ARLEIGH BURKE (DDG 51) CLASS GUIDED MISSILE DESTROYER WITH THE AN/SPY-1D RADAR

Navy ACAT IC Program

Total Number of Systems:	57
Total Program Cost (TY$):	$53881.3M
Average Unit Cost (TY$):	$945.9M
Full-rate production:	1QFY87

Prime Contractor

Bath Iron Works (Shipbuilder)
Ingalls Shipbuilding, Inc. (Shipbuilder)
Lockheed Martin (AEGIS Weapon System)

SYSTEM DESCRIPTION & CONTRIBUTION TO JOINT VISION 2010

The ARLEIGH BURKE (DDG 51) class of multi-mission, guided missile, and battle force capable destroyers form the core of the Navy's surface combatant force for the 1990s and beyond. These ships are designed for forward presence and are capable of ***precision engagement*** of targets ashore and ***full-dimensional protection*** of joint and allied forces operating at sea and in the littorals. As described in the section on the Navy Area Theater Ballistic Missile Defense, planned upgrades to the AEGIS Weapon System and Standard Missile will also give DDG 51 a ballistic missile defense capability. DDG 51's armament includes a mix of 90 missiles to support its missions, housed in two MK-41 vertical launch systems. The ship uses a computer-controlled machinery control system and an up-rated LM 2500 gas turbine propulsion system to provide a maximum speed of at least 30 knots.

The AEGIS Weapon System (AWS), which includes the SPY-1D radar and vertically launched SM-2 surface-to-air missiles, provides DDG 51's area defense anti-air warfare capability. For anti-submarine (ASW), DDG 51 uses the SQQ-89 surface ASW combat system, the LAMPS MK III ASW helicopter, over-the-side torpedoes, and vertically launched ASW standoff weapons. DDG 51 also employs TOMAHAWK and HARPOON missiles, and has a 5-inch gun for anti-surface and strike warfare missions. The Phalanx close-in weapons system, along with the SM-2 missiles and gun, provides self-defense against anti-ship missiles. The DDG 51 AEGIS Combat System is the integration of the AWS, the SQQ-89, and the ship's anti-surface, strike warfare and self-defense systems.

DDG 51s are being constructed in flights to incorporate technological advancements during construction. Flight II, authorized in FY92, incorporates improvements to the SPY radar and communications systems and adds active electronic countermeasures. Flight IIA, authorized in FY94, adds hangar facilities to accommodate two helicopters, removes HARPOON, and replaces Phalanx with the Evolved Sea Sparrow Missile (ESSM). FOT&E of a Flight IIA ship will occur in FY01.

The SPY-1D radar system is the multi-function, phased array, three-dimensional (range, altitude, and bearing) radar that conducts search, automatic detection, and tracking of air and surface targets. The SPY-1D also provides mid-course guidance for the SM-2 missile. SPY-1D is a variant of the SPY-1B radar system on later TICONDEROGA (CG 47) class cruisers tailored for a destroyer-sized ship. The AN/SPY-1D(V), intended for installation in later Flight IIA ships, is an improved system with better performance against targets in clutter, additional moving target indicator wave forms, and greater ability to counter deceptive electronic attack measures.

BACKGROUND INFORMATION

The DDG 51 program has undergone continuing OT&E since inception. DOT&E's FY91 report contains a complete summary of the eleven periods of testing prior to commissioning of the ship, along with assessments and significant deficiencies. Rigorous at sea testing of the Flight I ship was conducted during FOT&E from 1992-1996, thereby verifying the correction of previous deficiencies and finding the ship to be generally effective and suitable. A comprehensive Live Fire Testing Program for the Flight I ship, including the conduct of 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, has 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 AN/SPY-1D(V) underwent its first phase of OT in FY96. The test (designated OT-IIF1), which was conducted at the Aegis land-based test site at Moorestown, NJ, 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 affecting 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 TEMP for AN/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 AN/SPY-1D(V) as soon as a test article (including Baseline 7 computer programs) is available.

Although LFT&E testing of the for DDG 51 Flight I is complete, the Navy continued in FY99 its assessment efforts 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, 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 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 to limit the cost of repair of 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 to 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 lead 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.