-68 and CG-71 used their AEGIS sensors effectively and cross-linked the data effectively, proving that missiles could be fired based on off-board, netted data.

AEGIS upgrades continue and the system is designed to counter the anticipated threat well into the 1990s. The newest upgrade, being fielded on the DDG-51s in mid-decade, features an enhanced capability against sea-skimming targets.

The Navy and DoD consider AEGIS a key theater missile defense sensor. Because of the new need to fight in the littoral, the Navy is working to develop an inherent capability against a missile threat. Both the lower-altitude Navy Area and higher altitude, longer range Navy Theater Wide programs are receiving significant attention and priority – and they have both had their problems. But that has not lessened their support. A major aspect of the programs is developing ways to interconnect them with the land-based TBM systems.

This generated interest in finding a way to use modified AEGIS sensors and weapon systems with a more capable missile to serve as a National Missile Defense system. The study from the Heritage Foundation is pushing this approach to NMD. Although the committee makes a good case, saying that the sea-based approach will cost less and can be fielded sooner. But a variety of issues must be addressed. The ABM Treaty between the US and former Soviet Union, and agreed to by Russia can be interpreted as prohibiting such a missile defense system. The report recommends abandoning or changing ABM. Many on Capitol Hill have a significant political and ego interest in a ground-based NMD system and are unwilling to abandon them unless they cannot avoid it. The Pentagon did not immediately jump on the Heritage bandwagon, either. But hopefully the recommendation will stimulate an active debate of the issue and could result in a re-think of how to provide missile defense for both the battlefield and nation. Early plans continue to focus on a land-based solution, with Alaska being picked as the first NMD site.

Improvements are making the AEGIS sensor more capable of detecting missiles fired from launchers onshore, where they must be picked out of heavy clutter. The move toward ballistic missile operations is prompting other, major enhancements to both the radar and command system.

A significant upgrade is the improvement of the radar for operation in a coastal environment. The littoral warfare radar features an enhanced ability to detect, track and target sea-skimming cruise missiles. The upgrade will also include ballistic missile tracking upgrades. The Pentagon is making AEGIS the Navy's front-line ballistic missile detection system in the near term and plans to make it a key part of theater missile protection. Development and testing are ongoing. Estimates put the per-ship cost goal at US$25 million. R&D costs have been put at roughly US$80 million per ship.

No future AEGIS cruisers are planned. The US Navy is authorized to procure 34 Flight I/II guided missile destroyers. The Navy has instituted a development program for a new, lower-cost surface combatant as an alternative to a Flight III DDG-51. The original Flight III's per-unit cost was estimated between US$1 billion and US$1.2 billion. The DDV is also referred to as the Flight IIA. SPY-1 production will be in direct support of these ship programs.

The DD-21 future surface combatant is apparently not going to carry an AEGIS variant. Although this was proposed, the selection of a developer for the new Multi-Function Radar seems to have put that idea to rest. The plan seems to be capturing the latest technology available to create a new system which meets today's low-observability, low-life-cycle cost, and reduced manning for the new ships. The Navy decided to incorporate electric drive for the land-attack destroyer. This features robust engines powering generators which provide electric power to motors located close to the propellers. This makes it possible to re-distribute ship spaces, an advantage in survivability, livability, and effective use of space. It can also provide large amounts of electrical power for ship's systems. This could impact the design of the MFR; but may also delay construction of the ship. The

Navy has said that construction could be delayed by at least one year in order to make the necessary design changes.

The FY01 budget plan would adjust the DDG 51 plan to fill the construction gap. This could impact the production schedule for the radar and other ship systems. In February 2000, Navy Secretary Danzig said that the Navy could not wait any longer than 2005 to start buying the new class of destroyers. He did not think the delay of one or two years was acceptable and wanted to schedule to remain the same. The American Shipbuilding Association said that industry supported the Navy's decision to slip DD 21 procurement in its budget submission and invest further in research and development, but added that further slips would not be acceptable. Brown said that industry also believes the Navy should buy more DDG-51s, but that those additional DDG-51s should not be added to the budget plan at the expense of DD-21.

Given the current pressures on the Japanese economy, the Japanese Self-Defense Forces limited their requirement for the *Kongo* class destroyer program to four ships. The ability to use the system as protection against ballistic missiles prompted the addition of a fifth ship.

Spain's decision to put AEGIS on its MEKO frigates is significant. It broke the ice on interest from the European/NATO community. Although the goal was to use a Euro-produced sensor; the ability to interface a proven radar with an indigenous control system could prompt a re-thinking of that goal.

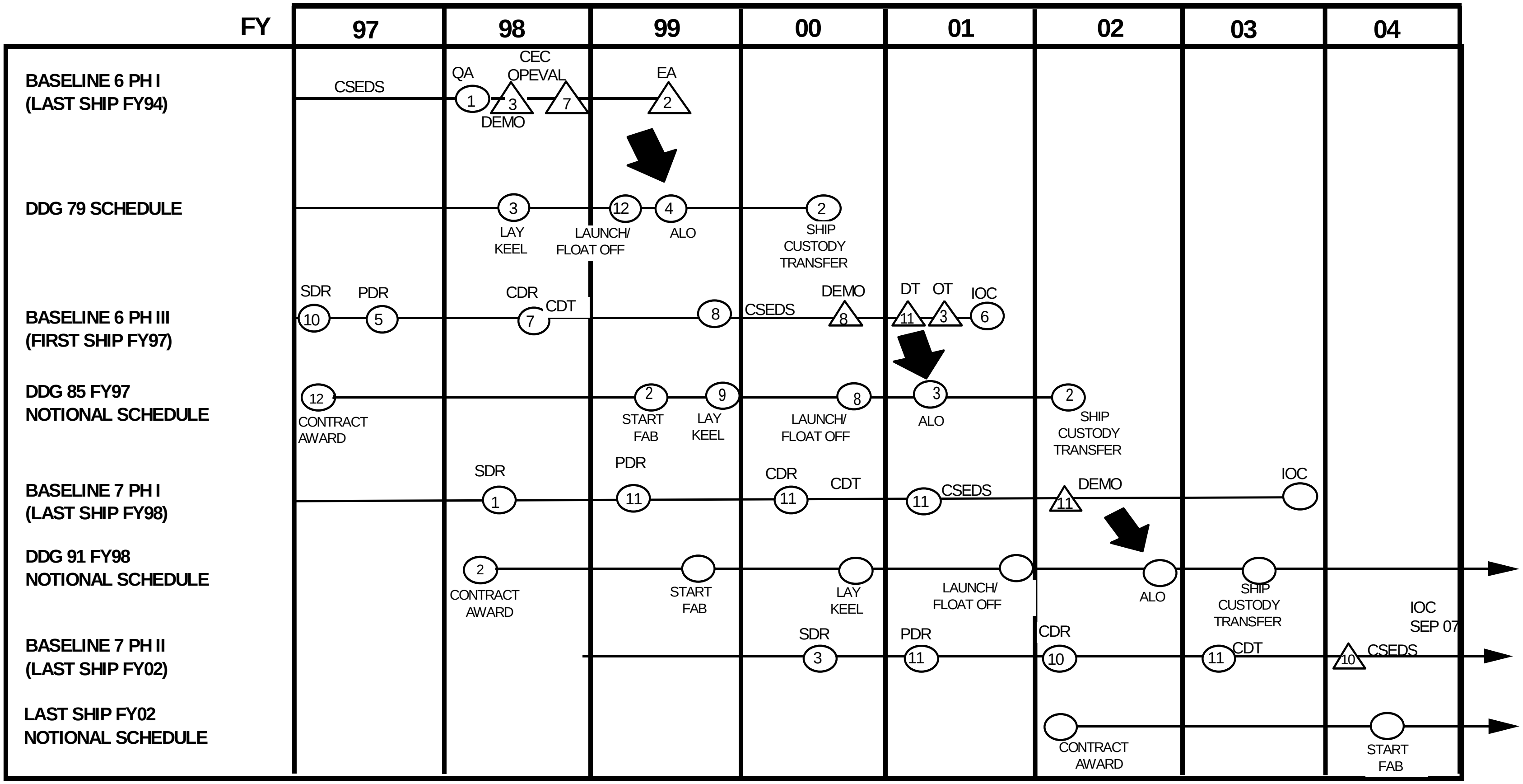
The White Paper and military posturing from China increased Taiwan's interest in the acquisition of four frigates or destroyers equipped with AEGIS to provide missile defense of the island. Taiwan was not as severely impacted by the fiscal crisis in the Pacific Rim as other Asian nations, so it may well be able to find the money to build these ships. But this, like any weapons sale to Taiwan, will result in a major political drama with the Peoples Republic of China. The whole issue revolves around what has become typical diplo-logic for that part of the world: China is reportedly massing missiles on its border facing Taiwan; Taiwanese officials want something to protect themselves from these missiles; the PRC objects to such a sale because it would, in fact, provide protection from its missiles… nd 'round and 'round we continue to go.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR PRODUCTION

			High Confidence Level			Good Confidence Level			Speculative			
Designation	**Application**	**Thru 99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**Total 00-09**
SPY-1A/B	Prior Prod'n:	27	0	0	0	0	0	0	0	0	0	0	0
SPY-1D	F-200 FRIGATE (SPAIN)	0	0	1	1	1	1	0	0	0	0	0	4
SPY-1D	DDG-51 (US NAVY)	43	3	3	2	2	1	1	0	0	0	0	12
SPY-1D	DESTROYER (JAPAN)	4	0	0	1	0	0	0	0	0	0	0	1
Total Production		74	3	4	4	3	2	1	0	0	0	0	17

AEGIS FORWARD FIT BASELINE DEVELOPMENT SCHEDULE



NOTE: IOC = SHIP CUSTODY TRANSFER (SCT)

ATTACHMENT 1