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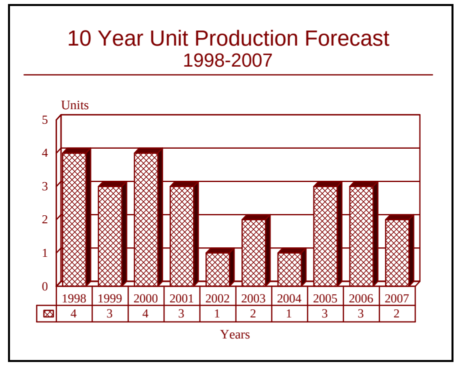
SPY-1(V) (AEGIS) - Archived 5/98

Outlook

- In production, ongoing logistics support and significant upgrade work continues
- Production supports US DDG-51 destroyer construction
- Production for Japanese Kongo class destroyers complete
- Variant selected for Spanish F-100 frigate program



Orientation

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

Sponsor

US Navy
Naval Sea Systems Command (NAVSEA)
2531 Jefferson Davis Highway
Arlington, Virginia (VA) 22202
USA
Tel: +1 703 602 3381

Contractors

Lockheed Martin Corp
6801 Rockledge Drive
Bethesda, Maryland (MD) 20817
USA
Tel: +1 301 897 6711
Fax: +1 301 897 6800
(Prime)

Sanders, a Lockheed Martin Co
95 Canal St
Nashua, New Hampshire (NH) 06061-0868
USA
Tel: +1 603 885 4321
Fax: +1 603 885 3655
(AIMS IFF/CIS system)

Computer Sciences Corp (CSC)
2100 E. Grand Ave
El Segundo, California (CA) 90245
USA
Tel: +1 310 615 0311
Fax: +1 310 640 2648
(Software/technical support)

Condor Systems Inc
2133 Samaritan Dr
San Jose, California (CA) 95124
USA
Tel: +1 408 371 9580
Fax: +1 408 371 9589
(SARTIS Recognition System)

Litton Industries
Electron Tube Division
Williamsport, Pennsylvania (PA)
USA
(Double-duty cross-field amplifier tubes)

Raytheon Systems Company

Sensors & Electronic Systems
1001 Boston Post Rd
Marlborough, Massachusetts (MA) 01752
USA
Tel: +1 508 490 1000
(Radar amplifiers, single and double-duty microwave tubes, radar transmitters, technical support, product improvement)

Teledyne Microwave Inc
1290 Terra Bella Ave
Mountain View, California (CA) 94043
USA
Tel: +1 415 968 2211
Fax: +1 415 960 8689
(Traveling wave tubes for SPY-1B/D)

Tracor Inc
1400 Georgia Ave
Silver Spring, Maryland (MD) 20906
USA
Tel: +1 301 231 1000
Fax: +1 301 231 2277
(Engineering & analytical support)

Varian Associates Inc
Crossed Field & Receiver Protector Products
Div 150 Sohier Rd
Beverly, Massachusetts (MA) 01915
USA
Tel: +1 508 922 6000
Fax: +1 508 922 8914
(Crossed field amplifiers)

Varian Associates Inc
Microwave Tube Div
3050 Hansen Way
Palo Alto, California (CA) 94304
USA
Tel: +1 415 493 4000
Fax: +1 415 493 0307
(Continuous wave illuminator traveling wave tubes and solenoids for SPY-1D)

Status. In production, ongoing logistics support and upgrades.

Total Produced. Through 1997, 27 SPY-1A/B and 36 SPY-1D systems had been delivered.

Application. US Navy CG-47 AEGIS class cruisers, DDG-51 AEGIS class destroyers, Japanese DDG-173 Kongo class destroyers, Spanish F-100 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).

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
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 ☞sec	
Pulse Compression:	128:1	
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 & 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 there are eight identical ones to ensure redundancy and survivability.

The SPY-1(V) is connected to the AEGIS weapons system via UYK-7 digital computers. These were upgraded with UYK-43/44s in Baseline 4 ships to increase target capacity and processor speed. The UYK-() controls the radar beams for search, detection and tracking. In addition, the UYK-7 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 or -21 large screen displays project processed anti-surface, anti-air, and anti-submarine warfare information. There are two console sets facing 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 of 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 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.

The processing power of AEGIS is its heart, and also its limitation. Efforts are ongoing to capture better computer capability for the system by capitalizing on Moore's Law, which says that the number of integrated circuits that can fit onto a computer chip doubles about every eighteen months. Designers are working hard to develop ways to incorporate advances in commercial equipment 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 interconnected design. Such a setup does not come close to running at the speed a commercial processor is capable of.

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 ties commercial processors together more effectively and takes advantage of the capabilities of commercial computers.

Concentrating on the EDM-5 AEGIS, the more muscled computers (six times to processing power of any AEGIS in existence), the system 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 of 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 that 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. Planners hope to develop a fully distributed architecture ready of 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. There is immediate digitization of any signal sent out 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 into 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 upgrading radar performance for the cluttered littoral environment.

Variants/Upgrades

SPY-1A. AEGIS cruisers up to and including CG-58.

SPY-1B. 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.

SPY-1D. 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 in place of the four target illuminators on the CG-47 ships, there are three. Use of VLSI technology resulted in a considerable space savings. The ECCM capabilities are enhanced.

An **SPY-1C** was proposed for use on aircraft carriers, but the program canceled.

The **SPY-1E** 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 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-1D(V). This is the latest development for the DDG-51 and is being 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 is 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. There will be a Moving Target Indicator clutter-cancellation system, with computer-selectable waveforms of two through seven pulses to 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 form 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 with 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 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-1F. This is the international version of the radar being installed on the Spanish F-11 frigates. It is a "frigate-sized" version of the SPY-1D and equivalent to the SPY-1D on DDG-51 Flight II ships..

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 included Deceptive Electronic Countermeasures, Track Load Control algorithms, and Track Initiation Processor. 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 Battle Force Tactical Trainer (BFTT). It also has the Advanced Display System, Evolved SEASPARROW Missile (ESSM), Identification (ID) and upgrades the 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, 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.

Program Review

Background. In the early 1960s, it became obvious to naval planners 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 of 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 SPY-1A 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 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 couldn't completely jam AEGIS. 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 AEGIS 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. The Navy continues to enforce a rigid shock-test program that includes all new construction vessels.

During debate and approval of the FY93 Defense Authorization and Appropriations, Congressional conference committees approved full funding of the AEGIS combat system engineering request of US$89.9 million. This included US$28.9 million to develop an upgrade to the AEGIS radar, the Engineering Development Model 4B (EDM-4B). In the Authorization Bill the House recommended the full authorization, but the Senate deleted the EDM-4B funds based on information that the Navy did not intend to proceed with the development.

When the conference members investigated and found that the Navy intended to develop the upgraded system, they approved full funding, but with restrictions. They restricted the Secretary of the Navy from spending more than 50 percent of the EDM-4B funds until submitting a report to the congressional defense committees giving an estimate of the threat from anti-ship missiles and the estimated cost and schedule for development and testing, along with estimated year-by-year procurement costs, by year, to add EDM-4B to future DDG-51 destroyers, and detailing the Navy's plan for fielding EDM-4B, as well as other ship self defense systems (including sensors and weapons).

The Appropriations conference restored EDM-4B funds deleted by the Senate, but directed that not more than US$11.6 million be obligated until the Secretary of the Navy certifies to Congress that development and procurement of the radar are fully funded in the next FYDP and provides an updated threat assessment addressing the need for the system. The Navy informed Congress that the spending restriction would not impact ongoing contractor activities.

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 analysis 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 sensor.

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.

The following focuses primarily on the radar-specific efforts of these projects.

<u>Project K1447 AEGIS Combat Systems Improvements</u>. This project provides AEGIS cruiser and destroyer combat system upgrades to integrate new equipment and systems to maintain pace with the threat and to capture advances in technology such as fiber optics and distributed architecture. The ships are upgraded in blocks and the combat system in a series of baselines.

Baseline 2 (CG-52 to -58) consisted of the vertical launching system, TOMAHAWK weapons system, and anti-submarine warfare upgrades.

Baseline 3 (CG-59 to -64) included the SPY-1B radar and AN/UYQ-21 consoles.

Baseline 4 (CG-65 to 73) integrated the AN/UYK-43/44 computers with superset computer programs developed for the DDG-51. Baseline 4 is the base combat system for DDG-51 to -67.

Baseline 5 is targeted for FY92 ships and 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), AN/SLQ-32(V)3 Active Electronic Countermeasures, and AEGIS Extended Range (ER) Missile.

Baseline 5 will be developed in three steps (phases):

<u>Phase I</u> integrates AEGIS ER and supports the missile Initial Operational Capability.

<u>Phase II</u> integrates all planned upgrades except for JTIDS so they can be backfitted into Baseline 4 ships (the computer programs can operate in Baseline 4 ships whether any or all of the Baseline 5 new systems are installed). The effort includes Deceptive Electronic Countermeasures, Track Load Control algorithms and the Track Initiation Processor.

<u>Phase III</u> integrates JTIDS and the O-663 color display Tactical Graphics capability into the AEGIS Combat System.

Baseline 6 will be developed in two phases. Phase I is planned for the last ship in FY94, and Phase II is planned for the first ship in FY97.

Baseline 6 upgrades will include embarked helicopters, Fiber Optics as applied to Data Multiplexing System (DMS), and implementation of affordability initiatives, as well as the Radar Set Controller Environmental Simulator (RSCES) and Battle Force Tactical Trainer (BFTT), Advanced Display System. Evolved SEA-SPARROW Missile (ESSM), Identification (ID) upgrades Phase I, Advanced TOMAHAWK Weapon Control System (ATWCS) Phase II, and Fire Control System upgrades are included.

Baseline 7 will be developed in two phases. Baseline 7 Phase I is planned for the last ship in FY98 and Phase II is planned 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, STANDARD Missile-2 Block IIIB full integration. It also includes 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.

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.

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. Also in FY93, the Navy performed the system definition to integrate Baseline 6 upgrades into the AEGIS Combat System (US$6.4 million).

In FY94, the Navy resolved problems identified during Combat System Engineering Development (CSED) Site system demo of Baseline 5 Phase I, spending US$400,000 on the effort. Planners also spent US$12.6 million 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. They also began developing the Baseline 6 Phase I design specifications.

FY95 accomplishments included spending US$19.519 million to complete computer program coding, debugging and testing of Baseline 5 Phase III.

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.

FY96 accomplishments included completing Baseline 5 Phase III (US$250,000). Planners spent US$18.965 million to conduct Baseline 6 Phase I Critical Design Review (CDR-1) and CDR-2. Designers started computer program coding, debugging and testing. They continued rehosting of AEGIS Combat Training System (ACTS) computer programs for BFTT Phase I and development of BFTT/ACTS interface. They continued rehosting ADS and the C&D display as well as ID-related computer programs into a COTS-based Advanced Display System architecture. Design of the ID upgrade Phase I for Baseline 6 Phase I continued, along with engineering for advanced processing architecture.

The program office budgeted US$4.9 million to conduct a rehost 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 implementing an open system networked architecture in Baseline 7.

The FY97 plan budgeted US$16.6 million to continue Baseline 6, Phase I computer program coding, debugging and testing. US$19.247 million was used for conducting a Preliminary Design Review for integration of Baseline 6 Phase II upgraded including ESSM into the AEGIS Combat System.

Designers used US$5.1 million to complete rehosting of 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 continue advanced processing EDM-5 development for open systems networked architecture in Baseline 7 Phase I ships.

US$1,710 million of the extramural program funding was reserved for Small Business Innovation Research in accordance with 15 U.S.C. 638.

The FY98 plan budgeted US$15.051 million to complete system definition/engineering for full integration of SPY-1D(V) into new construction AEGIS Combat System in Baseline 7 Phase I and start system design. US$10.965 million was budgeted to conduct Baseline 7 Phase I PDR for integration of upgrades into the AEGIS Combat System and continue advanced processing EDM-5 development for open systems networked architecture in Baseline 7 Phase I ships.

The FY99 plan budgeted US$15.981 million to continuing system engineering for full integration of SPY-1D(V) into new construction AEGIS Combat System in Baseline 7 Phase I.

US$29.50 million has been earmarked to conduct Baseline 7 Phase I CDR for integration of upgrades into the AEGIS Combat System and start computer program coding, debugging and testing. Engineers will also continue advanced processing EDM-5 development for open systems networked architecture in Baseline 7 Phase I ships. US$2.947 million is budgeted to conduct system definition and start design of an advanced combat system with fully distributed architecture leveraging HiPer-D and other technology efforts.

US$7.0 million has been planned to start system definition and engineering development for integration of the Area Air Defense Coordinator (AADC) capability into AEGIS Ships.

Project K1776 AEGIS Weapons System Mods. This program provides for modifications to the AEGIS Weapons System MK-7 to counter the threat (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.

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 and continued with system engineering studies to define and develop Electronic (ECCM)/Deceptive Electronic Countermeasures (DECM) design changes relative to the eventual incorporation of these changes in 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 (US$6.896 million) included coding, testing, and debugging the computer program for Operational Readiness Test System (ORTS) Man-Machine Interface (MMI) upgrade, at US$3.6 million. The Navy also continued to develop computer program algorithms to improve Anti-Air Warfare system performance against various Deceptive Electronic Countermeasures (DECM) threats (US$3.296 million).

FY94 saw US$2.15 million spent to complete Operational Readiness Test System (ORTS), Man-Machine Interface (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 Operational Readiness Test System (ORTS) Man-Machine Interface (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 spending US$300,000 for 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.

The plans for FY98 were to continue SPY-1B/D upgrade analysis support, 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 and US$1.20 million to continue SPY-1B/B(V)/D Moving Target Indicator analysis, design, development and engineering for radar enhancement.

US$1.40 million was set aside to begin system engineering for SPY-1B/D DECCM upgrades and US$1.684 million to begin design and engineering for Radar Set Controller Environmental Simulator (RSCES) for the SPY-1D(V) system.

The FY99 plan budgets 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. Planners budgeted US$3.125 million 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.

FY92 accomplishments were the continued systems engineering 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.

FY93 saw total funding of US$27.394 million 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 completing element integration and testing. Engineers installed and performed system-level integration at the CSED Site, funded at US$8.585 million.

FY95 continued system integration, spending US$1.316 million 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 for rehosting 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$5.0 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 rehosting the radar system computer program.

In FY97, US$3.538 million was spent to complete the radar system computer program rehosting.

Japan. The Japanese government announced in 1983 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 production of the AEGIS system would be in the US, with no co-production 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 Flight I and II DDG-51s, 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, completed qualification trials in late 1997. These 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 their new ships as an effective part of the Fleet.

Spain. The Spanish Navy decided to procure a version of the AEGIS SPY-1D for the four F-100 frigates they planned to build starting around the turn of the century. 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.

Initially, 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 with either the SPY-1D or SPY-1F radar. The F-100 destroyer program was then recast around a larger warship of the same size and general configuration as the DDG-51.

The F-100 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 is being 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. M Installed, the system will be equivalent to the US DDG-51 Flight IIA ships.

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

Funding

US FUNDING

	FY96		FY97		FY98		FY99 (Req)	
	QTY	AMT	QTY	AMT	QTY	AMT	QTY	AMT
RDT&E (USN)								
PE#0604307N								
AEGIS Combat System Engineering								
K1447 Improvements	-	73.2	-	79.0	-	80.4	-	102.7
K1776 Weapon Mods	-	2.7	-	4.7	-	4.6	-	2.2
K1937 DDG Development	-	10.4	-	4.4	-	0.0	-	0.0
K2100 Test Integr Fac		0.0	-	2.8	-	0.0	-	0.0
K2308 Smart Ship	-	0.0	-	0.0	-	5.6	-	*
RDT&E Total	-	89.0	-	88.4	-	87.9	-	115.6

* less than US$50,000

RDT&E	FY00(req)		FY01(req)		FY02(req)		FY03 (req)	
	QTY	AMT	QTY	AMT	QTY	AMT	QTY	AMT
(USN estimate)								
K1447	-	135.4	-	93.3	-	95.4	-	97.5
K1776	-	4.4	-	4.5	-	4.5	-	4.7
RDT&E Total	-	139.8	-	97.8	-	100.0	-	102.2

In the FY98 Defense Appropriation, Congress added US$720 million to the shipbuilding request to add one ship to the annual plan. This brought the procurement to US$3.411 billion for four ships. US$15.2 million of the increase was directed toward accelerating the Baseline 6 hardware and software for tactical missile defense operations. US$14 million was earmarked for installing CEC on one ship, and legislative language directed the Navy to include CEC and TBM on a significant number of DDG-51s to be procured under a 14-ship multi-year contract.

The Navy shipbuilding plan released with the FY99 budget request calls for funding four DDG-51s in FY98, three in FY99 and following years, committing to the acquisition of 13 ships over the FY98 through FY01 period. Plans are to eventually construct a total of up to 57 ships.

All US$ are in millions.

Recent Contracts

(Contracts over US$5 million)

Contractor	**Award ($ millions)**	**Date/Description**
Lockheed Martin	6.2	Apr 1996 – Modification to a previously awarded contract to exercise an option to provide engineering services in support of the Spanish FMS F-100 Combat System Design Program. Completed Dec 1996. (N00024-95-C-5161)
Lockheed Martin	7.6	Apr 1996 – Modification to previously awarded contract for engineering services in support of Japanese FMS AEGIS Combat Weapons System. Complete Dec 1998. (N00024-95-C-5153)
Lockheed Martin	110.6	May 1996 – Modification to previously awarded contract to exercise an option to provide AEGIS combat system baseline upgrade and critical experiment development. Work is expected to be completed by Mar 2000. (N00024-95-C-5159)
Lockheed Martin	131.2	Jun 1996 – FPI contract for production and integration testing of two FY 96 AEGIS Weapons Systems Mk 7 MOD 11, and the associated engineering and logistics support for DDG-83 and DDG84. Work is expected to be completed by Jun 2002. (N00024-96-C-5155)
Lockheed Martin	10.0	Jul 1996 – Modification to previously awarded contract for long lead material and associated planning for production of one AEGIS weapons system Mk 7 Mod 11 for DDG-85. Complete Jun 2002. (N00024-96-C-5155)

Contractor	**Award ($ millions)**	**Date/Description**
Lockheed Martin	14.0	Sep 1996 – Modification to a previously awarded contract to exercise an option to provide continuing lifetime support engineering for AEGIS Combat System and AEGIS Weapons System. Completed Sep 1997. (N60921-93-C-0529)
Computer Sciences	17.1	Sep 1996 – Modification to a previously awarded contract to provide systems engineering support for the AEGIS Combat System and AEGIS Weapons System, including FMS requirements (US 95.1%, Japan 3.4%, Spain 1.5%). Brings cumulative value of the contract to US$60 million. Completed Sep 1997. (N60921-94-C-A220)
Logicon Syscon	24.9	Sep 1996 – Modification to a previously awarded contract to provide continued test and evaluation of the AEGIS Combat System and AEGIS Weapons System, including FMS requirements (US 97%, Japan 2%, Spain 1%). Brings cumulative value of the contract to US$ 137.7 million. Completed Sep 1997. (N60921-91-C-A205)
Lockheed Martin	67.8	Dec 1996 – CPFF award for DDG-51 AEGIS Combat System installation and testing. Contains options which, if exercised, could bring the value of this contract to US$183,311,199. Complete Apr 2001. (N00024-97-C-5173)
Raytheon Co	54.1	Dec 1996 – Modification to previously awarded contract for production of four shipsets of AEGIS Weapon System OT-146/SPY-1D Transmitter Group and Fire Control System Mk 99 Mod 3 Ancillary Equipment for DDG-85, 86, 87 and 88. Complete Jan 2000. (N00024-95-C-5158)
Raytheon Co	13.9	Dec 96 – Modification to previously awarded contract for production of four shipsets of AEGIS Weapon System OT-146/SPY-1D Transmitter Group and Fire Control System Mk 99 Mod 3 components, installation parts microwave (IKEEE-M/U) and site support for DDG-85, 86, 87 and 88. Complete Sep 1999. (N00024-93-C-5100)
Raytheon Co	44.5	Mar 1997 – Not-to-exceed modification to previously awarded contract for advance procurement/long-lead material for AEGIS Weapon System OT-146/SPY-1D transmitter Group, OT-188/SPY-1D(V) Transmitter Group and Fire Control System Mk 99 Mod 3 Ancillary equipment for USN and FMS requirements. USN 33%, Spain 67% (FMS). Completed Dec 1997. (N00024-95-C-5158)
Lockheed Martin	98.6	Jun 1997 – CPAF contract for AEGIS Combat Systems Engineering in support of the Spanish Frigate FMS program. Complete Feb 2006. (N00024-97-C-5171)
Lockheed Martin	22.3	Jul 1997 – NTE letter contract for acquisition of Advance Procurement equipment/material in support of anticipated FY98 through FY01 12-ship AEGIS Weapon System multi-year procurement for DDG-51 destroyers DDG-89 through DDG-100. Complete Feb 2005. (N00024-97-C-5178)

Contractor	Award ($ millions)	Date/Description
Lockheed Martin	11.1	Jul 1997 – CPFF contract for Japanese FMS AEGIS Combat Systems Engineering. Provides for planning and management support, computer program maintenance services, combat systems engineering services, return/repair/reshipment support, in-country support services, training support, baseline J3 backfit, repair/overhaul/annual inspection, and engineering planning/validation/management support for future AEGIS FMS ship classes. Includes options which could bring the value to US$130,342,097. Complete Dec 1999. (N00024-97-C-5177)
Raytheon Co	85.6	Aug 1997 – FFP contract for AEGIS Weapon System OT-146/SPY-1D Transmitter Group and Fire Control System Mk 99 Mod TBD Ancillary Equipment for FMS requirements for the Government of Spain. Complete Dec 2003. (N00024-97-C-5193)
Logicon Syscon	30.9	Aug 1997 – CPFF contract for test and evaluation of AEGIS Combat System and AEGIS Weapon System software. Combines support for US Navy, the Government of Japan and the Government of Spain under FMS. Contains options which could bring cumulative value to US$187,953,294. Complete Sep 1998. (N00178-97-C-2002)
Lockheed Martin	12.9	Sep 1997 – CPAF level of effort contract for AEGIS Lifetime Support Engineering Services to ensure that performance characteristics of the AEGIS Weapon System and AEGIS Combat System are preserved while modifications are implemented throughout the lifetime of CG-47- and DDG-51-class ship combat systems. Complete Sept 1998. (N00024-98-C-2004)
Lockheed Martin	129.1	Oct 1997 – Modification to a previously awarded contract to exercise options for AEGIS Combat System Baseline Upgrades and Critical Experiments. Complete Nov 1998. (N00024-95-C-5159)
Lockheed Martin	6.0	Dec 1997 – Indefinite-delivery/indefinite-quantity order for 1,760 circuit card assemblies for the AEGIS Weapon System. Complete Dec 2000. (N00104-98-D-G001)
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. Complete Feb 1999. (N00024-94-C-6430)

Timetable

Month	Year	Major Development

	1969	Contract for prototype AEGIS to RCA
	1972	SPY-1 testing began
	1973	Installation of prototype AEGIS system aboard USS *Norton Sound*
	1974	AEGIS sea trials began
May	1981	Operational Test IIID of AEGIS
Jan	1983	First AEGIS ship, the USS *Yorktown*, commissioned
	1984	The Japanese Maritime Self-Defense Forces announced that they were 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 announced that it would second-source most elements of the AEGIS system
	FY86	Continued development of SPY-1A ORDALTS and began production of sub-elements. Initiated system studies to determine the added value to area defense of lower-frequency cueing radars to advanced versions of the SPY-1. Began efforts to identify critical technologies for radar operation against the threat environment expected in the year 2000. Began efforts to develop and demonstrate the following: 1) partial configurations of new technologies required, 2) system integration, 3) track sharing, and 4) achievable capabilities of such a system. SPY-1D became operational. Installed SPY-1A radar trainer
Oct	1986	Delegation of top US Navy officials called 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 on the NATO NFR-90 frigate program
Nov	1986	US approved Japanese purchase of SPY-1D to equip new class of four 6,500-ton destroyers
	FY87	Began SPY-1 ORDALT designs for the SPY transmitter and signal processor. Conducted SPY-1B/ D qualification tests
Apr	1987	SPY-1B/D qualification test
	FY88	Continued SPY-1 ORDALT designs for the transmitter and signal processor improvements. Conducted SPY-1D DT/OT-IID-2. Completed SPY-1D system engineering
Apr	1988	Unisys and its partner Westinghouse selected as second source for SPY-1D
Jul	1988	Completed and installed Radar Supervisor Controller Stress Trainer
	FY89	Completed proof-kit development and fabrication of SPY-1A ORDALTS and test at ACSC. Integrated and tested 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	Completed testing of SPY-1A signal processor ORDALTS. Continued 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. Built and tested SPY-1B/D signal processor changes for ECCM. Integrated and tested 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
Dec	1994	DDG-57 (7th of 29) commissioned
Feb	1995	DDG-66 (16th of 29) christened
Feb	1996	Selected by Spain for F-100 Class
	1996	Begin fielding of Cooperative Engagement Capability

Month	**Year**	**Major Development**
Mar	1998	Last Japanese AEGIS destroyer commissioned
	2003	SPY-1D(V) Littoral upgrade radar to become operational on DDG-91
	2007	Complete initial fielding of Cooperative Engagement Capability

Worldwide Distribution

Japan. The Japanese Navy uses the SPY-1D on its AEGIS class destroyer. A total of four are being built.

Spain. Four SPY-1(V) radar systems and four AEGIS combat direction systems are to be ordered for the F-100 destroyers. An additional system may be ordered as a shore training site.

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 29 destroyers approved.

Forecast Rationale

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

Pentagon planners are 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. This Cooperative Engagement Capability (CEC) system is the next major adjustment to the Fleet's operational hardware, software and defense tactics. The first development involved upgrades to data transmission and processing; sensor upgrades will come later. The 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 continues to be upgraded and is planned to be fully capable of dealing with 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 continue to consider AEGIS a key theater missile defense sensor. This idea has been prompted by Persian Gulf experience, which showed that potential adversaries may well possess a theater missile capability. The Navy is working to develop an inherent capability to go it alone in guarding against a missile threat. Upper tier defense will combine AEGIS, which will be called Navy Theater-Wide, and the THAAD program.

AEGIS is a capable system. Its design and architecture have become a baseline for sensors of tomorrow. The system is not perfect, but ongoing upgrade and improvement efforts are addressing design and operational concerns. The major opportunity for improvement comes from the capitalizing on computer power available in the industry if designers are not required to slavishly adhere to an old concept of computer architecture. The original radar was developed for open-water operations and anti-aircraft, anti-air-launched missile operations. The improvements are making the sensor more capable of detecting missiles fired from launchers onshore, where they must be picked out of heavy clutter.

A significant upgrade will come from improving the radar for operating 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 is 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.

There are no future AEGIS cruisers planned. The US Navy is authorized to procure 29 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.

In releasing the FY97 defense spending plan, the secretary of defense announced a plan to increase FY97 funding to US$3.4 billion for four ships. From FY98 to FY01, US$11.8 billion was planned to support the construction of 11 ships. The FY98 Defense Appropriation saw congressional funding increases to add another ship to the request and accelerate Baseline 6 TBMD development.

DDG-51 continued to be a high interest item in the FY99 budget release, with US$14.6 billion programmed for FY99 to FY03. The US forecast provides for the 26 ships authorized and assumes more will be approved. The plan anticipates hull construction and that the systems will be produced at the most economical and workable rate.

The future surface combatant may well carry an AEGIS variant. The radars for these ships will be based on the underlying SPY-1 architecture updated to state-of-the-art and capitalizing on lessons learned from the DDG-51.

Given the current pressures on the Japanese economy, the Japanese Self-Defense Forces are expected to limit their requirement for the Kongo class destroyer program to four ships. If the Japanese want to procure another four destroyers, they will have to wait until after the turn of the century.

Spain's decision to put AEGIS on its F-100s is significant. It breaks the ice on interest from the European/NATO community. In spite of the pressure to go with a European-developed sensor suite for the Tri-Lateral Frigate (or equivalent) program, selecting a proven, available system is tempting and could result in some future orders. The number would be small, though, because of cost and the fact that AEGIS has much more radar than many navies need.

Forecast International has picked up initial indications that Taiwan is interested in the possible acquisition of four frigates or destroyers equipped with AEGIS. The Republic of China has not been 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. Its security situation and fear of Mainland China are major drivers in the Republic of China's ongoing military upgrades.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR PRODUCTION

			High Confidence Level			Good Confidence Level			Speculative			
Designation	Application	thru 97	98	99	00	01	02	03	04	05	06	07	Total 98-07
SPY-1A/B	CG-47 (US NAVY)	27	0	0	0	0	0	0	0	0	0	0	0
SPY-1D	DDG-51 (US NAVY)	36	4	3	4	2	0	0	0	0	0	0	11
SPY-1D	DDG-173 (JAPAN)	4	0	0	0	0	0	0	0	0	0	0	0
SPY-1D	F-100 (SPAIN)	0	0	0	0	1	1	1	1	0	0	0	4
SPY(V)	SC-21 (US NAVY)	0	0	0	0	0	0	1	0	3	3	2	9
Total Production		63	4	3	4	3	1	2	1	3	3	2	24