FY16 TABLE OF CONTENTS

FY16 TABLE OF CONTENTS

Navy Programs

Aegis Modernization Program

Executive Summary

- The Navy is modernizing the Aegis Weapon System (AWS) installed on Baseline 3 USS *Ticonderoga* (CG 47)-class cruisers and Flight I USS *Arleigh Burke* (DDG 51) destroyers to the AWS Advanced Capability Build (ACB)-12 (Baseline 9A and 9C, respectively). New construction Flight IIA DDGs, beginning with USS *John Finn* (DDG 113), will be equipped with Baseline 9C as well.
- Baseline 9A cruiser operational testing began in FY15 and continued through FY16. Baseline 9C destroyer operational testing began in FY16. Neither variant has completed all planned events. In particular, no live-firing events intended to demonstrate surface warfare performance have been executed on any Baseline 9 variant. Additionally, air defense events against supersonic sea-skimming anti-ship cruise missile surrogates have been deferred for reasons including GQM-163A aerial target availability, schedule constraints, and weather.
- In FY16, the SECDEF directed the Navy to fund long-lead items for an Aegis Self-Defense Test Ship (SDTS) to be used for testing of Aegis ACB-20, DDG 51 Flight III, the Air and Missile Defense Radar (AMDR, a.k.a., AN/SPY-6), and Evolved SeaSparrow Missile (ESSM) Block II, and to produce Test and Evaluation Master Plan (TEMP) updates outlining the intended use of the test ship. The Navy has complied with the funding portion of the directive, but has not complied with the remainder of the direction to provide the TEMP or integrated test plan for Aegis ACB-20 and DDG 51 Flight III. Additionally, the Navy has not funded the remainder of the installation/integration cost for the test ship or the remaining test resources to conduct the self-defense testing for ACB-20/DDG 51 Flight III.
- Testing completed to date is insufficient to make a determination of operational effectiveness or suitability for Aegis Baseline 9A or 9C.
- The lack of an adequate modeling and simulation (M&S) suite of the Aegis Combat System (ACS), as well as the lack of an Aegis-equipped SDTS where the ship's full self-defense kill chain can be tested, precludes assessment of the Baseline 9 Probability of Raid Annihilation requirement self-defense mission.
- The Navy will not fully assess Aegis Integrated Air and Missile Defense (IAMD) until a validated M&S test bed is developed and validated. The test bed is planned to be available by FY20, but there is no agreed upon strategy to validate the model to support assessment of the close-in, self-defense battlespace.
- Navy Integrated Fire Control – Counter Air (NIFC-CA) From-the-Sea (FTS) Increment I became a fielded capability in 2015 and fully integrated as a tactical option in fleet air defense. Future testing of the ACB-16 and ACB-20 Aegis Modernizations and Standard Missile-6 (SM-6) will evaluate the NIFC-CA FTS Increment II capability.

System

- The Navy's Aegis Modernization program provides updated technology and systems for existing Aegis-guided missile cruisers and destroyers. This planned, phased program provides similar technology and systems for new construction destroyers.
- The AWS integrates the following components:
  - AWS AN/SPY-1 three-dimensional (range, altitude, and azimuth) multi-function radar
  - AN/SQQ-89 undersea warfare suite that includes the AN/SQS-53 sonar, SQR-19 passive towed sonar array (DDGs 51 through 78, CGs 52 through 73), and the SH-60B or MH-60R helicopter (DDGs 79 Flight IIA and newer have a hangar to allow the ship to carry and maintain its own helicopter)
  - Close-In Weapon System
  - A 5-inch diameter gun
  - Harpoon anti-ship cruise missiles (DDGs 51 through 78, CGs 52 through 73)
  - Vertical Launch System that can launch Tomahawk land attack missiles, Standard surface-to-air missiles, ESSMs, and Vertical Launch Anti-Submarine Rocket missiles
- The Navy is upgrading the AWS on USS *Ticonderoga* (CG 47)-class cruisers and Flight I USS *Arleigh Burke* destroyers to Baseline 9A and 9C, respectfully. Baseline 9 will provide the following new capabilities:
  - Full SM-6 integration
  - IAMD, to include simultaneous air defense and ballistic missile defense missions on Aegis destroyers equipped with the new Multi-Mission Signal Processor
  - NIFC-CA FTS capability

- Starting with USS *John Finn* (DDG 113), the AWS on new construction Aegis-guided missile destroyers is Baseline 9C.

Mission

The Joint Force Commander/Strike Group Commander employs AWS-equipped DDG 51-guided missile destroyers and CG 47-guided missile cruisers to conduct:

- Area and self-defense anti-air warfare in defense of the Strike Group
- Anti-surface warfare and anti-submarine warfare
- Strike warfare, when armed with Tomahawk missiles
- IAMD to include simultaneous offensive and defensive warfare operations
- Operations independently or in concert with Carrier or Expeditionary Strike Groups and with other joint or coalition partners

Major Contractors

- General Dynamics Marine Systems Bath Iron Works – Bath, Maine
- Huntington Ingalls Industries (formerly Northrop Grumman Shipbuilding) – Pascagoula, Mississippi
- Lockheed Martin Maritime Systems and Sensors – Moorestown, New Jersey

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Activity

- The Navy continued Baseline 9A operational testing in December 2015, but weather and schedule constraints prevented execution of a majority of the planned events. Uncompleted events include a combined surface warfare and air defense firing scenario and a combined supersonic sea-skimming and subsonic sea-skimming anti-ship missile raid. The Navy currently has not re-scheduled these events.
- The Navy began at-sea operational testing of Baseline 9C in March 2016. Two of three planned air defense scenarios were executed, with one of the scenarios executed twice due to execution difficulties. A multi-mission firing scenario combining air defense and surface warfare could not be conducted because of ship system problems and uncooperative weather. Additional surface warfare tracking exercises also remain unexecuted.
- The Baseline 9C testing in March 2016 included operational testing in the undersea warfare area in conjunction with AN/SQQ-89 testing. The undersea warfare testing included exercises against USS *Cheyenne* (SSN 773).
- The Navy planned to conduct Baseline 9C manned aircraft raids in late FY16, but was unable to schedule needed supporting assets. A planned live-firing event including both supersonic and subsonic anti-ship cruise missile surrogates was deferred prior to the start of the March 2016 testing due to GQM-163 aerial target availability.
- Remaining Baseline 9C operational testing, including previously unexecuted events, deferred events, a maintenance demonstration, and cybersecurity testing are planned to occur in FY17.
- The Navy conducted all operational testing in accordance with the DOT&E-approved test plans.
- In February 2016, the SECDEF directed the Navy to acquire long-lead items needed for an Aegis and AMDR SDTS required for conducting adequate self-defense operational testing for DDG 51 Flight III, Aegis ACB-20, AMDR (also known as AN/SPY-6), and ESSM Block II. The Navy complied with this direction by budgeting for a single face of the AMDR to be procured. However, the Navy has not budgeted for the needed Aegis Combat System or the test resources to support the self-defense operational testing for DDG 51 Flight III. The Navy also was directed to update the Aegis/Flight III, AMDR, and ESSM TEMPs, to include the Aegis SDTS and self-defense test events; the Navy has not complied with this direction.
- The Navy is developing an M&S suite that can supplement live testing and facilitate a robust statistical evaluation of air defense performance for DDG 51 Flight III ships after an Aegis-equipped SDTS is available in FY23. As part of the overall M&S development effort, the Navy plans to make limited use of the suite for operational testing of the ACB-16 (Baseline 9C2) in FY22.
- NIFC-CA FTS Increment I became a fielded capability in 2015 after completing developmental testing and is now fully integrated as a tactical option in fleet air defense. Future testing of the ACB-16 and ACB-20 Aegis Modernizations and SM-6 will evaluate the NIFC-CA FTS Increment II capability.
- In September 2016, at White Sands Missile Range, New Mexico, the Navy and Marine Corps successfully conducted a NIFC-CA FTS Increment I demonstration event using an F-35 Lightning II as a targeting source for the Aegis Baseline 9 Desert Ship test configuration and the SM-6. This demonstration was part of developmental testing and did not represent a fleet operational configuration of the ACS or the communications path that would be needed. The demonstration used a non-tactical engineering computer software build in the Aegis Desert Ship test site – itself not fully representative of the ACS – interfaced to a datalink gateway that could receive the F-35 Multifunction Advanced Data Link (MADL) and port track data from the aircraft sensor to the AWS. Using this track data, an SM-6 was initialized and launched at an MQM-107 unmanned target drone.

Assessment

- Baseline 9A and 9C testing completed to date was not sufficient to support an assessment of operational effectiveness or suitability prior the FY15 USS *Normandy* and USS *Benfold* deployments. In accordance with Section 231 of the National Defense Authorization Act for FY08, DOT&E submitted Early Fielding Reports for each baseline. The 12 live flight tests events on Baseline 9A and 9C ships to date suggest that area air defense performance against single subsonic and supersonic high-diving targets is consistent with historical performance against comparable threats, but is not necessarily operationally relevant. The Navy has not yet demonstrated performance against more stressing presentations during operational testing. Operational testing, to include more stressing presentations, is planned to continue through FY17.

- The Navy will not fully assess Aegis IAMD until an AWS M&S test bed is developed and validated. The test bed is under development and is planned to be available by FY20; however, there is no agreed upon strategy to validate the model to support assessment of the close-in, self-defense battlespace. A limited Baseline 9C IAMD operational assessment suggests that DDGs can simultaneously support limited air defense and ballistic missile defense missions, within overall radar resource constraints. This assessment is supported by a single successful live firing event, managed by the Missile Defense Agency, which included simultaneous live firing of SM-2 and SM-3 missiles against threat representative targets in an IAMD engagement.
- Although not presented for operational testing, the Baseline 9A surface warfare performance, specifically to counter high-speed surface threats in littoral waters, as demonstrated during developmental testing, indicated no improvements over previous Aegis baseline operational test results. For both Baseline 9A and 9C, these results indicate that AWS does not fully meet desired surface warfare performance levels.
- As appropriate, and until the full capability may be operationally tested, DOT&E will provide periodic capability assessments to inform Navy and OSD leadership, as well as Congress, on the progress of T&E of the IAMD mission area.
- Until an Aegis-equipped SDTS is available for testing, it is neither possible to characterize the self-defense capabilities of the Aegis cruisers and destroyers, nor possible to accredit an M&S suite to determine if the ships satisfy their Probability of Raid Annihilation requirements.
- The Navy's NIFC-CA FTS Increment I test events conducted to date were sufficient to demonstrate basic capability; however, these demonstrations were not conducted under operationally realistic conditions or against aerial targets representative of modern threats. Additionally, the scenarios conducted were not sufficiently challenging to demonstrate the NIFC-CA FTS requirements defined in the Navy's September 2012 NIFC-CA FTS Testing Capability Definition Letter. DOT&E will assess and report NIFC-CA FTS (Increment II) performance as part of the FY18-23 ACB-16 and ACB-20 Aegis Modernization operational testing and SM-6 FOT&E.
- The Navy's combined Baseline 9 and SM-6 FOT&E test events to date have been successful with no SM-6 integration issues revealed.
- The Navy's Aegis Baseline 9A cybersecurity testing revealed significant problems, which are classified. The nature of these problems is such that they could pose significant risk to the cybersecurity. Details can be found in DOT&E's Early Fielding Report dated July 2015.
- Changes made to the radar software presented unexpected problems during the initial phase of the Aegis cruiser at-sea operational test. The Navy is addressing these problems and remaining cruiser and destroyer operational testing will provide opportunities to confirm these items have been mitigated.
- During both integrated and operational test events, instability of the Aegis operator consoles adversely affected the conduct of test events. The Navy is addressing these problems and remaining cruiser and destroyer operational testing will provide opportunities to confirm these items have been mitigated.
- Aegis Baseline 9C has incorporated software changes to address performance against certain stressing air defense threat presentations; however, these changes proved ineffective during developmental testing.
- The Navy conducted under-sea warfare (USW) testing on Aegis Baseline 9C utilizing USS *Cheyenne* (SSN 773) as a live, reactive threat surrogate. This testing was more operationally realistic than previously reported USW testing that utilized non-reactive threat simulators. Analysis of test results is ongoing. DOT&E will report on USW mission effectiveness in the final Aegis Baseline 9 operational test report.
- In September 2016, at White Sands Missile Range, New Mexico, the Navy and Marine Corps successfully conducted a NIFC-CA FTS Increment I demonstration event using an F-35 Lightning II as a targeting source to allow the ACS (partial) installed at the Desert Ship test facility, WSMR New Mexico, to engage an aerial target with the SM-6. The configuration of the F-35 and the Desert Ship was not operationally representative, nor was the communications path that would be needed replicated for the test. This demonstration was part of developmental testing and did not represent a fleet operational configuration of the ACS. The demonstration used a non-tactical engineering computer software build in the Aegis Desert Ship test site – itself not fully representative of the ACS – interfaced to a datalink gateway that could receive the F-35 MADL and port track data from the aircraft sensor to the AWS. Using this track data, an SM-6 successfully engaged an MQM-107 unmanned target drone. This demonstration was conducted as a proof of concept to show that the NIFC-CA FTS Increment I capability could utilize additional airborne sensors to provide fire control quality data to the AWS. In the context of the event, this objective was met; however, this demonstration should not be construed as an operational capability.

Recommendations

- Status of Previous Recommendations. The Navy has not addressed the following previous recommendations from FY14. The Navy still needs to:
  1. Continue to improve Aegis ships' capability to counter high-speed surface threats in littoral waters.
  2. Synchronize future baseline operational testing and reporting with intended ship-deployment schedules to ensure that testing and reporting are completed prior to deployment.
  3. Provide the necessary funding to support the procurement of an advanced air and missile defense radar and Aegis-equipped SDTS that are needed to support Aegis Modernization, advanced AMDR DDG 51 Flight III, and ESSM Block 2 operational testing.
  4. For Baseline 9A, develop and deploy necessary cybersecurity corrective actions and verify correction with a follow-on operational cybersecurity test.
- FY16 Recommendations. The Navy should:
  1. Complete the planned FOT&E events as detailed in the approved test plan as soon as practical.
  2. Produce an integrated test strategy and capture that in the TEMPs to be approved by DOT&E for the DDG 51 Flight III, AMDR, Aegis Modernization, and ESSM Block 2 programs as soon as possible.
  3. Include planning for NIFC-CA FTS Increment II and NIFC-Collateral (CC) testing in future updates to the Aegis Modernization ACB-16 and ACB-20 and SM-6 TEMPs.

AGM-88E Advanced Anti-Radiation Guided Missile (AARGM) Program

Executive Summary

- The AGM-88E Advanced Anti-Radiation Guided Missile (AARGM) is not operationally suitable and not operationally effective after Block 1 operational testing was prematurely terminated. DOT&E rescinded approval of the Block 1 operational test plan on June 13, 2016, after numerous performance problems were discovered but not corrected, a significant decline below Capability Production Document (CPD) Key System Attribute (KSA) requirements in reliability occurred, and multiple revisions to the software were made causing serious concern over software stability.
- AARGM was previously evaluated as operationally suitable, but not operationally effective due to multiple deficiencies discovered during IOT&E in FY11-12. Reliability problems below CPD requirements were noted during IOT&E, but the subsequent Verification of Correction of Deficiencies resulted in an improving reliability growth curve projection and numbers which met the CPD reliability requirements.
- The Block 1 Upgrade integrated testing was conducted by Navy test squadrons VX-31 and VX-9 beginning in 4QFY14 and ending after DOT&E rescinded approval in 3QFY16.
- The Navy held a Gate 6 Review on August 2, 2016, to determine the way forward for the program. At this review, the operational test community for the AARGM program (VX-9, Commander, Operational Test and Evaluation Force (COTF), and DOT&E) detailed the numerous problems and deficiencies noted affecting weapon accuracy, declining weapon reliability well below the CPD requirements, and software stability concerns after multiple software changes during the Block 1 Upgrade testing. The Program Office stated that they were now meeting all Key Performance Parameters (KPPs) and should be allowed to continue testing. The operational test community acknowledged that the program is meeting KPPs, but pointed out that the weapon system is failing to meet a KSA (reliability) and several other significant CPD requirements, which affect system performance and accuracy and significantly limit effectiveness against many advanced threats and threat counter-anti-radiation missile (ARM) tactics. Moreover, software was being revised and was not stable for operational testing. Software must be stable and fully production representative with numerous new versions used during operational testing. The Navy leadership agreed with the Program Office and directed that testing continue as developmental testing with VX-9, COTF, and DOT&E participating in an assisting role as necessary/desired.
- The Navy intends to release the Block 1 Upgrade software to the fleet in 3QFY17 without completing operational testing and without adequately addressing the numerous performance, reliability, and software stability problems discovered during Block 1 Upgrade testing.
- AARGM Extended Range (ER) is currently based on the Block 1 Upgrade weapon and will require extensive work to correct the accuracy, reliability, and software deficiencies discovered during Block 1 testing.

System

- AARGM supplements the AGM-88B/C High-Speed Anti-Radiation Missile (HARM) and is specifically designed to prosecute targets that stop radiating, executing point-to-point missions against traditional and non traditional air defense systems.
- AARGM uses a new guidance section and a modified HARM control section and fins. The Navy intends to employ AARGM on F/A-18A-F and EA-18G platforms.
- AARGM incorporates digital Anti-Radiation Homing, a GPS, Millimeter Wave guidance, and a Weapon Impact Assessment transmitter.
  - Anti-Radiation Homing improvements include an increased field of view and increased detection range compared to HARM.
  - The GPS allows position accuracy in location and time.
  - The Weapons Impact Assessment capability allows transmission of real-time hit assessment via a national broadcast data system.
  - The Millimeter Wave radar technology allows target discrimination and guidance during the terminal flight phase.
  - The Weapon uses an internal GPS and Inertial Navigation System with mission planning data to establish Missile Impact Zones and Missile Avoidance Zones in an effort to reduce fratricide.

- The Navy intended for the AARGM Block 1 Upgrade (a software-only upgrade) to deliver Full Operational Capability, including Block 0 capability improvements and software changes to provide deferred capability requirements and address deficiencies identified during IOT&E.

Mission

Commanders employ aircraft equipped with AARGM to conduct pre-planned, on-call, and time-sensitive reactive anti-radiation targeting to suppress, degrade, and destroy radio frequency enabled surface-to-air missile defense systems regardless whether the systems continue radiating or shut down.

Major Contractor

Orbital/Alliant Techsystems – Northridge, California

Activity

- In June 2015, DOT&E approved the AARGM FOT&E test plan developed by the Program Office and COTF. The test plan was adequate to address the testing of deferred capabilities and deficiencies discovered during initial developmental test and evaluation and IOT&E.
- The Block 1 Upgrade integrated testing was conducted by Navy test squadrons VX-31 and VX-9 beginning in 4QFY14 and ending after DOT&E rescinded approval in 3QFY16.
- Based on numerous deficiencies discovered during Phase 1 testing and subsequent rounds of testing, significant software updates were required, and an additional integrated test phase was introduced (Phase 1a). Software versions R2.1, R2.2, R2.2.1, R2.2.2, and R2.2.3 were created and delivered during integrated testing to address some of these deficiencies. R2.2.3 is the current version of software for the Block 1 Upgrade.
- The Navy conducted eight live fire test events during Block 1 Upgrade testing. Two of the eight tests have been determined failures, with both impacting the ground significant distances away from their intended targets and having little to no weapons effect on the actual targets. A thorough analysis of the causes of these weapon misses revealed several significant classified problems affecting the accuracy of the weapon. While these problems do not affect KPPs, they do negatively affect weapon performance and accuracy.
- Multiple operational mission failures (OMFs) occurred during the Block 1 Upgrade testing. Four of the nine weapons delivered to China Lake, California, for testing had hardware failures and were returned to the manufacturer. Subsequent testing revealed a much higher number of OMFs than was previously encountered during IOT&E with system-of-system reliability of 20.77 hours Mean Time Between Operational Mission Failure (MTBOMF) as compared to the CPD requirement and KSA of 28.0 hours (Production Threshold and 280.0 hours Production Objective) and a system under test reliability of 31.15 hours MTBOMF as compared to the CPD requirement of 72.0 hours.
- DOT&E rescinded approval of the operational test plan on June 13, 2016, and directed additional measures to restart OT&E to correct the classified problems affecting weapon accuracy.
- DOT&E also directed the Navy to develop an updated live fire test plan that would result in an acceptable level of statistical confidence after two of the eight live fire shots failed. At a minimum, DOT&E believed that 5 more live fire shots, for a total of 13, would be needed to gain the required statistical confidence in the Block 1 Upgrade.
- DOT&E recommended that the Navy develop a plan to improve weapon reliability as weapon reliability during FOT&E was considerably worse than demonstrated in the poor results of IOT&E.
- The Navy appropriated funding for Orbital/Alliant Techsystems to conduct an assessment to identify near term risks of thermal protection properties of the current nose cone and seeker if the rocket motor were redesigned to extend the missile range. If the assessment results are positive, the Navy is considering funding Orbital/Alliant Techsystems to redesign the rocket motor to use with the current Block 1 seeker for an AARGM ER variant.

Assessment

- The FY16 status is assessed as not operationally suitable and not operationally effective due to numerous deficiencies with weapon performance, accuracy, reliability, and software stability revealed during Block 1 Upgrade testing. The details of these deficiencies will be discussed in the forthcoming classified Block 1 Upgrade Operational Test Report.
- Based on IOT&E test data, AARGM was determined to be operationally suitable, but not operationally effective. The details of these deficiencies are discussed in the classified DOT&E IOT&E report published in August 2012.
- The Navy streamlined the Block 1 Upgrade test design and utilized a combined test strategy of developmental and operational testing simultaneously in a prolonged integrated test phase. There was no dedicated developmental testing designed into this test plan. In retrospect and for future AARGM ER testing, a dedicated developmental test phase is necessary for a weapon system software upgrade of this magnitude. This creates a dedicated period of problem discoveries and corrections to take place prior to beginning operational testing with an operationally representative and stable software version and weapon system.
- The discovery of significant problems found during the detailed analysis of the two live fire test shot failures are classified but significantly affect weapon accuracy and performance. The Navy has chosen to accept the problems

without correction because they are not tied to KPPs and will continue with the software release and fielding. These significant problems mean AARGM will not be effective if used to target existing advanced threat surface-to-air missile systems in current and future conflicts using AARGM. Future doctrine is being developed on the faulty premise that AARGM will be able to address these advanced systems, particularly in an Anti-Access and Area Denial (A2AD) environment. The Navy needs to fix the problems discovered during the Block 1 Upgrade FOT&E, or change their future doctrine to reflect the limitations discovered during this failed operational test.

- The Navy is planning on releasing the Block 1 Upgrade to the fleet without adequate operational testing after DOT&E rescinded approval of the test plan and required the Navy to fix several classified problems affecting weapon accuracy and performance and to correct its declining reliability. The Navy decided to continue testing without correcting the majority of these classified deficiencies or addressing the reliability problems. The Block 1 Upgrade only corrects two deferred KPPs from Block 0 and delivers only a small increase in capability while introducing a host of new performance and worsening reliability problems.
- Block 1 Upgrade performance provides limited employment capability against advanced threat surface-to-air radar systems. AARGM ER is currently based on the Block 1 Upgrade technology and will require extensive work to correct the accuracy, reliability, and software deficiencies discovered during Block 1 testing and documented in DOT&E's memo to the Assistant Secretary of the Navy for Research, Development, and Acquisition dated June 13, 2016.

Recommendations

- Status of Previous Recommendations. The Navy addressed all previous recommendations.
- FY16 Recommendations. The Navy should:
  1. Submit an updated operational test plan for DOT&E's approval to correct the accuracy, reliability, and software deficiencies discovered during previous Block 1 testing prior to fleet release. Conduct dedicated developmental testing prior to further operational testing to ensure the operational test asset performance is stable and is production representative.
  2. Assess current and future Navy and Marine Corps doctrine to counter advanced threat surface-to-air missile systems, particularly in an A2AD environment, taking into account the classified problems discovered during previous testing.
  3. Improve seeker performance against advanced threat surface-to-air radar systems prior to investing time, money, and resources in extending the current system's range in an AGM-88E AARGM ER concept.

Amphibious Assault Vehicle (AAV) Survivability Upgrade (AAV-SU)

Executive Summary

- The Amphibious Assault Vehicle (AAV) – Survivability Upgrade (AAV-SU) program initiated prototype build and test planning in FY15. The Marine Corps started test execution in FY16.
  - Ballistic testing of new external armor coupons completed in June 2016. Preliminary results demonstrate specification-level performance against direct and indirect fire threats, but additional testing is required to fully characterize all areas of the crew-occupied space against the expected range of threats.
  - System-level live fire testing to assess the survivability of the AAV-SU and its crew against mines and IEDs began in September 2016 and will be followed by ballistic exploitation testing to further assess all vulnerable areas.
- Operational testing is scheduled to commence in 2QFY17.

System

- The AAV Family of Vehicles is the U.S. Marine Corps' principal amphibious lift system and armored personnel carrier. It is designed to provide combat support, armor-protected firepower, and mobility for a reinforced rifle squad and associated combat equipment for operations on land or at sea.
- After-action reports from Operation Iraqi Freedom highlighted AAV shortfalls in survivability against explosive threats such as landmines and IEDs. These shortfalls limited the employment of AAVs in Iraq after 2007 and precluded employment in Afghanistan.
- The Marines intend for the AAV-SU program to improve force protection against underbelly explosive threats and maintain land and water mobility performance.
  - The survivability upgrades include new external armor, added spall liner, underbelly protection, lower sidewall protection, integrated blast-mitigating seats, and improved fuel tanks.
  - The performance upgrades account for the added weight due to survivability upgrades and include improvements to the powertrain and suspension in order to maintain or increase the vehicle's land and water mobility performance compared to the current vehicle.
- Initial Operational Capability for the AAV-SU is planned for FY19. It will reach Full Operational Capability in FY23 and it must be sustained until at least 2030. The remainder of the legacy AAVs will be phased out as Amphibious Combat Vehicle increments are fielded. The Marine Corps will field AAV-SU vehicles to each of its two active-component Assault Amphibian Battalions, as well as to the Combat Assault Battalion, 3rd Marine Division, and the Combat Assault Company, 3rd Marine Regiment. Additional vehicles will be utilized for training, testing, and supporting the maintenance cycle.

Mission

- Commanders employ Assault Amphibian Battalions to provide task organized forces to transport assault elements, equipment, and supplies ashore; execute ship-to-shore, shore-to-shore, and riverine operations; support breaching of barriers and obstacles; and provide embarked infantry with armor-protected firepower, communication assets, and mobility.
- AAV-SU-equipped units support surface power projection and, if necessary, forcible entry against a defended littoral region.

Major Contractor

- SAIC – McLean, Virgina

Activity

- The Marine Corps conducted armor coupon testing from May to June 2016 in accordance with a DOT&E-approved test plan.
- DOT&E approved the detailed live fire test plan for the AAV-SU Engineering Manufacturing Development (EMD) Phase in April 2016. The plan includes system-level live fire testing scheduled to occur from September through December 2016 followed by ballistic exploitation testing intended to assess targeted damage tolerance of unique and anticipated system design weaknesses (e.g., armor seams).
- Operational testing is scheduled to begin in 2QFY17.

Assessment

- Preliminary analysis of armor coupon testing confirms that the armor is on track to meet its specifications but additional testing is required to fully characterize all areas of the crew-occupied space against the expected range of threats. Due to the lack of sufficient quantity of armor coupons, the Program Office deferred the additional armor characterization to the ballistic exploitation phase of testing. Armor characterization at this stage in the program could complicate design changes if testing reveals significant armor shortfalls.
- Preliminary evaluation of the first underbody event data, conducted against the AAV-SU at the end of FY16, revealed a system design vulnerability that the Program Office is already investigating and addressing. Analysis of all four system-level live fire events is ongoing and will be reported in the FY17 DOT&E LFT&E report.

Recommendations

- Status of Previous Recommendations. This is the first annual report for this program.
- FY16 Recommendation.
  1. The Marine Corps should ensure that enough test assets (e.g., armor coupons) are allocated for the appropriate phases of test for both the AAV-SU and Amphibious Combat Vehicle 1.1 programs.

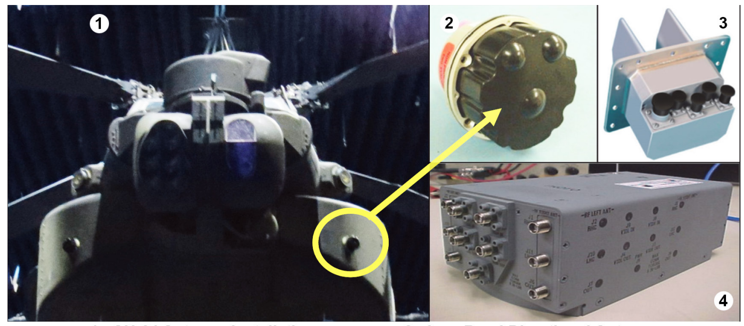
AN/APR-39D(V)2 Radar Signal Detection Set (RSDS)

Executive Summary

- Preliminary results indicate that the AN/APR-39D(V)2 Radar Signal Detection Set (RSDS) has resolved the legacy deficiencies of the AN/APR-39 family (A(V)2, A(V)4, B(V)2, and C(V)2) of Radar Warning Receivers (RWRs).
- Preliminary results indicate an integration problem between the AH 64E platform and AN/APR 39D(V)2 audio warnings. Lack of audio warnings from the AN/APR 39D(V)2, as experienced in developmental test period 2 (DT2), could reduce an aircrew's situational awareness in contested environments.
- Preliminary results indicate the system has a low Mean Time Between Operational Mission Failure (MTBOMF) as tested on the Army's AH 64E platform.

System

- The AN/APR-39D(V)2 is a digital upgrade to the AN/APR-39 family of analog RWRs used by nearly all DOD rotorcraft.
- The AN/APR-39D(V)2 RSDS consists of the following:
  - Four new dual-polarized E through M band (high band) antennas, and a C though D band (low band) direction of arrival antenna.
  - New quadrant receivers (two to four per aircraft). Each receiver has two channels that can accept signals from two E through M band antennas.
  - A new radar data processor with two wideband digital receivers.
  - A crystal video receiver processor and a Quad Core i7 based processor.



1 - AH-64 Antenna Installation
2 - High Band Quadrant Antenna
3 - Low Band Directional Antenna
4 - Quadrant Receiver

- The system uses either a separate display unit or integrates with the onboard aircraft displays to visually and aurally alert the pilots to active threat radars.
- For Navy aircraft, the system also acts as the electronic warfare bus controller.

Mission

Commanders employ units equipped with the AN/APR-39D(V)2 RSDS to improve the mission survivability of Navy and Army aircraft by identifying radio frequency signals from threat surface-to-air missiles, airborne interceptors, and anti-aircraft artillery through cockpit alerts.

Major Contractor

Northrop Grumman – Rolling Meadows, Illinois

Activity

- This is a Navy-led program, but the Army has assumed the test lead due to Navy test aircraft availability problems.
- The Army completed Developmental Test period 1 (DT1) with the AH-64E at the Electronic Combat Range in China Lake, California, in April 2016.
- The Army completed anechoic chamber integrated developmental/operational testing with the AH-64E at the Joint Preflight Integration of Munitions and Electronic Systems facility at Eglin AFB, Florida, in July 2016.
- The Army completed DT2 with the AH 64E at the Electronic Combat Range in October 2016.
- The Army conducted all testing in accordance with the DOT&E-approved test plans.
- The Army completed an operational assessment with the AH-64D and AH-64E at the Electronic Combat Range in November 2016.

Assessment

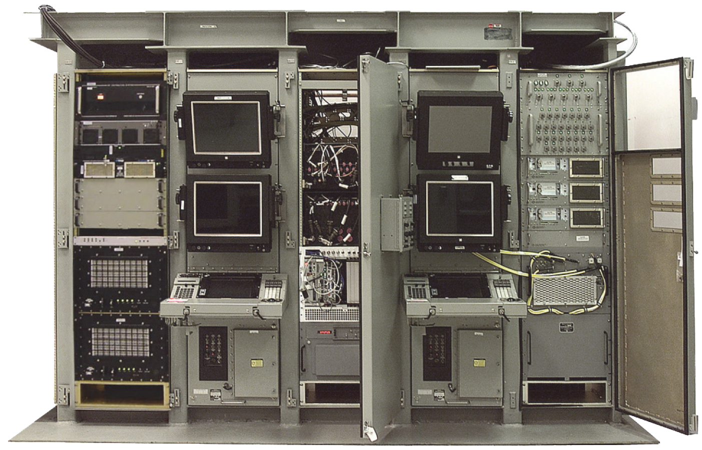
- Preliminary results indicate that the AN/APR-39D(V)2 RSDS has resolved most of the legacy deficiencies of the AN/APR-39 family of RWRs (A(V)2, A(V)4, B(V)2, and C(V)2).
- Preliminary results indicate an integration problem between the AH-64E platform and AN/APR 39D(V)2 audio warnings. Lack of audio warning from the AN/APR 39D(V)2, as experienced in DT2, could reduce an aircrew's situational awareness in contested environments.
- Preliminary results from laboratory testing indicate that a small number of radar modes could not be detected by the AN/APR-39D(V)2 system. The Navy and Army have requested modifying those symbols to mitigate this limitation.
- Excessive system resets and system degrades occurred during DT1. A reduced number of system resets and system degrades occurred during DT2 as compared with DT1.

- Preliminary results indicate the system has a low MTBOMF. Testing on the Army's AH-64E platform demonstrated an MTBOMF of 6.7 hours, well below the mission-based derived requirement of 102 hours for the AH-64E and 81 hours for the MV-22B. The Navy intends to fly a KC-130T as a surrogate to accumulate flight hours for system reliability assessment, but available flight hours will not allow demonstration of reliability requirements by the end of FOT&E.
- The system passed all electro-magnetic interference requirements except conductive susceptibility. The system experienced some anomalies for conductive susceptibility during electro-magnetic interference requalification.

Recommendations

- Status of Previous Recommendations. The Navy accomplished all previous recommendations.
- FY16 Recommendations. The Navy and Army should:
  1. Investigate and correct the integration problem related to the lack of AN/APR 39D(V)2 audio warning messages before the Army's AH-64E OT&E in 3QFY17.
  2. Investigate and correct the causes of all system software resets and system degrades.
  3. Incorporate all software and hardware corrections prior to the Navy's anechoic chamber testing with the MV-22 in 2QFY17.
  4. Plan and fly additional KC-130T flights to accumulate more operational flight hours for system reliability assessment.

AN/BLQ-10 Submarine Electronics Warfare Support System



Executive Summary

The Navy conducted an FOT&E of the AN/BLQ-10 system with the Technical Insertion 10 (TI-10) upgrade and the Multifunction Modular Mast (MMM) in August 2016. Analysis of the test results is in progress. DOT&E will provide the final assessment in a 2QFY17 FOT&E Report.

System

- The AN/BLQ-10 system is an electronic warfare support system for U.S. submarines. It provides automatic intercept capability (detection, classification, localization, and identification) for both radar and communications signals. Multiple subsystems process radar and communications signals.
- The AN/BLQ-10 processes signals collected with the submarine's masts. Radar signals are collected by the imaging mast, which is either a photonics mast (on the *Virginia* class) or a periscope (on all other classes). Communications signals are collected from both the imaging mast and a dedicated communications intercept mast, which is either an AN/BRD-7 (on the *Los Angeles* and *Seawolf* classes), an AN/BSD-2 (on the *Virginia* class), or an MMM (recently fielded on some *Los Angeles*- and *Virginia*-class ships). These masts provide largely the same functionality but with different frequency coverage and localization accuracy.
- The program is adopting an open architecture, incremental development process. Hardware and software updates, referred to as a TI, will be fielded every 2 years. TI-08 was the first such upgrade, which added a subsystem to intercept some Low Probability of Intercept (LPI) radar signals.
- The AN/BLQ-10 provides support for specialized, carry-on electronic warfare equipment and personnel.
- TI-10 has been fielded. It consists of updates to commercial off-the-shelf (COTS) processors and displays, as well as upgrades of the Radar Narrowband to improve reliability and maintainability, the addition of Auto Specific Emitter Identification (Auto SEID) to enable automation of the SEID collection processes, and a Nonlinear Resonance Classifier (NRC) upgrade for Improved Communications Acquisition and Direction Finding (ICADF).
- The first TI-14 installations will complete in early FY17, with the first deployment in late FY17 or FY18. It consists of updates to COTS processors and displays, Electronic Warfare Server First Generation, which provides the Electronic Support System operator and platform decision makers with improved tactical situational awareness, and a Radar Rules of Thumb algorithm to provide an assessment of counter detection.

Mission

Submarine Commanders use the AN/BLQ-10 electronic warfare support system to provide threat warning information to avoid counter-detection and collision, and to conduct intelligence, surveillance, and reconnaissance in support of fleet or battlegroup objectives

Major Contractor

Lockheed Martin Mission Systems and Training – Syracuse, New York

Activity

- The Navy:
  - Performed developmental testing on the radar cross section (RCS) of the MMM in June 2015, and released a classified report of the findings in 4QFY15. The Navy conducted additional developmental RCS testing of the MMM in August 2016.
  - Conducted system integration testing in September 2015, to support future developmental tests for TI-14, the next technical insertion release on AN/BLQ-10.
- Commander, Operational Test and Evaluation Force (COTF), the Navy operational test activity:

- Performed a maintenance demo of AN/BLQ-10 in December 2015 to assess maintainability at the Naval Undersea Warfare Center, Newport, Rhode Island.
- Conducted an FOT&E of AN/BLQ-10 TI-10 in August 2016 on a *Virginia*-class submarine while underway. This test assessed the improvement in the direction finding abilities of AN/BLQ-10, improvements in the probability of detection and identification of radar emitters, and the integration of the Auto SEID capability. The test was performed in accordance with the DOT&E-approved test plan.

Assessment

- This report provides only a preliminary assessment of the AN/BLQ-10 system with TI-10 based on a June 2015 developmental test report supporting the August 2016 operational test. DOT&E will provide the final assessment in the 2QFY17 FOT&E report after the August 2016 TI-10 operational test data have been analyzed.
- Based on results from the at-sea developmental test in August 2014, there have been no significant changes to communications Direction Finding or radar Direction Finding accuracy from TI-08 to TI-10.
- The addition of the NRC algorithm was intended to reduce workload and improve the performance of ICADF. Initial developmental test results suggest the algorithm has been integrated successfully, but the data analysis of the August 2016 TI-10 operational test must be completed before the operational effectiveness of the system for communications intercept can be assessed.
- Similarly, the performance and functionality of Auto SEID cannot be assessed until the data analysis of the August 2016 TI-10 operational test is complete.
- Several results from previous (TI-08) testing are still applicable to TI-10:
  - The AN/BLQ-10 system is limited in operational effectiveness for some threat radars. The Navy has not yet conducted operational testing against some modern threat radars or appropriate surrogates. The system does detect some radars at long ranges; however, operational testing was inadequate to determine the extent operators can use the AN/BLQ-10 to support submarine missions.
  - The TI-08 upgrade provided improved intercept capability against the intended LPI radars. However, the number of threat LPI radars in the world is increasing and the Navy will need to develop future upgrades to keep up with newer technology.
  - The MMM provides communications localization accuracy that would be sufficient for most submarine missions. TI-08 operational testing showed the system did not meet the Navy's established thresholds.
  - During the TI-08 operational testing, AN/BLQ-10 was not operationally suitable because the Navy's training system was not sufficient to allow fleet operators to maintain proficiency on the system. The Navy has updated their training program, both in classrooms and on individual submarine platforms. While data analysis is not complete, observations taken during the TI-10 operational test did not note any training shortfalls. DOT&E will assess TI-10 suitability once data analysis of the reliability data is completed.

Recommendations

- Status of Previous Recommendations. The Navy has addressed all previous recommendations.
- FY16 Recommendations. As the data analysis is currently ongoing, any future recommendations will be included in the 2QFY17 FOT&E Report.

AN/BQQ-10 Acoustic Rapid Commercial Off-the-Shelf Insertion (A-RCI) Sonar

Executive Summary

- DOT&E submitted a classified FOT&E report on the Advanced Processing Build 2011 (APB-11) variant of the AN/BQQ-10 Acoustic Rapid Commercial Off-the-Shelf Insertion (A-RCI) sonar system in November 2015.
- The Navy commenced FOT&E on the APB-13 variant of the AN/BQQ-10 A-RCI sonar system with an evaluation of the cybersecurity capability and in-lab comparison testing between APB-11 and APB-13. At-sea operational testing of APB-13 is expected to complete in FY17.

System

- The AN/BQQ-10 A-RCI sonar system is the undersea sensing system utilized by U.S. submarines. It uses active and passive sonar to conduct anti-submarine warfare (ASW) and submerged operations in the execution of all submarine assigned missions. Acoustic energy is processed and displayed to enable operators to detect, classify, localize, and track threat submarines and other waterborne objects (surface ships, mines, bottom features, etc.).
- AN/BQQ-10 A-RCI sonar system is an open architecture system that includes biennial software upgrades (APBs) and quadrennial hardware upgrades (Technology Insertions). These upgrades are intended to maintain an advantage in acoustic detection of threat submarines.
- The AN/BQQ-10 A-RCI sonar system consists of:
  - Interface to submarine acoustic sensors to include the spherical array or large aperture bow array, hull array, wide aperture array, conformal array, high-frequency array, and two towed arrays (i.e., the fat line array consisting of the TB-16 or TB-34, and the thin line array consisting of the TB-23 or TB-29).
  - Processing capability that utilizes environmental data (i.e., water depth, bottom contour, sound velocity profiles, etc.) and received acoustic energy on all acoustic sensors and displays the processed data in a way that supports operator search, detection, classification, and localization/track of contacts of concern or contacts of interest.

Mission

The Operational Commander will employ submarines equipped with the AN/BQQ-10 A-RCI sonar system to:

- Search for, detect, and track submarine and surface vessels in open-ocean and littoral sea environments
- Search for, detect, and avoid mines and other submerged objects
- Covertly conduct intelligence, surveillance, and reconnaissance
- Covertly conduct Naval Special Warfare missions
- Perform under-ice operations

Major Contractor

Lockheed Martin Maritime Systems and Sensors – Manassas, Virginia

Activity

- In November 2015, DOT&E submitted a classified FOT&E report on the APB-11 variant of the AN/BQQ-10 A-RCI sonar system.
- In July 2016, the Navy conducted cybersecurity testing on the APB-13 variant of the AN/BQQ-10 A-RCI sonar system in accordance with a DOT&E-approved test plan.
- In August 2016, the Navy commenced in-lab comparison testing between variants APB-11 and APB-13 of the AN/BQQ-10 A-RCI sonar system using recorded data. Data are being collected during a combined developmental and operational test event in accordance with a DOT&E-approved data collection plan. The Navy will supplement its operational assessment with in-lab comparison testing for environments that are not available for at-sea testing. An operational test of APB-13 at-sea performance will commence in FY17.

Assessment

- In the November 2015 classified FOT&E report, DOT&E determined that the APB-11 variant of the AN/BQQ-10 A-RCI sonar system's overall mission performance remains unchanged from previous assessments and further observed an

improvement in system reliability. The report concluded the following regarding performance:
- For ASW, APB-11 passive sonar capability is effective against older classes of submarines in some environments, but is not effective in all environments or against modern threats. Despite an unchanged overall assessment, APB-11 demonstrated improved operator performance metrics over previous APB variants.
- APB-11 is not effective in supporting operator situational awareness and contact management in areas of high contact density; however, platforms equipped with a Light Weight Wide Aperture Array demonstrated improved performance over previous APB variants.
- APB-11 cybersecurity is not effective and remains unchanged from previous variants.
- APB-11 is operationally suitable.
- Analysis of the APB-13 cybersecurity testing is ongoing and results will be reported in FY17.
- In-lab comparison testing between APB-11 and APB-13 will continue into FY17. DOT&E can make no preliminary assessment due to testing being incomplete.
- Due to the biennial software and quadrennial hardware development cycle, the Navy generates and approves the requirements documents and Test and Evaluation Master Plans in parallel with APB development and installation. As a result, the fleet assumes additional risk, since most operational testing is not completed before the system is initially deployed.

Recommendations
- Status of Previous Recommendations. The Navy made progress in addressing four of five recommendations outlined in DOT&E's classified FOT&E report on APB-11, dated November 12, 2015. Six significant recommendations remain outstanding from previous DOT&E reports. The significant unclassified recommendations are:
  1. Re-evaluate the use of the current time difference between system and operator detection times as the ASW Key Performance Parameter for a more mission-oriented metric to accurately characterize system effectiveness.
  2. Evaluate the covertness of the high-frequency sonar during a future submarine-on-submarine test.
  3. Determine the performance of the AN/BQQ-10 A-RCI sonar system in detecting near surface mines.
  4. Evaluate AN/BQQ-10 A-RCI metrics to improve performance under varying environmental conditions and to focus on earlier and longer range operator detection.
  5. Perform an ASW event against a high-end, diesel-electric, hunter-killer submarine at least with the other APB variants (i.e., APB-11 and again in APB-15) of the AN/BQQ-10 A-RCI sonar system and upon introduction of new wet end sensor or software capabilities improving ASW mission capability.
- FY16 Recommendations. None.

AN/SQQ-89A(V)15 Integrated Undersea Warfare (USW) Combat System Suite

Executive Summary

- In December 2014, DOT&E submitted a classified Early Fielding Report on the Advanced Capability Build 2011 (ACB-11) variant. The report was submitted due to the installation of the ACB-11 variant on ships that deployed prior to IOT&E. From the data collected, DOT&E concluded the system demonstrated some capability to detect submarines and incoming U.S. torpedoes in deep water.
- Operational testing of the ACB-11 variant of the AN/SQQ-89A(V)15 Integrated Undersea Warfare Combat System Suite began in FY14 and is expected to conclude in FY17. The Navy completed at-sea testing in FY16 and is scheduled to complete the cybersecurity evaluation in FY17.

System

- AN/SQQ-89A(V)15 is the primary undersea warfare system used aboard U.S. Navy surface combatants to locate and engage threat submarines. AN/SQQ-89A(V)15 is an open architecture system that includes staggered biennial software upgrades (ACBs) and biennial hardware upgrades called Technology Insertions.
- AN/SQQ-89A(V)15 uses active and passive sonar to conduct anti-submarine warfare (ASW) search. The acoustic energy received is processed and displayed to enable operators to detect, classify, localize, and track threat submarines.
- AN/SQQ-89A(V)15 uses passive sonar (including acoustic intercept) to provide early warning of threat torpedoes.
- The Navy intends to improve sensor display integration and automation, reduce false alerts, and improve onboard training capability to better support operations within littoral regions against multiple sub-surface threats.
- The system consists of:
  - Acoustic sensors – hull-mounted array, Multi-Function Towed Array (MFTA) TB-37 including a towed acoustic intercept component, calibrated reference hydrophones, helicopter and/or ship-deployed sonobuoys.
  - Functional segments used for processing and displaying active, passive, and environmental data.
  - Interfaces with Aegis Combat System for MK 46 and MK 54 torpedo prosecution using surface vessel torpedo tubes, Vertical Launch Anti-Submarine Rocket, or MH 60R helicopters.
- The system is deployed on a DDG 51 class destroyer or CG 47 class cruiser.

Mission

- Theater Commanders use surface combatants with AN/SQQ-89A(V)15 to locate, monitor, and engage threat submarines.
- Maritime Component Commanders employ surface combatants with AN/SQQ-89A(V)15 as escorts to high-value units to protect against threat submarines during transit. Additionally, they use AN/SQQ-89A(V)15 to conduct area clearance and defense, barrier operations, and ASW support during amphibious assault.
- Unit Commanders use AN/SQQ-89A(V)15 to conduct ASW search, track, engage, and defense.

Major Contractor

Lockheed Martin Mission Systems and Training – Manassas, Virginia

Activity

- In December 2014, DOT&E submitted a classified Early Fielding Report for the ACB-11 variant of AN/SQQ-89A(V)15 Integrated Undersea Warfare Combat System Suite. The report was submitted due to the installation of the ACB-11 variant on ships that deployed prior to IOT&E.
- In September 2015, the Navy completed a formal study that identified capability gaps in currently available torpedo surrogates and presented an analysis of alternatives for specific investments to improve threat emulation ability. The Navy

has since taken the following actions to address the identified capability gaps:

- The Navy received funding through an FY16 Resource Enhancement Project (REP) proposal and is currently in development of a threat-representative high-speed quiet propulsion system.
- The Navy submitted an FY17 REP proposal to develop a General Threat Torpedo (GTT) that is intended to expand upon the propulsion system under development and provide representation of threat torpedoes in both acoustic performance and tactical logic.

- The Commander, Operational Test and Evaluation Force continued IOT&E on the ACB-11 variant in March 2016. Testing was conducted in accordance with a DOT&E-approved test plan and included ASW transit search and area search operations using AN/SQQ-89A(V)15 onboard a DDG 51 class destroyer. Testing was conducted in conjunction with an Aegis Baseline 9C operational test event in the Pacific Missile Range Facility Operating Areas. Testing focused on ACB-11 capability to support submarine search in shallow water.
- Remaining ACB-11 operational testing is scheduled for March 2017 and will evaluate ACB-11 cybersecurity effectiveness.
- The Navy is reducing delays to MFTA repair by increasing spare MFTA inventory, implementing processes to expedite MFTA replacement on deployed ships, and investment in shipboard diagnostic capability. The Navy intends to further improve MFTA availability by increasing reliability and pre-placement of spare MFTAs in strategic locations.

Assessment

- The final assessment of ACB-11 is not complete, as testing will continue into FY17. DOT&E's classified Early Fielding Report and additional analysis conducted in FY16 suggest the following regarding performance:
  - The ACB-11 variant demonstrated some capability to localize and support prosecution of a threat submarine.
  - The ACB-11 variant does not meet program performance metrics for torpedo detection as assessed against U.S. exercise torpedoes. The Navy is incorporating system modifications in ACB-15 that are intended to improve torpedo detection capability. ACB-13 was determined to be too far in its development process to incorporate these modifications.
  - The ACB-11 variant is currently not suitable due to low operational availability. ACB-11 software reliability is sufficient; however, significant delay in the repair of MFTA and MFTA handling gear resulted in extended periods of limited system capability. MFTA requires continued monitoring to validate effectiveness of Navy actions towards improving its availability. MFTA is the primary sensor for submarine detection and torpedo alertment.
  - No assessment can be made against the smaller midget and coastal diesel submarines due to the Navy having no test surrogates to represent this prevalent threat.
- A representative threat torpedo surrogate is needed for adequate operational assessment of subsequent variants of AN/SQQ-89A(V)15 with improvement in torpedo alertment. The proposed development of the GTT will address many of the DOT&E concerns and is supported by DOT&E. However, the GTT's capability to support operational testing is further dependent upon future Navy decisions to procure a sufficient quantity of GTTs.
- Analysis of in-water testing and the remaining cybersecurity evaluation are expected to complete in FY17. DOT&E expects to submit an IOT&E report for AN/SQQ-89A(V)15 in FY17.

Recommendations

- Status of Previous Recommendations. The Navy has made some progress on the FY15 recommendations. However, the Navy should still:
  1. Develop and integrate high-fidelity trainers and realistic, in-water test articles to improve training and proficiency of operators in ASW search and track of threat submarines, including midget and coastal diesel submarines.
  2. Revisit system requirements to ensure that funded improvement in subsequent ACBs is supporting Navy objectives for ASW against current and imminent threat submarines.
  3. Address the four classified recommendations listed in the December 2014 Early Fielding Report.
- FY16 Recommendations. The Navy should:
  1. Schedule and complete dedicated IOT&E to assess cybersecurity vulnerabilities.
  2. Acquire sufficient quantity of GTT, when developed, to support evaluation of the next ACB that has modifications effecting torpedo recognition capability (detection and/or classification).

CH-53K – Heavy Lift Replacement Program

Executive Summary

- The CH-53K program has four Engineering Development Model (EDM) aircraft to support integrated developmental and operational flight testing. All four aircraft have been flying in the test program since EDM-4 achieved its first flight on August 31, 2016.
- Additionally, the CH-53K program is using a Ground Test Vehicle (GTV) to qualify key dynamic components and assess aircraft stresses, vibrations, and rotor performance. The GTV is a complete CH-53K that is fully representative of the EDM aircraft. Previous main gear box testing on the GTV revealed gear box failures and required engineering changes to correct deficiencies.
- The CH-53K design is not finalized. Some problems discovered during testing have not been solved by Sikorsky. These include high temperatures in the #2 engine bay, main rotor damper overheating, and #2 engine flameouts. The flameouts are caused by fuel system anomalies, necessitating the use of fuel boost pumps for prevention. Fuel boost pumps are not planned for fielding.
- Live fire tests have fallen behind schedule by 6 to 9 months, due in large part to the failure of an H-53 test fixture at China Lake, California. The test fixture has been rebuilt and live fire tests restarted in December 2016.

System

- The CH-53K is a new-build, fly-by-wire, dual-piloted, three-engine, heavy lift helicopter slated to replace the aging CH-53E. The CH-53K is designed to carry 27,000 pounds of useful payload (three times the CH-53E payload) over a distance of up to 110 nautical miles, climbing from sea level at 103 degrees Fahrenheit to 3,000 feet above mean sea level at 91.5 degrees Fahrenheit.
- The greater lift capability is facilitated by increased engine power (7,500 shaft horsepower versus 4,380 horsepower per engine in the CH-53E) and a composite airframe. This composite airframe is lighter than the CH-53E metal airframe.
- The CH-53K design incorporates the following survivability enhancements:
  - Aircraft Survivability Equipment (ASE) to include Large Aircraft Infrared Countermeasures with the advanced threat warning sensors (combines infrared, laser, and hostile fire functions into a single system), AN/APR 39D(V)2 radar warning receiver, and AN/ALE-47 countermeasure dispensing system
  - Pilot armored seats, cabin armor for the floor and sidewalls, fuel tank inerting, self-sealing fuel bladders, and 30-minute run-dry capable gear boxes
- The Navy intends the CH-53K to maintain a logistics shipboard footprint equivalent to that of the CH-53E.

Mission

- Commanders will employ the Marine Air-Ground Task Force equipped with the CH-53K for:
  - Heavy lift missions, including assault transport of weapons, equipment, supplies, and troops
  - Supporting forward arming and refueling points and rapid ground refueling
  - Assault support in evacuation and maritime special operations
  - Casualty evacuation
  - Recovery of downed aircraft, equipment, and personnel
  - Airborne control for assault support

Major Contractor

Sikorsky Aircraft Corporation (owned by Lockheed Martin since November 2015) – Stratford, Connecticut

Activity

- The program has four EDM aircraft to support integrated developmental and operational flight testing. Sikorsky is manufacturing the first of six system development test article aircraft at its facility in West Palm Beach, Florida; delivery of the first four is projected for FY17.
- All four EDM aircraft have been flying in the integrated test program since EDM-4 achieved first flight on August 31, 2016. The four EDM aircraft have flown 221.2 hours as of October 25, 2016.

- The first operational assessment using Marine Corps pilots and ground personnel completed all ground and flight events at the contractor facility in West Palm Beach, Florida, concluding on October 19, 2016.
- The Navy has used ongoing GTV testing to qualify design changes to key dynamic components and assess aircraft stresses, vibrations, and rotor performance. The GTV is supporting long-term verification and reliability testing. After 72.8 hours of running under representative flight loads, the GTV was torn down for detailed inspection of dynamic components. Inspections revealed no anomalies.
- The GTV will be used for transportability demonstrations on a C-17 airlifter and it will be the test article for full-up system-level LFT&E projected for FY19.
- The pilots' armored seats experienced thermal cracking during initial environmental qualifications and had to be redesigned in FY13. The new design was qualified by analysis and has been part of the qualification program to date. Final environmental and live fire testing of the redesigned pilot seat armor against the specification small arms threat occurred in November 2015.
- In FY15, the Navy completed ballistic testing of four flight-critical main and tail rotor system components. Testing was conducted against a range of operationally relevant small arms threats and under static loads representative of flight conditions. Two of these damaged components were subjected to post-ballistic endurance testing in FY16 to assess the residual flight capability representative of get-home flight and landing conditions. The remaining two components will be tested in FY17.
- In October 2016, the Navy completed live fire testing of the main rotor gear box. Testing was conducted against a range of operationally relevant small arms threats.
- Due to the failure of a test fixture at Naval Air Weapons Station China Lake, California, the live fire testing of two major drive system components, originally scheduled for FY16, was delayed approximately 6 to 9 months. The test fixture has been rebuilt and testing restarted in December 2016.
- Live fire testing of the main and tail rotor servos have been delayed due to problems with arranging testing at the manufacturer's facility in the United Kingdom. Testing of these components has now slipped into FY17.
- The Navy is modifying ASE to address cybersecurity requirements (data at rest protection), mitigate obsolescence (removable media and computer processors), and reduce life cycle cost (elimination of components). The Navy is upgrading the infrared countermeasure subsystem and adding hostile fire indication.
- Due to ASE program delays, the Navy has deferred deployment and testing of the updated ASE and it will not be available for IOT&E. Legacy ASE will be used during IOT&E and will be employed for Initial Operational Capability, which is projected for FY19. Updated ASE will be tested in follow-on tests and retrofitted to the fleet as it becomes available.
- The Navy has continued testing in accordance with a DOT&E-approved Test and Evaluation Master Plan (TEMP) and a DOT&E-approved 2010 Alternative LFT&E plan.
- The Program Office is revising the TEMP to reflect programmatic changes and updates to the cybersecurity test strategy for Milestone C to include a Cooperative Vulnerability and Penetration Assessment and an Adversarial Assessment. Completion of the revised TEMP has slipped into FY17.

Assessment

- Previous main gear box testing on the GTV revealed gear box failures. The required engineering changes and additional testing have contributed to the schedule slip.
- Design of the CH-53K is not finalized. Problems discovered in developmental testing have not been solved.
  - The #2 engine bay is experiencing temperatures high enough to trigger the engine fire light. The contractor has not yet identified a permanent solution.
  - Main rotor dampers are overheating. The contractor has proposed a new rotor damping configuration involving lower damping action, which has been installed on EDM-1. Flight test data are being gathered and analyzed to evaluate the effectiveness of the change.
  - The fuel system configuration has not been finalized in that the original design called for suction-only fuel feed to reduce vulnerability to ballistic threats. When the #2 engine has been run without using a fuel boost pump, prolonged hovering for at least 15 minutes with a 6 degree nose-up attitude has caused the #2 engine to flame out on landing. The contractor has not identified a non-boost pump solution. If boost pumps are required, additional live fire testing may be required.
- Preliminary assessment of the sponson fuel cell qualification test data indicates acceptable performance against small arms threats. Additional live fire ballistic tests will be performed on the GTV in FY19.
- The program successfully completed ballistic qualification testing of the redesigned cockpit armored seats in November 2015. The copilot seat wing armor is being redesigned. This should not invalidate the ballistic results. Once the seat wing armor final design is known, additional qualification testing will be done to evaluate the changes.
- Three of the four flight-critical main and tail rotor system components tested to date demonstrated the required ballistic damage tolerance to the specified projectile. Structural cyclic endurance testing of two of these components in operationally representative conditions has been completed. The Navy will report on any consequent effect of the observed damage on aircraft survivability and fly-home capability in FY17.

Recommendations

- Status of Previous Recommendations. The Navy should continue to address the FY15 recommendations.
  1. Review data resulting from a DOT&E-funded joint live fire program to assess CV-22 armor performance against threats that the Navy did not address in the CV-22 Advanced Ballistic Stopping System LFT&E program. This will enable the Navy to better understand the effectiveness of the similar seats and armor used in CH-53K against additional operationally realistic threats, and to adjust the CH-53K tactics, techniques, and procedures, as needed.
  2. Finish TEMP Revision C, which has slipped from FY16 into FY17.
- FY16 Recommendations. The Navy should
  1. Finalize the CH-53K configuration while remediating problems identified in developmental testing.
  2. Continue testing and finalize the CH-53K design.
  3. Hold Milestone C after the testing has provided confidence in the CH-53K design and data for reliability growth have been collected against the final design.
  4. Consider re-baselining the program to an event-based schedule instead of fixed calendar dates.

Close-in Weapon System (CIWS) – SeaRAM Variant

Executive Summary

- The Navy tested SeaRAM on the Self-Defense Test Ship (SDTS) at the Pacific Test Range, Pt Mugu, California, from December 2015 to March 2016 and on USS *Porter* (DDG 78) at the Spanish sea range, Rota, Spain, in March 2016. None of these tests were conducted with DOT&E-approved operational test plans or conducted by the Navy's Commander, Operational Test and Evaluation Force since SeaRAM is not a formal acquisition program with approved requirements documents or milestone decisions.
- DOT&E published a classified report to Congress in December 2016 since SeaRAM was deployed on operational DDG 51-class ships without having conducted any operational testing. That report stated that, based on the results of the Navy testing, although SeaRAM has demonstrated some capability against anti-ship cruise missile (ASCM) threats, the lack of ASCM surrogate targets to adequately represent advanced ASCM threats combined with the paucity of test data does not support a meaningful and quantitative assessment of SeaRAM's ability to provide the DDG 51 class with an adequate self-defense against threat ASCMs.

System

- SeaRAM is a non-acquisition program that is a standalone self-defense system composed of the Close-in Weapon System (CIWS) radar, an electronic warfare sensor suite, and a modified CIWS command/decision capability combined with an 11-round Rolling Airframe Missile (RAM) launcher (instead of the CIWS 20 mm gun). It provides a short-range, lightweight, self-defense system to defeat ASCMs.

- SeaRAM, as used on selected DDG 51-class ships, can launch the RAM Block 2 that incorporates changes to improve its kinematic capability and its capability to guide on certain types of ASCM radio frequency threat emitters in order to defeat newer classes of ASCM threats

Mission

Commanders of naval surface forces use SeaRAM to provide a short-range, hard-kill engagement capability against ASCM threats for ship self-defense.

Major Contractor

Raytheon Missile Systems – Tucson, Arizona

Activity

- The Navy tested SeaRAM on the SDTS at the Pacific Test Range, Pt Mugu, California, from December 2015 to March 2016, and on USS *Porter* (DDG 78) at the Spanish sea range, Rota, Spain, in March 2016. None of these tests were conducted with DOT&E-approved operational test plans or conducted by the Navy's Commander, Operational Test and Evaluation Force since SeaRAM is not a formal acquisition program with approved requirements documents or milestone decisions.
- DOT&E published a classified Early Fielding Report to Congress in December 2016 since SeaRAM was deployed on operational DDG 51-class ships without having conducted any operational testing.

Assessment

- The classified December 2016 DOT&E report to Congress stated that, based on the results of the Navy testing, although SeaRAM has demonstrated some capability against ASCM threats, the lack of ASCM surrogate targets to adequately represent advanced ASCM threats combined with the paucity of test data does not support a meaningful and quantitative assessment of SeaRAM's ability to provide the DDG 51 class with an adequate self-defense against threat ASCMs.
- An adequate set of DOT&E-approved SeaRAM operational tests against a broader, more threat representative set of ASCM threat surrogates are required to demonstrate that the DDG 51-class destroyer's other defensive weapons do not degrade SeaRAM's effectiveness and to fully assess

SeaRAM's ability to effectively defend DDG 51-class destroyers. Along with additional missile firings, these tests would involve modeling and simulation using an end-to-end model of the DDG 51-class destroyer's combat system that could be accredited for operational testing.
- Further details of SeaRAM's demonstrated capability to provide the DDG 51-class destroyer with an adequate self-defense against threat ASCMs are classified.
- The SeaRAM electronic warfare suite prevents SeaRAM from utilizing the RAM Block 2 missile to its full capability.
- Due to the Navy's inability to develop a Multi-Stage Supersonic Target (MSST), no assessment of SeaRAM's capability against MSST-like ASCM threats is possible.

Recommendations

- Status of Previous Recommendations. This is the first annual report for this program.
- FY16 Recommendations. The Navy should:
  1. Plan and program funds for an adequate set of SeaRAM operational tests against a broader set of ASCM threats (to include a phase of modeling and simulation) to fully assess SeaRAM's ability to effectively defend DDG 51-class destroyers. The missile firing portion of these tests could be conducted on an Aegis-equipped SDTS.
  2. Develop threat surrogate aerial targets that adequately represent advanced ASCM threats.
  3. Upgrade the SeaRAM electronic warfare system so that SeaRAM may take full advantage of the RAM Block 2 missile capabilities.
  4. Develop an MSST adequate for use in OT&E. The Test Resources section of this Annual Report provides further details.

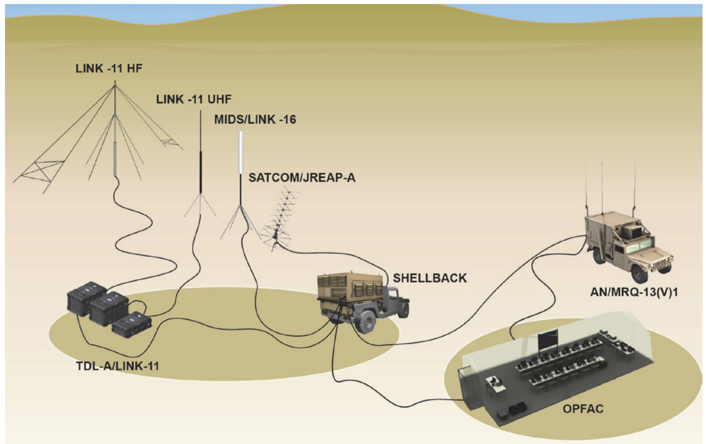
Common Aviation Command and Control System (CAC2S)

Executive Summary

- In 2QFY15, the Assistant Secretary of the Navy for Research, Development, and Acquisition (ASN(RD&A)), as the Milestone Decision Authority, conducted a Milestone C review for the Common Aviation Command and Control (C2) System (CAC2S), which resulted in an approval to enter the Production and Deployment Phase of its life cycle and to procure low-rate initial production items to support IOT&E.
- During 3QFY15 and 4QFY15, the Marine Corps conducted additional data fusion testing using updated operational scenarios, and integrated/interoperability testing with the Composite Tracking Network. The Marine Corps continued risk reduction efforts by conducting a full Tactical Air Command Center (TACC) functionality demonstration during a 1QFY16 Weapons and Tactics Instructors' (WTI) exercise at Marine Corps Air Station (MCAS) Yuma, Arizona, as well as conducted datalink testing and an integration demonstration with the Ground/Air Task Oriented Radar (G/ATOR).
- During the 1QFY16 WTI exercise, the Marine Corps continued operational testing of CAC2S using effectiveness and suitability data collected to support the 3QFY16 CAC2S IOT&E.
- In 3QFY16, the Marine Corps Operational Test and Evaluation Activity (MCOTEA) completed the IOT&E for the CAC2S Increment I Phase 2 during the WTI exercise at MCAS Yuma. The IOT&E was conducted in accordance with a DOT&E-approved test plan.
- During the IOT&E, CAC2S demonstrated that it was operationally effective and operationally suitable to support mission accomplishment of the three Marine Corps aviation command and control agencies. Additionally, CAC2S demonstrated the ability to provide data fusion of real-time, near real-time, and non real-time information onto a single tactical display.
- Cybersecurity testing of CAC2S during IOT&E identified significant system vulnerabilities that make it susceptible to compromise in a contested network environment.
- In 4QFY16, Program Executive Officer Land Systems conducted the Fielding Decision Review.

System

- CAC2S consists of tactical shelters, software, and common hardware. The hardware components are expeditionary, common, modular, and scalable. Components may be assembled in a number of configurations to include transportable shelters (via the High Mobility Multi-purpose Wheeled Vehicle), tactical shelters, general-purpose tents, and available military or civilian facilities.



HF - High Frequency
JREAP - Joint Range Extension Application Protocol
MIDS - Multi-Functional Information Distribution System
OPFAC - Operations Facility
SATCOM - Satellite Communications
TDL - Tactical Data Link
UHF - Ultra High Frequency

- CAC2S Increment I is being delivered in two phases. Phase I previously delivered hardware and software to fully support the Direct Air Support Center (DASC) mission requirements and partially support Tactical Air Operations Center (TAOC) mission requirements. Phase 2 combines the three legacy Phase 1 systems into two functional subsystems and fully supports the requirements of the DASC, TACC, and TAOC.
  - The Communication Subsystem provides the capability to interface with internal and external communication assets and the means to control their operation.
  - The Aviation Command and Control System provides:
    - The operational command post and functionality to support mission planning, decision making, and execution tools to support all functions of Marine Aviation
    - An open architecture interface capable of integrating emerging active and passive sensor technology for organic and non-organic sensors to the Marine Air Command and Control System
    - The capability to display real-time, near real-time, and non real-time sensor data to support C2 of Marine Air Ground Task Force (MAGTF) aviation assets

Mission

- The MAGTF Commander will employ Marine Corps aviation C2 assets, including the DASC, TAOC, and TACC equipped with CAC2S, to integrate Marine Corps aviation into joint and combined air/ground operations in support of Operational

Maneuver from the Sea, Sustained Operations Ashore, and other expeditionary operations.
- The MAGTF Commander will execute C2 of assigned assets afloat and ashore in a joint, allied, or coalition operational environment by using CAC2S capabilities to:
  - Share mission-critical voice, video, sensor, and C2 data and information to integrate aviation and ground combat planning and operations
  - Display a common, real-time, and near real-time integrated tactical picture with the timeliness and accuracy necessary to facilitate the control of friendly assets and the engagement of threat aircraft and missiles
  - Provide fusion of real-time, near real-time, and non real-time information to support the MAGTF
  - Access theater and national intelligence sources from a multi-function C2 node
  - Standardize Air Tasking Order and Airspace Control Order generation, parsing, interchange, and dissemination throughout the MAGTF and theater forces by using the joint standard for Air Tasking Order interoperability

Major Contractors
- Phase 1
  - Government Integrator: Naval Surface Warfare Center – Crane, Indiana
  - Component Contractor: Raytheon-Solipsys – Fulton, Maryland
- Phase 2
  - Prime Contractor (no Government Integrator): General Dynamics – Scottsdale, Arizona

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Activity
- In 2QFY15, the ASN(RD&A), as the Milestone Decision Authority, conducted a Milestone C review for CAC2S, which resulted in an approval to procure low-rate initial production items to support IOT&E.
- In 2015, the Marine Corps conducted data fusion testing using an updated and operationally realistic scenario that more adequately stressed the system.
- During the 1QFY16 WTI course, the Program Office and MCOTEA conducted integrated testing of CAC2S for all operations cells within the TACC and also conducted operational endurance testing as risk reduction for the upcoming IOT&E. During this test period, they also conducted an integration demonstration of CAC2S with G/ATOR as a risk reduction effort since the G/ATOR system is still in development. Data collected during the 1QFY16 WTI exercise were used to support the CAC2S IOT&E in accordance with a DOT&E-approved test plan.
- In 2QFY16, MCOTEA conducted cybersecurity testing of CAC2S with a Cooperative Vulnerability and Penetration Assessment at Marine Corps Base Camp Pendleton, California.
- In 3QFY16, MCOTEA conducted an IOT&E of CAC2S during the 3QFY16 WTI exercise at MCAS Yuma, Arizona. During the IOT&E, MCOTEA also conducted a Cooperative Vulnerability and Penetration Assessment, and the Marine Corps Information Assurance Red Team conducted an Adversarial Assessment. DOT&E published a classified CAC2S IOT&E report in August 2016.
- In 4QFY16, the Program Executive Officer Land Systems conducted the Fielding Decision Review.

Assessment
- The following assessment is based on quantitative and qualitative evaluation of data from the DT-C2 developmental test period and IOT&E that the Marine Corps conducted during the 1QFY16 and 3QFY16 WTI courses. It is also based on previous data fusion testing. Results are as follows:
  - CAC2S demonstrated that it was both operationally effective and operationally suitable to support the primary mission areas for all three agencies – direct air support for the DASC, control aircraft and missiles for the TAOC, and C2 aviation and planning support for the MAGTF commander in the TACC.
  - CAC2S demonstrated an ability to fuse real-time, near real-time, and non real-time data onto a single tactical display, at low and high operational tempos, and densities of aircraft and targets against current generation threats.
  - DOT&E did observe interoperability/integration of CAC2S with G/ATOR, but since that system is still undergoing development, the Marine Corps will need to conduct an additional evaluation. However, with respect to currently fielded radars (AN/TPS-59) and datalinks, testing successfully demonstrated CAC2S's ability to receive information from those systems displaying both radar plot and track data.
  - Throughout testing, DOT&E observed Tactical Display Framework Chat and Transverse Chat instability as well as problems associated with Voice Laptop freezes. The root causes of these problems were not clear.
  - Reliability, availability, and maintainability data collected during DT-C2 and IOT&E showed CAC2S met its availability and maintainability requirements. CAC2S also met reliability requirements for Mean Time Between Operational Mission Failure but did not meet Mean Time Between Failure requirements during testing. However, Mean Time Between Failure did not affect mission effectiveness as operational availability exceeded the threshold value throughout testing.
  - CAC2S has significant cybersecurity vulnerabilities that make it susceptible to compromise in a contested network

environment. As identified in the classified CAC2S IOT&E report, one cyber-related vulnerability found during penetration assessments should be corrected prior to system fielding.

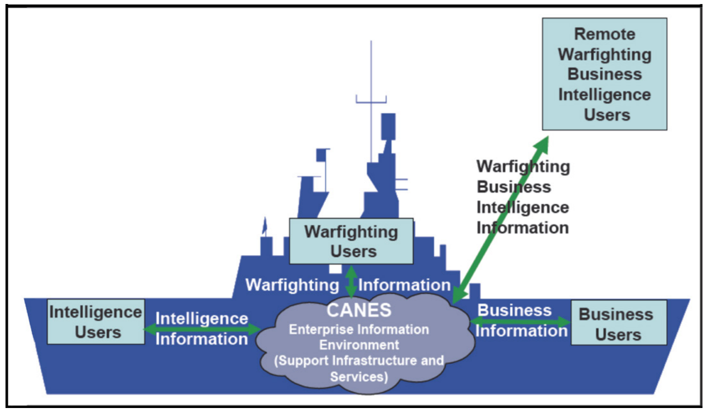
Recommendations

- Status of Previous Recommendations. The Marine Corps addressed all the previous recommendations.
- FY16 Recommendations. Based on the results of IOT&E and related testing, the Marine Corps should:
  1. Correct cybersecurity vulnerabilities identified in the CAC2S IOT&E report.
  2. Continue data fusion testing of CAC2S with the AN/TPS-80 G/ATOR in FOT&E when G/ATOR becomes available.
  3. Identify root causes and correct Tactical Display Framework Chat and Transverse Chat instability and problems associated with voice laptop freezes. Verify the resolution of both during FOT&E.

Consolidated Afloat Networks and Enterprise Services (CANES)

Executive Summary

- USD(AT&L) approved full deployment of the Consolidated Afloat Networks and Enterprise Services (CANES) on October 13, 2015, after DOT&E evaluated CANES for unit-level ships to be operationally effective, suitable, and survivable. The Commander, Operational Test and Evaluation Force (COTF) conducted IOT&E for the unit-level variant on USS *Higgins* (DDG 76) from August 2014 through March 2015.
- COTF started FOT&E of the force-level CANES variant on the USS *John C. Stennis* (CVN 74) in August 2015. COTF is working to complete the cybersecurity portion of FOT&E without affecting the Navy's mission. COTF expects to conclude cybersecurity operational testing in early 2017.
- The Navy plans to conduct an FOT&E for the submarine variant in FY19.



System

- CANES is an enterprise information system consisting of computing hardware, software, and network services (e.g., phone, email, chat, video teleconferencing, web hosting, file transfer, computational resources, storage, and network configuration and monitoring). CANES will replace legacy networks on ships, submarines, and shore sites.
- The CANES program mitigates hardware and software obsolescence on naval vessels and shore sites through the increased use of standard components and regularly scheduled hardware and software updates.
- The CANES network provides a single, consolidated physical network with logical sub-networks for Unclassified, Secret, Secret Releasable, and Top Secret security domains. It includes a cross-domain solution for information transfers across these security boundaries. This consolidation reduces the network infrastructure footprint on naval platforms and the associated logistics, sustainment, and training costs.
- CANES has three variants tailored to the employing platform: unit level for smaller ships such as destroyers and cruisers, force level for large deck ships such as aircraft carriers and large deck amphibious ships, and a submarine variant.

Mission

Naval Commanders and crew afloat and ashore use CANES to connect weapon systems, host applications, and share command and control, intelligence, and business information via chat, email, voice, and video in support of all naval and joint operations.

Major Contractors

- Northrop Grumman – Herndon, Virginia
- BAE Systems – Rockville, Maryland
- Serco – Reston, Virginia
- DRS Laurel Technologies – Johnstown, Pennsylvania

Activity

- COTF conducted the CANES IOT&E on the unit-level variant from August 2014 through March 2015.
- USD(AT&L) approved CANES full deployment on October 13, 2015, after DOT&E evaluated CANES for unit-level ships to be operationally effective, suitable, and survivable.
- COTF completed the performance and suitability testing portions of FOT&E on the force-level variant aboard USS *John C. Stennis* in August 2015, but could not complete cybersecurity testing at that time because the ship's operational schedule could not support this testing.
- COTF conducted a preliminary Cooperative Vulnerability and Penetration Assessment (CVPA) on USS *John C. Stennis* in December 2015. This test was not intended to satisfy operational testing requirements, but to identify and mitigate as many vulnerabilities as possible before the ship deployed.
- Due to the size and complexity of the force-level CANES, combined with limited ship and Red Team availability, COTF is conducting cybersecurity testing in multiple phases. The first phase focused on embarkable assets (those brought aboard by the destroyer squadron and the ship's air wing). COTF

executed this portion of the test in June 2016 while the ship was underway with the necessary units and assets.
- The test of embarkable assets included both a CVPA and Adversarial Assessment (AA).
- COTF expects to perform a CVPA for the rest of the ship in November 2016 and an AA in March 2017 pending availability of the USS *John C. Stennis* or another suitable test platform.

Assessment
- DOT&E assessed the unit level variant as operationally effective, suitable, and survivable.
- DOT&E will publish an FOT&E report on the CANES force-level variant after the completion of cybersecurity testing in FY17.

Recommendations
- Status of Previous Recommendation. The Navy is addressing the previous recommendation.
- FY16 Recommendations. The Navy should:
  1. Complete the planned cybersecurity tests for force-level ships.
  2. Continue planning the FOT&E for the submarine variant.

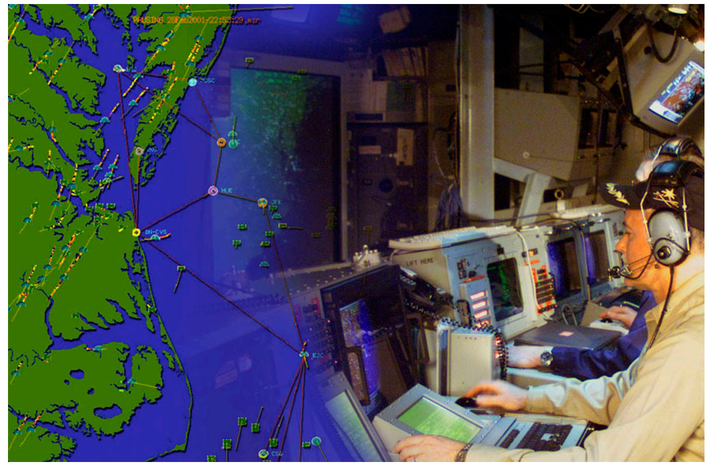
Cooperative Engagement Capability (CEC)

Executive Summary

- The Navy's Commander, Operational Test and Evaluation Force (COTF) continued FOT&E of the Cooperative Engagement Capability (CEC) USG-2B with the Aegis Baseline 9A Combat System in December 2015 and commenced FOT&E of the CEC USG-2B with the Aegis Baseline 9C Combat System in March 2016. Data analysis is ongoing. Preliminary indications are that the CEC USG-2B, as integrated in the Aegis Baseline 9A and 9C Combat Systems, remains operationally effective and suitable and continues to perform comparably to previous CEC USG-2 and USG-2A variants.
- DOT&E will provide a full assessment of the CEC USG-2B's operational effectiveness and suitability on Aegis Baseline 9A and Baseline 9C Combat System platforms upon completion of the CEC USG-2B FOT&Es in late 2017.

System

- CEC is a real-time, sensor-netting system that enables high-quality situational awareness and integrated fire control capability.
- There are four major U.S. Navy variants of CEC:
  - The USG-2/2A is used in selected Aegis cruisers and destroyers, LPD 17/LHD amphibious ships, and CVN 68-class aircraft carriers.
  - The USG-2B, an improved version of the USG-2/2A, is used in selected Aegis cruisers/destroyers as well as selected amphibious assault ships. The USG-2B is planned for use in the CVN 78 and DDG 1000 ship classes.
  - The USG-3 is used in the E-2C Hawkeye 2000 aircraft.
  - The USG-3B is used in the E-2D Advanced Hawkeye aircraft.
- The two major hardware pieces are the Cooperative Engagement Processor, which collects and fuses sensor data, and the Data Distribution System, which exchanges data between participating CEC units.



- The CEC increases Naval Air Defense capabilities by integrating sensors and weapon assets into a single, integrated, real-time network that:
  - Expands the battlespace
  - Enhances situational awareness
  - Increases depth-of-fire
  - Enables longer intercept ranges
  - Improves decision and reaction times

Mission

Naval Commanders use CEC to:

- Improve battle force air and missile defense capabilities by combining data from multiple battle force air search sensors on CEC-equipped units into a single, real-time, composite track picture.
- Provide accurate air and surface threat tracking data to ships equipped with the Ship Self-Defense System.

Major Contractor

Raytheon Systems Co., Command, Control and Communications, Data Systems – St. Petersburg, Florida

Activity

COTF conducted the following CEC test events in FY16 in accordance with the DOT&E-approved test plans:

- Continued FOT&E of the CEC USG-2B with the Aegis Baseline 9A Combat System in December 2015
- Commenced FOT&E of the CEC USG-2B with the Aegis Baseline 9C Combat System in March 2016

Assessment

- CEC test results to date indicate that the CEC USG-2B, as integrated with the Aegis Baseline 9A and 9C Combat Systems, remains operationally effective and suitable and continues to perform comparably to previous CEC USG-2 and CEC USG-2A variants. DOT&E will provide a full assessment of the CEC USG-2B's operational effectiveness and suitability upon completion of all FOT&Es of Aegis Baselines 9A and 9C with the CEC USG-2B in late 2017.

- Test results indicate that, under certain conditions, some CEC messages were not being distributed to all participating CEC units in the network, resulting in CEC-equipped units having inconsistent tactical pictures which could adversely affect fire control solutions.
- Integration problems were identified during the December 2015 testing when a legacy Aegis baseline ship operated as an assist ship, providing track support to the CEC network. This problem resulted in unnecessary loading of the CEC network. Further details are classified.

Recommendations

- Status of Previous Recommendations. The Navy has not satisfied the following previous recommendations to:
  1. Demonstrate corrections to the problem that degrades the USG-3B CEC's Track File Concurrence in a phase of FOT&E.
  2. Implement changes to the USG-3B CEC interface with the E-2D mission computer that would allow data from the E-2D's APY-9 radar to be used by the USG-3B CEC without first requiring the creation of an E-2D Mission Computer track.
  3. Reassess the USG-3B CEC reliability requirement and whether the logistic supply system can support the demonstrated USG-3B CEC reliability.
  4. Correct the cause of the electromagnetic interference between the USG-3B CEC and the E-2D radar altimeter and demonstrate the corrections in a phase of FOT&E.
  5. Take action on the recommendations contained in DOT&E's classified report to Congress on the CEC USG-3B FOT&E.
  6. Complete the FOT&E of the CEC USG-2B with the Aegis Baseline 9A Combat system
  7. Update the CEC Test and Evaluation Master Plan to include details of:
     - The second phase of the USG-3B FOT&E with the supersonic sea-skimming target scenario
     - FOT&E of corrections made to the CEC USG-3B
     - FOT&E of the CEC USG-2B with the Aegis Baseline 9 Combat System
     - FOT&E of the CEC USG-2B with the DDG 1000 Zumwalt Combat System
     - FOT&E of the CEC USG-2B with the CVN 78 Combat System
     - FOT&E of USG-3B CEC to demonstrate the system's ability to support the E-2D's Theater Air and Missile Defense and Battle Force Command and Control missions
     - The test program supporting the Acceleration of Mid-term Interoperability Improvements Project
- FY16 Recommendations. The Navy should:
  1. Complete the FOT&E of the CEC USG-2B with the Aegis Baseline 9C Combat System.
  2. Investigate and correct the cause of some CEC messages not being consistently distributed to all participating units in the CEC network and demonstrate the correction in a phase of FOT&E.
  3. Investigate and correct the integration problems with legacy Aegis baseline combat systems operating in a CEC network and demonstrate the correction in a phase of FOT&E.

CVN 78 *Gerald R. Ford* Class Nuclear Aircraft Carrier

Executive Summary

- The Navy's Commander, Operational Test and Evaluation Force (COTF) is conducting a DOT&E-approved operational assessment that began in September 2015. The assessment was originally scheduled to end in mid-2016 after CVN 78 completed Builder's Sea Trials and Acceptance Trials, but the slip in CVN 78's delivery date has led to a slip in the completion of the operational assessment.
- DOT&E's assessment of CVN 78 remains consistent with the DOT&E Operational Assessment report submitted in December 2013. Poor or unknown reliability of the newly designed catapults, arresting gear, weapons elevators, and radar, which are all critical for flight operations, could affect CVN 78's ability to generate sorties, make the ship more vulnerable to attack, or create limitations during routine operations. The poor or unknown reliability of these critical subsystems is the most significant risk to CVN 78. Based on current reliability estimates, CVN 78 is unlikely to be able to conduct the type of high-intensity flight operations expected during wartime.
- CVN 78 is unlikely to achieve its Sortie Generation Rate (SGR) (number of aircraft sorties per day) requirement. The threshold requirement is based on unrealistic assumptions including fair weather and unlimited visibility, and that aircraft emergencies, failures of shipboard equipment, ship maneuvers, and manning shortfalls will not affect flight operations. DOT&E plans to assess CVN 78 performance during IOT&E by comparing it to the demonstrated performance of the *Nimitz*-class carriers as well as to the SGR requirement.
- The Navy identified an inability to readily electrically isolate Electromagnetic Aircraft Launching System (EMALS) and Advanced Arresting Gear (AAG) components to perform maintenance. This limitation will preclude some types of EMALS and AAG maintenance during flight operations, decreasing their operational availability. The Navy plans to examine system improvements in FY17.
- Previous testing at the EMALS functional demonstration test site at Joint Base McGuire-Dix-Lakehurst, New Jersey, discovered excessive airframe stress during launches of F/A-18E/F and EA-18G with wing-mounted 480-gallon external fuel tanks (EFTs). Similar issues were discovered with 330-gallon EFTs on the F/A-18A-D. Additionally, end-of-stroke dynamics with heavy wing stores were discovered for the F/A-18E/F and EA-18G, which will limit maximum launch speed. These discoveries, until corrected, will preclude the Navy from conducting normal operations of the F/A-18A-F and EA-18G from CVN 78. The Navy plans to correct these problems prior to the end of CVN 78 Post-Shakedown Availability (PSA).
- The Navy continued performance testing of the AAG at a jet car track site at Joint Base McGuire-Dix-Lakehurst, New Jersey. This testing examined the performance of the redesigned arresting gear to meet the system specifications. Runway Arrested Landing Site (RALS) with manned aircraft commenced in 2016 and completed 200 aircraft arrestments as of October 28, 2016 (188 roll-in arrestments and 12 fly-in arrestments). RALS testing supports development of the F/A-18E/F limited envelope Aircraft Recovery Bulletin required for the first arrestments onboard CVN 78.

- The CVN 78 design is intended to reduce manning. As manning requirements have been further developed, analysis indicates the ship is sensitive to manpower fluctuations. Workload estimates for the many new technologies such as catapults, arresting gear, radar, and weapons and aircraft elevators are not well-understood. Some of these concerns have already required redesignation of some berthing areas and may require altering standard manpower strategies to ensure mission accomplishment.
- The CVN 78 combat system for self defense is derived from the combat system on current carriers and is expected to have similar capabilities and limitations. The ship's Dual Band Radar (DBR) is being integrated with the combat system and continues to undergo developmental testing at Wallops Island, Virginia. That testing has uncovered tracking, clutter/false track, track continuity, and engagement support problems typical of those seen in early developmental testing, affecting air traffic control and self-defense operations. The Navy is investigating solutions to these problems, but as ship delivery approaches, the likelihood that these problems will persist into IOT&E increases.
- Funding shortfalls are expected to affect testing of the CVN 78 Integrated Warfare System. In July, the Navy noted that a lack of enterprise funding will result in delays to developmental testing of DBR and the CVN 78 Integrated Warfare System during CVN 78's shakedown period. Ultimately, this will lead

to a 10- to 11-month delay in the ship's Combat System Ship Qualification Trial.
- The development and testing of EMALS, AAG, DBR, and the Integrated Warfare System will continue to drive the *Gerald R. Ford's* timeline as it progresses into OT&E.

System

- The CVN 78 *Gerald R. Ford*-class aircraft carrier program is a new class of nuclear-powered aircraft carriers. It has the same hull form as the CVN 68 *Nimitz* class, but many ship systems, including the nuclear plant and the flight deck, are new.
- The newly designed nuclear power plant is intended to operate at a reduced manning level that is 50 percent of a CVN 68-class ship and produces significantly more electricity. The CVN 78 will incorporate EMALS (electromagnetic, instead of steam-powered catapult launchers) and AAG, and will have a smaller island with a DBR (phased-array radars, which replaces/combines several legacy radars used on current aircraft carriers and serve in air traffic control and ship self-defense).
- The Navy intends for the Integrated Warfare System to be adaptable to technology upgrades and varied missions throughout the ship's projected operating life, including increased self-defense capabilities compared to current aircraft carriers.
- In addition to the self-defense features (hard- and soft-kill), the ship has the following survivability features:
  - Improved protection for magazines and other vital spaces as well as the inclusion of shock hardened systems/components intended to enhance survivability.
  - Various installed and portable damage control, firefighting, and dewatering systems intended to support recoverability from peacetime shipboard fire and flooding casualties and from battle damage incurred during combat.
- The Navy redesigned weapons stowage, handling spaces, and elevators to reduce manning, increase safety, and increase throughput of weapons.
- CVN 78 has design features intended to enhance its ability to launch, recover, and service aircraft, such as a slightly larger flight deck, dedicated weapons handling areas, and an increased number of aircraft refueling stations. The Navy set the SGR requirement for CVN 78 to increase the sortie generation capability of embarked aircraft to 160 sorties per day (12-hour fly day) and to surge to 270 sorties per day (24-hour fly day) as compared to the CVN 68 *Nimitz* class SGR demonstration of 120 sorties per day/240 sorties per 24-hour surge.
- The Consolidated Afloat Networks and Enterprise Services (CANES) program replaces five shipboard legacy network programs to provide a common computing environment for command, control, intelligence, and logistics.
- CVN 78 is intended to support the F-35 and future weapons systems over the expected 50-year ship's lifespan. CVN 78 will include a new Heavy underway replenishment system that will transfer cargo loads of up to 12,000 pounds.
- The Navy intends to achieve CVN 78 Initial Operational Capability in late-FY17 or early-FY18 after successful completion of Post Shakedown Availability and Full Operational Capability in FY21 after successful completion of IOT&E and Type Commander certification.

Mission

Carrier Strike Group Commanders will use the CVN 78 to:
- Conduct power projection and strike warfare missions using embarked aircraft
- Provide force and area protection
- Provide a sea base as both a command and control platform and an air-capable unit

Major Contractor

Huntington Ingalls Industries, Newport News Shipbuilding – Newport News, Virginia

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Activity

Test Planning
- The CVN 78 *Gerald R. Ford*-class carrier Program Office is revising the Test and Evaluation Master Plan (TEMP) 1610 to align planned developmental tests with corresponding operational test phases and to identify platform-level developmental testing.
- The Navy updated the Post Delivery Test and Trials schedule to incorporate the Full Ship Shock Trial (FSST) as directed by the Deputy Secretary of Defense.
- The Navy is planning for a live test to demonstrate the SGR with six consecutive 12-hour fly days followed by two consecutive 24-hour fly days. DOT&E concurs with this live test approach; however, the Navy plan for extrapolating the 8 days of live results to the 35-day design reference mission on which the SGR requirement is based is yet to be decided.

EMALS
- The Navy is conducting installation and checkout of the EMALS in CVN 78. As of July 2016, 121 dead loads (non-aircraft, weight equivalent sled) and 217 no-load tests have been completed on the bow catapults, and 121 dead loads and 168 no-load tests have been completed on the waist catapults.
- In 2014, testing discovered excessive EMALS holdback release dynamics during F/A-18E/F and EA-18G catapult launches with wing-mounted, 480-gallon EFTs. During test launches, the stress limits of the aircraft were exceeded. Testing also discovered similar problems with 330-gallon

EFTs and with end-of-stroke dynamics that affect heavy wing stores. The program has developed fixes, but testing to verify the fixes on manned aircraft has been delayed until 2017 on F/A-18E/F and EA-18G and until 2018 for F/A-18A/B/C/D.

AAG

- The Navy is conducting installation and checkout of the AAG in CVN 78.
- The Navy continues to test the AAG on a jet car track at Joint Base McGuire-Dix-Lakehurst, New Jersey. Earlier testing prompted system design changes that are now being tested. The jet car track testing examined the F/A-18E/F performance envelope with the new design. Overall, land-based jet car track testing has conducted a total of 1,381 dead load arrestments as of November 2016. Testing in 2016 examined degraded mode performance for the safe recovery of aircraft in the event of an AAG component failure. Testing began at RALS to develop the limited envelope Aircraft Recovery Bulletin needed for the first at-sea arrestments on CVN 78.

CANES

- The Navy completed the performance and suitability portions of the CANES follow-on operational testing of the force-level CANES configuration used on the *Nimitz* and *Ford* classes. The cybersecurity testing of this variant is expected to conclude in 2017.
- USD(AT&L) approved full deployment of CANES on October 13, 2015, based on the results of the IOT&E for the unit-level variant conducted from August 2014 through March 2015.

DBR

- The radar consists of fixed array antennas both in the X- and S-bands. The X-band radar is the Multi-Function Radar (MFR) and the S-band radar is the Volume Search Radar (VSR).
- The Navy is testing a production array MFR and an Engineering Development Model array of the VSR at the Surface Combat System Center at Wallops Island, Virginia. Integration testing of DBR continues at Wallops Island and is expected to continue through 4QFY17. The MFR will then be installed on the Self-Defense Test Ship (SDTS) for further CVN 78 testing.
- Limited testing of the production DBR has begun on CVN 78 in the shipyard. While the program has completed over 80 percent of industrial testing, the DBR cannot be fully tested without going to sea and safety precautions within the shipyard limit the extent of testing conducted to date.

Electric Plant

- The newly designed medium-voltage electrical distribution system was initially energized in 2013. Shipboard testing earlier this year, directed by Naval Sea Systems Command (NAVSEA), demonstrated high-power operation of the power generation components using reactor-power generated steam, including support of large electric loads (e.g., EMALS). During recent NAVSEA shipboard testing, an instrumentation transformer associated with the system's main turbine generators voltage regulating system failed. Detailed investigation into this problem indicated that the specific failure was most likely due to a manufacturing defect, but investigation of that original transformer defect continues. To address this component failure and keep the ship on schedule, an alternate design transformer (proven in other electrical applications) was installed but the new configuration was not tested at the land-based test facility to the same degree as the original transformer. Shipboard testing following installation of the alternative transformer revealed design vulnerabilities with the new transformers that must be addressed prior to ship delivery. Voltage regulating system design changes are being implemented and detailed repair plans are in place to address these problems.

Manning

- CVN 78 has been manned in the shipyard, and the Navy is working with the ship's personnel to refine manpower, personnel, training, and education planning.

LFT&E

- The Navy is making progress for executing the Shock Trial on CVN 78 in FY19. The Navy has held internal meetings to discuss shock trial logistics, environmental requirements, and the way forward regarding component shock qualification of mission critical systems.

Assessment

Test Planning

- A TEMP 1610 revision is under development to address problems with the currently-approved TEMP 1610, Revision B. The Program Office is in the process of refining the post-delivery schedule to further integrate testing and to include the FSST.
- The Navy has not finalized how it intends to extrapolate the live SGR testing (six consecutive 12-hour fly days followed by two consecutive 24-hour fly days) to the 35-day design reference mission on which the SGR requirement is based. COTF is working with the Program Office to identify required upgrades for the Seabasing/Seastrike Aviation Model to perform this analysis.
- The schedule to deliver the ship has slipped to December 2016 "under review," meaning the Navy is currently evaluating the power plant problems and repair timeline and is determining a new date for delivery. This new date is planned to be announced in mid-December 2016. Further slips in the delivery are likely to affect schedules for the first at-sea OT&E of CVN 78. Currently, the Program Office is planning for two phases of initial operational testing. The first phase examines basic ship functionality as the ship prepares for flight operations; the second phase focuses on flight operations once the ship and crew are ready. The Navy plans to begin the first phase of testing in late FY18 or early FY19 before CVN 78's FSST. The FSST is followed by CVN 78's first Planned Incremental Availability (PIA), an extended

maintenance period. The Navy then plans to complete the second phase of operational testing after the PIA in FY21, subsequent to when the ship would first deploy. To save resources and lower test costs, the test phases are aligned with standard carrier training periods as CVN 78 prepares for its first deployment. Further delays in the ship delivery are likely to push both phases of testing until after the PIA. As noted in previous annual reports, the CVN 78 test schedule has been aggressive, and the development and testing of EMALS, AAG, DBR, and the Integrated Warfare System are driving the ship's schedule independent of the requirement to conduct the FSST. Continued delays in the ship's delivery will compress the ship's schedule and are likely to have ripple effects. Given all of the above, it is clear that the need to conduct the FSST is not a key factor driving the first deployment to occur in FY21.

Reliability

- CVN 78 includes several systems that are new to aircraft carriers; four of these systems stand out as being critical to flight operations: EMALS, AAG, DBR, and the Advanced Weapons Elevators (AWEs). Overall, the poor reliability demonstrated by AAG and EMALS and the uncertain reliability of DBR and AWEs pose the most significant risk to the CVN 78 IOT&E. All four of these systems are being tested for the first time in their shipboard configurations aboard CVN 78. The Program Office provided updates on the reliability of these systems in April 2016. Reliability estimates derived from test data for EMALS and AAG are discussed below. For DBR and AWE, only engineering reliability estimates have been provided to date.

EMALS

- EMALS testing to date has demonstrated that EMALS should be able to launch aircraft planned for CVN 78's air wing. However, present limitations on F/A-18E/F and EA-tim18G configurations, as well as the system's demonstrated poor reliability during developmental testing, suggest operational difficulties lie ahead for meeting requirements and in achieving success in combat.
- With the current limitations on EMALS for launching the F/A 18E/F and EA-18G in operational configurations (e.g., wing-mounted 480-gallon EFTs and heavy wing stores), CVN 78 will be able to fly F/A-18E/F and EA-18G, but not in configurations required for normal operations. Presently, these problems substantially reduce the operational effectiveness of F/A-18E/F and EA-18G flying combat missions from CVN 78. The Navy has developed fixes to correct these problems, but testing with manned aircraft to verify the fixes has been postponed to 2017.
- As of April 2016, the program estimates that EMALS has approximately 400 Mean Cycles Between Critical Failure (MCBCF) in the shipboard configuration, where a cycle represents the launch of one aircraft. While this estimate is above the rebaselined reliability growth curve, the rebaselined curve is well below the requirement of 4,166 MCBCF. At the current reliability, EMALS has a 7 percent chance of completing the 4-day surge and a 67 percent chance of completing a day of sustained operations as defined in the design reference mission. Absent a major redesign, EMALS is unlikely to support high-intensity operations expected in combat.
- The reliability concerns are exacerbated by the fact that the crew cannot readily electrically isolate EMALS components during flight operations due to the shared nature of the Energy Storage Groups and Power Conversion Subsystem inverters onboard CVN 78. The process for electrically isolating equipment is time-consuming; spinning down the EMALS motor/generators takes 1.5 hours by itself. The inability to readily electrically isolate equipment precludes EMALS maintenance during flight operations, reducing the system's operational availability.

AAG

- Testing to date has demonstrated that AAG should be able to recover aircraft planned for the CVN 78 air wing, but the poor reliability demonstrated to date suggests AAG will have trouble meeting operational requirements.
- The Program Office redesigned major components that did not meet system specifications during land-based testing. In April 2016, the Program Office estimated that the redesigned AAG had a reliability of approximately 25 Mean Cycles Between Operational Mission Failure (MCBOMF) in the shipboard configuration, where a cycle represents the recovery of one aircraft. This reliability estimate is well below the rebaselined reliability growth curve and well below the requirement of 16,500 MCBOMF specified in the requirements documents. At the current reliability, AAG has an infinitesimal chance of completing the 4-day surge and less than a 0.2 percent chance of completing a day of sustained operations as defined in the design reference mission. Without a major redesign, AAG is unlikely to support high intensity operations expected in combat.
- The reliability concerns are worsened by the current AAG design that does not allow Power Conditioning Subsystem equipment to be electrically isolated from high power buses, limiting corrective maintenance on below-deck equipment during flight operations. This reduces the operational availability of the system.

DBR

- Previous testing of Navy combat systems similar to CVN 78's revealed numerous integration problems that degrade the performance of the Integrated Warfare System. Many of these problems are expected to exist on CVN 78. The DBR testing at Wallops Island is typical of early developmental testing with the system still in the problem discovery phase. Current results reveal problems with tracking and supporting missiles in flight, excessive numbers of clutter/ false tracks, and track continuity concerns. The Navy recently extended DBR testing at Wallops Island until 4QFY17; however, more test-analyze-fix cycles are likely to be needed to develop and test DBR fixes so that the DBR can properly perform air traffic control and engagement support on CVN 78.

- Currently, the Navy has only engineering analysis of DBR reliability. The reliability of the production VSR equipment in the shipboard DBR system has not been assessed. While the Engineering Development Model (EDM) VSR being tested at Wallops Island has experienced failures, it is not certain whether these EDM VSR failure modes will persist during shipboard testing of the production VSR. Reliability data collection will continue at Wallops Island and during DBR operations onboard CVN 78. The Navy has identified funding shortfalls that are likely to delay important developmental testing of DBR and the Integrated Warfare System. Test delays are likely to affect CVN 78's readiness for IOT&E. Delays in the development and testing of these systems at Wallops Island have significantly compressed the schedule for self-defense testing of DDG 1000 and CVN 78 on the SDTS. This testing is essential for understanding these ships' capabilities to defend themselves and prevail in combat. The completion of self-defense testing for CVN 78, and the subsequent use of Probability of Raid Annihilation test bed for assessing CVN 78 self-defense performance, are dependent upon future Navy decisions that could include canceling MFR component-level shock qualification or deferring the availability of the SDTS MFR for installation on DDG 1002.

SGR

- CVN 78 is unlikely to achieve its SGR requirement. The target threshold is based on unrealistic assumptions including fair weather and unlimited visibility, and that aircraft emergencies, failures of shipboard equipment, ship maneuvers, and manning shortfalls will not affect flight operations. DOT&E plans to assess CVN 78 performance during IOT&E by comparing it to the SGR requirement as well as to the demonstrated performance of the *Nimitz*-class carriers.
- During the 2013 operational assessment, DOT&E conducted an analysis of past aircraft carrier operations in major conflicts. The analysis concludes that the CVN 78 SGR requirement is well above historical levels and that CVN 78 is unlikely to achieve that requirement.
- There are also concerns with the reliability of key systems that support sortie generation on CVN 78. Poor reliability of these critical systems could cause a cascading series of delays during flight operations that would affect CVN 78's ability to generate sorties, make the ship more vulnerable to attack, or create limitations during routine operations. DOT&E assesses the poor or unknown reliability of these critical subsystems will be the most significant risk to CVN 78's successful completion of IOT&E. The analysis also considered the operational implications of a shortfall and concluded that as long as CVN 78 is able to generate sorties comparable to *Nimitz*-class carriers, the operational capabilities of CVN 78 will be similar to that of a *Nimitz*-class carrier.

Electric Plant

- A full-scale qualification unit of the shipboard component was manufactured and tested in a land-based facility in 2004. This test revealed no problems with the design of the original transformers or any other part of the main turbine generator. The design issues revealed during troubleshooting of the failed main turbine generator voltage regulating system transformer were introduced with the design changes incorporated following the transformer failure. Once alternate transformers were selected, the Navy did not perform sufficient land-based testing to validate that no system design flaws or vulnerabilities with the revised voltage regulating system design existed. The Navy considered the risk was low and did not want to further delay ship delivery for the testing. However, due to the failure, ship delivery continues to be delayed.

Manning

- Based on earlier Navy analysis of manning and the Navy's early experience with CVN 78, several areas of concern have been identified. The Navy is working with the ship's crew to resolve these problems.
- During some exercises, the berthing capacity for officers and enlisted will be exceeded, requiring the number of evaluators to be limited or the timeframe to conduct the training to be lengthened. This shortfall in berthing is further exacerbated by the 246 officer and enlisted billets (roughly 10 percent of the crew) identified in the Manning War Game III as requiring a face-to-face turnover. These turnovers will not all happen at one time, but will require heavy oversight and will limit the amount of turnover that can be accomplished at sea and especially during evaluation periods.
- Manning must be supported at the 100 percent level, although this is not the Navy's standard practice on other ships and the Navy's personnel and training systems may not be able to support 100 percent manning. The ship is extremely sensitive to manpower fluctuations. Workload estimates for the many new technologies such as catapults, arresting gear, radar, and weapons and aircraft elevators are not yet well-understood. Finally, the Navy is considering placing the ship's seven computer networks under a single department. Network management and the correct manning to facilitate continued operations is a concern for a network that is more complex than historically seen on Navy ships.

LFT&E

- CVN 78 has many new critical systems, such as EMALS, AAG, AWE, and DBR that have not undergone shock trials on other platforms. Unlike past tests on other new classes of ships with legacy systems, the performance of CVN 78's new critical systems is unknown. Inclusion of data from shock trials early in a program has been an essential component of building survivable ships. The current state of modeling and component-level testing are not adequate to identify the myriad problems that have been revealed only through full ship shock testing. DOT&E has requested that the Navy provide the status of the programs component shock qualification at a minimum on a semi-annual basis to understand the vulnerability and recoverability of the ship.

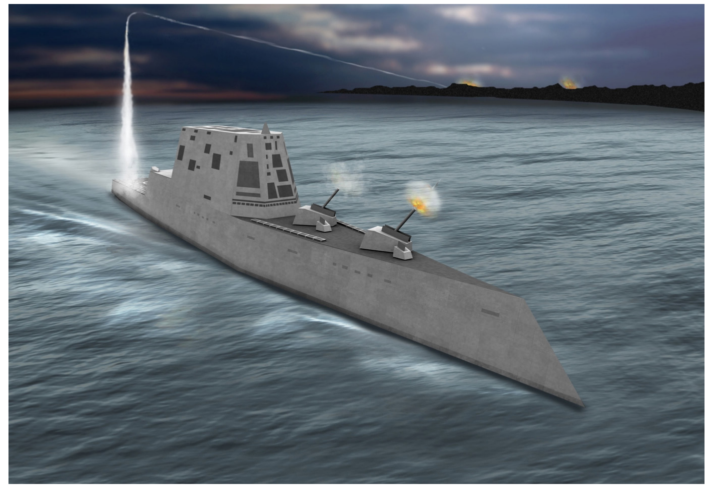
Recommendations

- Status of Previous Recommendations. The Navy should continue to address the nine remaining FY10, FY11, FY13, FY14, and FY15 recommendations.
  1. Finalize plans that address CVN 78 Integrated Warfare System engineering and ship's self-defense system discrepancies prior to the start of IOT&E.
  2. Provide scheduling, funding, and execution plans to DOT&E for the live SGR test event during the IOT&E.
  3. Continue to work with the Navy's Bureau of Personnel to achieve adequate depth and breadth of required personnel to sufficiently meet Navy Enlisted Classification fit/fill manning requirements of CVN 78.
  4. Conduct system-of0systems developmental testing to preclude discovery of deficiencies during IOT&E.
  5. Address the uncertain reliability of EMALS, AAG, DBR, and AWE. These systems are critical to CVN 78 flight operations, and are the largest risk to the program.
  6. Aggressively fund and address a solution for the excessive EMALS holdback release dynamics during F/A-18E/F and EA-18G catapult launches with wing-mounted 480-gallon EFTs.
  7. Begin tracking and reporting on a quarterly basis systems reliability for all new systems, but at a minimum for EMALS, AAG, DBR, and AWE.
  8. The Navy should ensure the continued funding for component shock qualification of both government- and contractor-furnished equipment.
  9. Submit a TEMP for review and approval by DOT&E incorporating the Deputy Secretary's direction to conduct the FSST before CVN 78's first deployment.
- FY16 Recommendations. The Navy should:
  1. Ensure adequate funding of DBR and Integrated Warfare System developmental testing to minimize delays to the test schedule.
  2. Provide DOT&E with component shock qualification program updates at a minimum of semi-annually, and maintain DOT&E's awareness of FY19 shock trial planning.

DDG 1000 *Zumwalt* Class Destroyer

Executive Summary

- The first ship in the *Zumwalt* class of destroyers was launched on October 28, 2013. The Navy accepted delivery of DDG 1000 in an incomplete condition. In September 2016, the ship set sail for the west coast in order to begin, upon arrival, an 18-month post-delivery availability to complete installation, integration, and shipyard testing of its combat systems. The Navy plans to conduct a second Acceptance Trial when that availability has been completed and expects IOT&E to commence in 3QFY18.
- The Navy is concerned with the high cost of projectiles for the Long Range Land Attack Projectile (LRLAP) for the DDG 1000 Advanced Gun System (AGS) and has not funded LRLAP rounds required to evaluate AGS performance during IOT&E. Without these projectiles, the destroyers' primary mission capability of land attack will be limited to strike with Tomahawk Land Attack Missiles (TLAMs) until a replacement land attack projectile is identified and the AGS is modified to fire the new projectile.
- The roles and missions of DDG 1000 are under review. The Navy expects to complete a study to determine the concept of operations for DDG 1000 by 2QFY17.
- The Navy has requested funding in FY18/19 to execute a reduced scope component shock qualification program, and is going through the process to identify the equipment/systems and shock grade to which these will be qualified.
  - Indications are that the number of components undergoing shock qualification will be a reduced set, which will introduce risk for the shock trial. Additionally, by reducing the number of components undergoing shock qualification, the assessment of the vulnerability and recoverability capability of the ship at design levels for underwater threats will be limited. The Navy had indicated in prior years that the component shock testing would be funded and conducted prior to installation of any equipment on the first ship, which is the normal, common-sense approach. However, the Navy diverted that funding to other uses; thus, the component shock testing was not done and now cannot be done in the normal sequence.
  - Despite these limitations, the shock trials currently scheduled for FY20 must be performed at the traditional severity levels for a surface combatant. These trials will now be the sole source of comprehensive data on the survivability of mission-critical ship systems to shock, and are therefore critical to the success in combat of the ship and her crew.
- Additional AN/SPY-3 multi-function (X-band) radar development and testing at the Wallops Island test facility has significantly compressed the schedule for self-defense testing of both the *Zumwalt*-class destroyer and the CVN 78 *Gerald R. Ford*-class nuclear aircraft carrier on the Navy's self-defense test ship (SDTS). The completion of this live-fire testing, and the subsequent use of the Probability of Raid Annihilation test bed, is essential to be able to evaluate the self-defense and survivability of the *Zumwalt*-class destroyer. The Navy must identify how the required ship self-defense testing will be completed prior to deployment of a *Zumwalt*-class destroyer. This may mean delaying the AN/SPY-3 radar installation on DDG 1002.



System

The *Zumwalt*-class destroyers are new surface combatants with a wave-piercing tumblehome hull form designed both for endurance and low-radar detectability. The Navy currently plans to acquire three ships of the class. The *Zumwalt*-class destroyer is equipped with the following:

- Total Ship Computing Environment Infrastructure that hosts all ship functions on an integrated and distributed computing plant.
- Two 155 mm AGS designed to fire LRLAPs.
- AN/SPY-3 Multi-Function (X-band) radar modified to include a volume search capability. (The Navy removed the Volume Search Radar (S-band) from the ship's baseline design for cost reduction in compliance with an Acquisition Decision Memorandum of June 1, 2010.)
- Eighty vertical launch cells that can hold a mix of TLAMs, Standard Missiles, Vertical Launch Anti-Submarine Rockets, and Evolved SeaSparrow Missiles.
- An integrated undersea warfare system with a dual frequency bow-mounted sonar and multi-function towed array sonar to detect submarines and assist in avoiding in-volume mines.

- Two MK 46 30 mm close-in gun systems for self-defense against small boat swarms. The MK 46 30 mm close-in gun system replaces the MK 110 57 mm close-in gun system. (Configuration change resulted from a Gate 6 Configuration Steering Board of June 2012.)
- An ability to embark and maintain MH-60R helicopters and vertical take-off unmanned aerial vehicles.
- An Integrated Power System that can direct electrical power to propulsion motors, combat systems, or other ship needs.
- In addition to the self-defense features installed on the ship (hard and soft kill), the following survivability features are included in the design:
  - Improved ballistic protection for magazines and other vital compartments and shock hardened systems/components
  - Installed and portable damage control, firefighting, and dewatering systems intended to support recoverability from peacetime shipboard fire and flooding casualties, and from damage incurred during combat
  - Tele-robotic fire nozzles that cover selected areas of the ship

Mission

- The Joint Force Maritime Component Commander intends to employ *Zumwalt*-class destroyers to provide:
  - Joint surface strike/power projection
  - Joint surface fire support
  - Surface warfare
  - Anti-air warfare
  - Anti-submarine warfare
- The Navy expects *Zumwalt*-class destroyers to operate independently or in conjunction with an Expeditionary or Carrier Strike Group, as well as with other joint or coalition partners in a Combined Expeditionary Force environment.

Major Contractors

- General Dynamics Marine Systems Bath Iron Works – Bath, Maine
- Huntington Ingalls Industries – Pascagoula, Mississippi
- BAE Systems – Minneapolis, Minnesota
- Raytheon – Waltham, Massachusetts

Activity

- In September 2015, the Navy completed a formal study that identified capability gaps in currently available torpedo surrogates and presented an analysis of alternatives for specific investments to improve threat emulation ability. The Navy has since taken the following actions to address the identified capability gaps:
  - The Navy received approximately $1.0 Million through an FY16 Resource Enhancement Project (REP) proposal and is currently in development of a threat-representative high-speed quiet propulsion system.
  - The Navy submitted an FY17 REP proposal for $6.2 Million to develop a General Threat Torpedo (GTT) that will expand upon the propulsion system under development and provide representation of threat torpedoes in both acoustic performance and tactical logic.
- In June 2016, the Navy elected to delay installation of the AN/SPY-3 radar on the Navy's SDTS in order to conduct additional development and testing of the AN/SPY-3 radar at the Wallops Island test facility. The AN/SPY-3 array at the Wallops Island test facility is used for system development and testing of the radar systems of both the *Zumwalt*-class destroyer and the CVN 78 *Gerald R. Ford*-class nuclear aircraft carrier. Further, the same AN/SPY-3 array will ultimately be installed on the DDG 1002.
- The Navy ceased planning for live fire events using LRLAP due to concern with the high cost of projectiles for the LRLAP for the DDG 1000 AGS. The Navy continued planning for structural firings and reliability testing of AGS on DDG 1000 using inert firing shapes. The Navy is investigating options to replace the LRLAP land attack capability.
- The roles and missions of DDG 1000 are under review. The Navy expects to complete a study to determine the concept of operations for DDG 1000 by 2QFY17.
- The Navy revised the Test and Evaluation Master Plan (TEMP) and is currently routing it within the Navy for approval.
- The Navy continued development of the DDG 1000 Probability of Raid Annihilation test bed. The test bed is a high-fidelity modeling and simulation (M&S) tool that will be used, in conjunction with live fire testing conducted aboard DDG 1000 and the SDTS to assess *Zumwalt*-class destroyers' capability to defeat hostile anti-ship cruise missiles and aircraft.
- In October 2015, the SECDEF directed the Navy to conduct the *Zumwalt*-class destroyers shock trial prior to the first deployment of any ship of the class. The Navy is developing a plan of action to shock qualify a limited amount of equipment prior to the shock trial to ensure the trial can be safely conducted. The focus of the reduced effort will be on shock qualifying equipment that is critical to personnel safety prior to conducting the shock trial; it is unclear how much of the mission-critical equipment (hull; mechanical; electrical; and command, control, communications, computers, combat systems, and intelligence) will be shock qualified and to what level.

Assessment

- The threat torpedo surrogates currently available for operational assessment of the *Zumwalt*-class destroyer have significant limitations in their representation of threat torpedoes. The proposed development of a GTT addresses many of the DOT&E concerns; however, the GTT's capability to support realistic operational testing is dependent upon future Navy decisions to procure sufficient quantity of GTTs.

- All three ships of the *Zumwalt* class share significant new designs, including the unique wave-piercing tumblehome hull form, as well as the new Integrated Power System, Total Ship Computing Environment (software, equipment, and infrastructure), Integrated Undersea Warfare System, Peripheral Vertical Launching System, the AGS, and the associated automated magazines. These systems and equipment have not been subjected to shock testing on previous ship classes. Moreover, the significant automation and relatively small crew may limit the sailors' ability to conduct repairs needed to enable recovery from shock-induced damage.
- Additional AN/SPY-3 radar development and testing at the Wallops Island test facility has significantly compressed the schedule for self-defense testing of the *Zumwalt*-class destroyer and the *Gerald R. Ford*-class nuclear aircraft carrier on SDTS. The completion of this live-fire testing, and the subsequent use of the Probability of Raid Annihilation test bed, is essential to be able to evaluate the self-defense and survivability of the *Zumwalt*-class destroyer. The Navy must identify how the required ship self-defense testing will be completed prior to deployment of a *Zumwalt*-class destroyer. This may mean delaying the AN/SPY-3 radar installation on DDG 1002.
- The Navy has requested funding in FY18/19 to execute a reduced scope component shock qualification program, and is going through the process to identify the equipment/systems and shock grade to which these will be qualified.
  - Indications are that the number of components undergoing shock qualification will be a reduced set, which will introduce risk for the shock trial. Additionally, by reducing the number of components undergoing shock qualification, the assessment of the vulnerability and recoverability capability of the ship at design levels for underwater threats will be limited. The Navy had indicated in prior years that the component shock testing would be funded and conducted prior to installation of any equipment on the first ship, which is the normal, common-sense approach. However, the Navy diverted that funding to other uses; so, the component shock testing was not done and cannot now be done in the normal sequence.
  - Despite these limitations, the shock trials currently scheduled for FY20 must be performed at the traditional severity levels for a surface combatant. These trials will now be the sole source of comprehensive data on the survivability of mission-critical ship systems to shock, and are therefore critical to the success in combat of the ship and her crew.
- The Program Office and the Navy Technical Community encountered problems when attempting to upgrade the survivability M&S tools, which led them to an off-ramp decision to perform the DDG 1000 vulnerability analysis using the existing M&S tools and methods with known shortfalls. The Navy could benefit largely from existing improvements in specific M&S modules by troubleshooting the upgraded M&S modules in a stand-alone mode before integrating them into the over-arching survivability M&S tool that has demonstrated module interface and integration issues. The Navy should also develop a long-term investment strategy to improve the confidence and fidelity levels of its vulnerability and recoverability M&S tools.
- If the *Zumwalt*-class destroyers are not outfitted with LRLAP because of the high cost of the projectiles, the ships will have no capability to conduct Joint Surface Fire Support missions until replacement projectiles are acquired and the AGS is modified to fire the new projectiles. Thus, *Zumwalt*-class destroyers' land attack capability will be limited to TLAMs.
- The currently approved version of the TEMP does not address significant changes to the *Zumwalt*-class destroyer baseline, test strategies and delays in the production schedule. The TEMP revision in Navy routing is required to support operational test.

Recommendations

- Status of Previous Recommendations. The Navy should address the following open recommendations from FY15 and earlier:
  1. Fund and schedule component shock qualification to support the *Zumwalt*-class destroyers' requirement to maintain all mission essential functions when exposed to underwater explosion shock loading.
  2. Develop and conduct an accreditation plan to assess the acceptability of the Probability of Raid Annihilation test bed to support operational testing of the ship's air defense effectiveness.
- FY16 Recommendations. The Navy should:
  1. Complete the revision to the TEMP that accounts for *Zumwalt*-class destroyer baseline changes and system delivery schedule.
  2. Acquire a sufficient quantity of GTTs, when developed, to support testing and fully characterize *Zumwalt*-class destroyer capability to defeat threat torpedoes during FOT&E.
  3. Develop and implement a strategy to address the current limitations with damage predictions in the underwater and air explosion vulnerability assessment tools.
  4. Update DOT&E on the details of the component shock qualification program.
  5. Develop and implement a strategy to complete self-defense testing of the *Zumwalt*-class destroyer on the SDTS.

DDG 51 Flight III Destroyer/Air and Missile Defense Radar (AMDR)/Aegis Combat System

Executive Summary

- On February 10, 2016, the Deputy Secretary of Defense (DEPSECDEF) directed the Navy to adjust funds within existing resources to procure long-lead items to begin procurement of an Aegis/Air and Missile Defense Radar (AMDR)-equipped Self-Defense Test Ship (SDTS). He further directed the Navy to work with DOT&E to develop an integrated test strategy for the DDG 51 Flight III, AMDR, Aegis Modernization, Evolved SeaSparrow Missile (ESSM) Block 2 programs, document that strategy into draft Test and Evaluation Master Plans (TEMPs), and provide them to DOT&E by July 29, 2016. The Navy has complied with the funding direction but has not complied with the DEPSECDEF direction to provide an integrated test strategy for those programs.
- Despite budgeting for the long-lead AMDR components, the Navy did not program funding in the Future Years Defense Plan to complete all other activities (including procuring Aegis Combat System equipment and targets) necessary to modify the SDTS and support adequate operational testing of the DDG 51 Flight III's self-defense capabilities in FY23 as planned. On November 21, 2016, the DEPSECDEF directed the Navy to fully fund those activities.

System

- The DDG 51 Flight III Destroyer will be a combatant ship equipped with the:
  - AMDR three-dimensional (range, altitude, and azimuth) multi-function radar
  - Aegis Combat System used for air warfare missions and self-defense against anti-ship cruise missiles (ASCMs)
  - AN/SQQ-89 undersea warfare suite that includes the AN/SQS-53 sonar
  - MH-60R helicopter that supports undersea warfare
  - Close-In Weapon System for ship self-defense
  - Five-inch diameter gun for surface warfare and land attack
  - Vertical Launch System that can launch Tomahawk; Standard Missiles 2, 3, and 6; and ESSM Blocks 1 and 2
- The Navy is developing the AMDR to provide simultaneous sensor support of integrated air and missile defense (IAMD) and air defense (including self-defense) missions. IAMD and air defense missions require extended detection ranges and increased radar sensitivity against advanced threats with high speeds and long interceptor fly-out times. The three major components of AMDR are:
  - The AMDR S-band radar that will provide IAMD, search, track, cueing, missile discrimination, air defense non-cooperative target recognition, S-band missile communications, surveillance capability for ship self defense and area air defense, and S-band kill assessment support functions.
  - The AMDR X-band radar – intended to provide horizon and surface search capabilities as well as navigation and periscope detection/discrimination functions – is being delayed. In the interim, the legacy AN/SPQ-9B radar will provide these functions.
  - The AMDR Radar Suite Controller that will provide radar resource management and coordination and an open interface with the ship's combat system.
- The Aegis Combat System is an integrated naval weapons system that uses computers and radars to form an advanced command and decision capability and a weapons control system to track and guide weapons to destroy enemy targets.
- The ESSM, cooperatively developed among 13 nations, is a medium-range, ship-launched, self-defense guided missile designed to defeat ASCM, surface, and low-velocity air threats. There are two variants of ESSM:
  - ESSM Block 1 is a semi-active radar-guided missile that is currently in-service.
  - ESSM Block 2 is in development and will have semi-active radar guidance as well as active radar guidance.
- In comparison to the previous DDG 51 version (Flight IIA), Flight III includes, in addition to the upgraded Aegis Combat System and the AMDR, the following modifications:
  - An upgraded fire extinguishing system
  - New ship service turbine generators
  - Additional transformers
  - Power Conversion Modules

- Modified controllers for the Machinery Control System and Multifunction Monitors
- Upgraded air-conditioning plants
- Flight III is also structurally different from the prior DDG 51 version. The design will add starboard enclosures and a stack of small boats, as well as additional structure in the fantail to increase reserve buoyancy and help compensate for additional weight increase. It will also include structural modifications to increase plate thicknesses to lower the ship's center of gravity and enhance girder strength.
- In addition to the self-defense features discussed above, the ship has the following survivability features:
  - Improved ballistic protection for magazines and other vital spaces as well as the inclusion of some shock hardened systems/components intended to enhance survivability.
  - Various installed and portable damage control, firefighting, and dewatering systems intended to support recoverability from peacetime shipboard fire and flooding casualties and from battle damage incurred during combat.

Mission

- Naval Commanders will use the DDG 51 Flight III destroyer equipped with the Aegis Combat System and AMDR to provide joint battlespace threat awareness and defense capability to counter current and future threats in support of:
  - Area air defense (to include self-defense with the ESSM) to counter advanced air and cruise missile threats and increase ship survivability
  - Detecting, tracking, discriminating, and providing missile engagement support (including kill assessment) to counter ballistic missile threats
  - Countering surface threats through surface surveillance, precision tracking, and missile and gun engagements
  - Conducting undersea warfare with periscope detection and discrimination
  - Detecting and tracking own-ship gun projectiles to support surface warfare and naval surface fire support

Major Contractors

- DDG 51 Flight III Destroyer: To be determined. Current DDG 51 destroyer major contractors are:
  - General Dynamics Marine Systems Bath Iron Works – Bath, Maine
  - Huntington Ingalls Industries, Ingalls Shipbuilding Division – Pascagoula, Mississippi
- AMDR: Raytheon – Sudbury, Massachusetts
- Aegis Combat System: Lockheed Martin Marine Systems and Sensors – Moorestown, New Jersey
- ESSM Blocks 1 and 2: Raytheon – Tucson, Arizona

Activity

- On February 10, 2016, the DEPSECDEF directed the Navy to adjust funds within existing resources to procure long-lead items to begin procurement of an Aegis/AMDR-equipped SDTS. He further directed the Navy to work with DOT&E to develop an integrated test strategy for the DDG 51 Flight III, AMDR, Aegis Modernization, ESSM Block 2 programs and document that strategy into draft TEMPs for those programs to DOT&E by July 29, 2016. The Navy has programmed for long-lead procurement of an AMDR radar face but has not complied with the DEPSECDEF direction to provide an integrated test strategy for those programs despite being provided the integrated operational test plan by DOT&E.
- Despite budgeting for the long-lead AMDR components, the Navy did not program funding in the Future Years Defense Plan to complete all other activities (including procuring Aegis Combat System equipment and targets) necessary to modify the SDTS and support adequate operational testing of the DDG 51 Flight III's self-defense capabilities in FY23 as planned. On November 21, 2016, the DEPSECDEF directed the Navy to fully fund those activities.

Assessment

- DOT&E's assessment is that, absent an AMDR and Aegis-equipped SDTS, the Navy's operational test programs for the AMDR, Aegis Combat System, ESSM Block 2, and DDG 51 Flight III destroyer programs cannot be adequate to fully assess their capabilities, in particular those associated with self-defense. They would also not be adequate to test the following Navy-approved DDG 51 Flight III, AMDR, Aegis Combat System, and ESSM Block 2 requirements.
  - The AMDR Capability Development Document (CDD) describes AMDR's IAMD mission, which requires AMDR to support simultaneous defense against multiple ballistic missile threats and multiple advanced anti-ship cruise missile (ASCM) threats. The CDD also includes an AMDR minimum track range Key Performance Parameter.
  - The DDG 51 Flight III destroyer has a survivability Key Performance Parameter requirement directly tied to meeting a self-defense requirement threshold against ASCMs described in the Navy's Surface Ship Theater Air and Missile Defense Assessment document of July 2008. It clearly states that area defense will not defeat all the threats, thereby demonstrating that area air defense will not completely attrite all ASCM raids and individual ships must be capable of defeating ASCM leakers in the self defense zone.
  - The ESSM Block 2 CDD has a requirement to provide self-defense against incoming ASCM threats in clear and jamming environments. The CDD also includes an ESSM Block 2 minimum intercept range Key Performance Parameter.

- Use of manned ships for operational testing with threat-representative ASCM surrogates in the close-in, self-defense battlespace is not possible due to Navy safety restrictions because targets and debris from intercepts pose an unacceptable risk to personnel at ranges where some of the engagements will take place. The November 2013 mishap on USS *Chancellorsville* (CG 62) involving an ASCM surrogate target resulted in even more stringent safety constraints.
  - In addition to stand-off ranges, safety restrictions require that ASCM targets not be flown directly at a manned ship, but at some cross range offset, which unacceptably degrades the operational realism of the test.
  - Similar range safety restrictions will preclude manned ship testing of five of the seven self-defense ASCM scenarios included in the Navy-approved requirements document for the Aegis Modernization Advanced Capability Build 20 Combat System upgrade and will severely limit the operational realism of the two scenarios that can be flown against a manned ship. Restrictions also preclude testing of the AMDR minimum track range requirement against threat representative ASCM threat surrogates at the land-based AMDR Pacific Missile Range Facility test site.
  - To overcome these safety restrictions for the LHA 6, Littoral Combat Ship, DDG 1000, LPD 17, LSD 41/49, and CVN 78 ship classes, the Navy developed an Air Warfare/Ship Self-Defense Enterprise Modeling and Simulation (M&S) test bed, which uses live testing in the close-in battlespace with targets flying realistic threat profiles and manned ship testing for other battlespace regions, as well as soft-kill capabilities to validate and accredit the M&S test bed. The same needs to be done for the DDG 51 Flight III destroyer with its AMDR, as side-by-side comparison between credible live fire test results and M&S test results form the basis for the M&S accreditation. Without an SDTS with AMDR and an Aegis Combat System, there will not be a way to gather all of the operationally realistic live fire test data needed for comparison to accredit the M&S test bed.
- Since Aegis employs ESSMs in the close-in, self-defense battlespace, understanding ESSM's performance is critical to understanding the self-defense capabilities of the DDG 51 Flight III destroyer.
  - Past DOT&E annual reports have stated that the ESSM Block 1 operational effectiveness has not been determined. The Navy has not taken action to adequately test the ESSM's operational effectiveness.
  - The IOT&E for ESSM Block 2 will be conducted in conjunction with the DDG 51 Flight III destroyer, AMDR, and Aegis Combat System operational testing.
  - Specifically, because safety limitations preclude ESSM firing in the close-in self-defense battlespace, there are very little test data available concerning ESSM's performance, as installed on Aegis ships, against supersonic ASCM surrogates.
  - Any data available regarding ESSM's performance against supersonic ASCM surrogates are from a Ship Self-Defense System-based combat system configuration, using a completely different guidance mode or one that is supported by a different radar suite.
- The cost of building and operating an Aegis SDTS, estimated to be about $350 Million, is small when compared to the total cost of the AMDR development/procurement and the eventual cost of the 22 or more DDG 51 Flight III ships that are planned for acquisition ($55 Billion or higher). Even smaller is the cost of the SDTS compared to the cost of the ships that the DDG 51 Flight III destroyer is expected to protect (approximately $450 Billion in new ship construction over the next 30 years). If DDG 51 Flight III destroyers are unable to defend themselves, these other ships are placed at substantial risk. Therefore, it is essential that the Navy program fully now to support all the tests, targets, and Aegis combat system equipment needed to conduct realistic self-defense testing using an AMDR and Aegis-equipped SDTS.
- The modification/upgrades being planned for DDG 51 Flight III are significant enough to warrant an assessment of the impact of these changes on ship survivability. The Navy has unofficially indicated the DDG 51 Flight III LFT&E strategy will include Component Shock Qualification, a Total Ship Survivability Trial, and a Full Ship Shock Trial. Other LFT&E program particulars are still under discussion to ensure DDG 51 Flight III adequately addresses survivability requirements against operationally relevant threats and recoverability requirements.

Recommendations

- Status of Previous Recommendations. The Navy has not addressed the following previous recommendations. The Navy should:
  1. Program and fully fund an SDTS equipped with the AMDR, ESSM Block 2, and DDG 51 Flight III Aegis Combat System in time to support the DDG 51 Flight III destroyer and ESSM Block 2 IOT&Es.
  2. Modify the AMDR, ESSM Block 2, and DDG 51 Flight III TEMPs to include a phase of IOT&E using an SDTS equipped with the AMDR and DDG 51 Flight III Combat System.
  3. Modify the AMDR, ESSM Block 2, and DDG 51 Flight III TEMPs to include a credible M&S effort that will enable a full assessment of the AMDR, ESSM Block 2, and DDG 51 Flight III Combat System's self-defense capabilities.
  4. Comply with the DEPSECDEF direction to develop and fund a plan, to be approved by DOT&E, to conduct at-sea testing of the self-defense of the DDG 51 Flight III destroyer with the AMDR, ESSM Block 2, and Aegis Combat System.
  5. Provide DOT&E the DDG 51 Flight III LFT&E Strategy for approval in coordination with the TTEMP.
- FY16 Recommendations. The Navy should:
  1. Comply with the DEPSECDEF direction to work with DOT&E to develop an integrated test strategy for the DDG 51 Flight III, AMDR, Aegis Modernization, ESSM

Block 2 programs, and document that strategy into draft TEMPs for those programs to be provided to DOT&E.

2. Program funds in the Future Years Defense Plan to complete all activities and procurements required to conduct adequate operational testing of the DDG 51 Flight III, AMDR, and ESSM Block 2's self-defense capabilities on an Aegis-equipped SDTS scheduled for FY23.
3. Include within the LFT&E Strategy, testing aimed at addressing LFT&E knowledge gaps that can be included in codes/tools designed to assist in determining the platforms' vulnerability and recoverability.

Department of the Navy Large Aircraft Infrared Countermeasures (DON LAIRCM)

Executive Summary

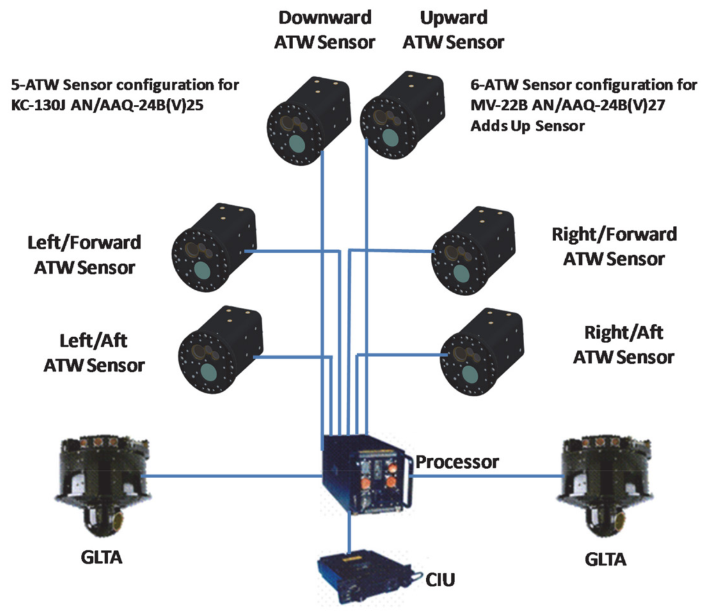
- The Navy conducted developmental tests and continued operational test planning on the Department of the Navy Large Aircraft Infrared Countermeasure (DON LAIRCM) system with the Advanced Threat Warning (ATW) upgrade. The Navy plans for two FOT&E periods in FY17 – one for the MV-22 and one for the KC-130J – as well as a Quick Reaction Assessment for the MV-22.
- The Army conducted integrated developmental/operational testing for installation of the DON LAIRCM ATW system on the Army AH-64, in response to a U.S. Special Operations Command (USSOCOM) Joint Urgent Operational Need (JUON) statement.

System

- The DON LAIRCM system, a variant of the Air Force LAIRCM system, is a defensive system for aircraft designed to defend against surface-to-air infrared missile threats.
- The system combines two-color infrared missile warning sensors with the Guardian Laser Transmitter Assembly (GLTA). The missile warning sensor detects an oncoming missile threat and sends the information to the processor, which then notifies the crew through the control interface unit and simultaneously directs the GLTA to slew to and begin jamming the threat.
- The ATW capability upgrades the processor and missile warning sensors to provide improved missile detection, and adds hostile fire and laser warning capability with visual/audio alerts to the pilots.
- The Navy plans to fully integrate the DON LAIRCM ATW system on the MV-22 and KC-130J with the mission system software.
- The Army plans to integrate AH-64, UH/HH-60, and CH-47 rotary-wing aircraft with the DON LAIRCM ATW system as a federated installation.

Mission

- Commanders employ Marine Corps fixed- and rotary-wing aircraft equipped with DON LAIRCM ATW to conduct medium-lift assault support and aerial refueling of multi-mission aircraft conducting Marine Air-Ground Task Force air operations.



- Commanders employ Army rotorcraft equipped with DON LAIRCM ATW to conduct medium and heavy lift logistical support, medical evacuation, search-and-rescue, armed escort, and attack operations.
- DON LAIRCM ATW will be used during Marine Corps and Army missions to:
  - Provide automatic protection for fixed-wing, tiltrotor, and rotary-wing aircraft against shoulder fired, vehicle-launched, and other infrared-guided missiles
  - Provide automatic hostile fire and laser warning capability for illuminators, beam riders, laser range finders, small arms, rocket-propelled grenades, unguided rockets, and anti-aircraft artillery

Major Contractor

Northrop Grumman, Electronic Systems, Defensive Systems Division – Rolling Meadows, Illinois

Activity

- DOT&E submitted a classified FOT&E report on the DON LAIRCM ATW upgraded installation on the CH-53E in June 2016.
- The Navy conducted developmental tests and operational test planning of DON LAIRCM with the ATW upgrade on the MV-22 and KC-130J between October 2015 and

September 2016. An FOT&E period for the KC-130J and a Quick Reaction Assessment for the MV-22 are planned in FY17.
- The Navy provided materiel support to the Army for the developmental tests and operational test planning for installation of DON LAIRCM with the ATW upgrade on Army AH-64, UH/HH-60, and CH-47 rotary-wing aircraft in response to a USSOCOM JUON.
- The Army began testing the AH-64 installation of DON LAIRCM in 4QFY16 to support the USSOCOM JUON early fielding. Testing was completed in 1QFY17.
- The Navy delayed fielding of the DON LAIRCM ATW upgrade on CH-53E to ensure sufficient quantities of equipment were available to support testing related to the USSOCOM JUON.

Assessment
- DOT&E assessed the DON LAIRCM ATW upgraded installation on the CH-53E as operationally effective but not operationally suitable because of inadequate reliability of the ATW sensors and logistics supportability concerns. The test was adequate to determine both operational effectiveness and operational suitability.
- The Navy is proceeding appropriately during developmental testing on the MV-22 and KC-130J.
  - Developmental test designs were based on lessons learned during previous operational testing.
  - Program delay decisions have been based on results of testing, which have uncovered new failure modes.
  - New failure modes have been identified because of unique mission-based test designs not relevant during previous infrared countermeasure tests on other aircraft.

Recommendations
- Status of Previous Recommendations. The Navy continues to address the previous FY15 recommendations which include:
  1. Continue to improve reliability of the ATW sensors, and monitor and report reliability growth to DOT&E.
  2. Resolve the logistic supportability obsolescence problems with the smart cards used to operate, maintain, and reprogram the DON LAIRCM system.
  3. Resolve the logistic supportability and human factors problem with the location of the control indicator unit.
  4. Resolve the logistic supportability shortfall in the technical documentation and training regarding operational employment aspects of in-flight power cycles.
  5. Collect effectiveness data in a denied-GPS or GPS-jammed environment during FOT&E on either the MV-22 or KC-130J installations of DON LAIRCM.
- FY16 Recommendation.
  1. The Navy should address additional recommendations detailed in the classified June 2016 DOT&E report on the DON LAIRCM ATW installed on the CH-53E.

Distributed Common Ground System – Navy (DCGS-N)

Executive Summary

- The Commander, Operational Test and Evaluation Force (COTF) conducted an FOT&E of the Distributed Common Ground System – Navy (DCGS-N) Increment 1, Block 2 from August 2015 through January 2016.
- On May 9, 2016, DOT&E reported DCGS-N Increment 1, Block 2 to be operationally effective and suitable, but not survivable against cyber threats to the system.
- The USD(AT&L) approved the DCGS-N Increment 2 Milestone B on September 19, 2016.

System

- DCGS-N is the Navy Service component of the DOD DCGS family of systems, providing multi-Service integration of intelligence, surveillance, reconnaissance, and targeting capabilities.
- DCGS-N Increment 1 uses commercial off-the-shelf (COTS) and mature government off-the-shelf (GOTS) software, tools, and standards. It interoperates with the DCGS family of systems via implementation of the DCGS Integration Backbone and Net-Centric Enterprise Services standards.
- Increment 1 is divided into two blocks: Block 1 delivered initial capability on the legacy ship networks, and Block 2 is a hosted application on the Consolidated Afloat Networks and Enterprise Services (CANES).
- Increment 2 will continue to integrate mature COTS and GOTS services and hardware, but it will be hosted on a cloud computing platform provided by CANES for afloat nodes and maritime operations centers (MOCs).
- Increment 2 will be delivered via five Fleet Capability Releases, vice block releases, using an agile development framework. The key additional capabilities for Increment 2 are: enhanced all-source fusion and analysis to provide better maritime domain awareness; enhanced tasking, collection, processing, exploitation, and dissemination; and enhanced sharing of information across commands, Services, and agencies.

Mission

- The operational commanders use DCGS-N to participate in the Joint Task Force-level targeting and planning processes and to share and provide Navy-organic intelligence, reconnaissance, surveillance, and targeting data to Joint Forces.
- Units equipped with DCGS-N will:
  - Identify, locate, and confirm targets through multi-source intelligence feeds
  - Update enemy track locations and provide situational awareness to the Joint Force Maritime Component Commander by processing data drawn from available sensors

Major Contractor

BAE Systems, Electronics, Intelligence and Support (EI&S) – San Diego, California, and Charleston, South Carolina (for Increment 1 only, Increment 2 contractor is TBD)

Activity

- COTF conducted an FOT&E of DCGS-N Increment 1, Block 2 August 2015 through January 2016 onboard the USS *John C. Stennis*. COTF collected performance data during August through November 2015 and declared the end of test on January 11, 2016, after completing cybersecurity testing. Testing was conducted in accordance with the DOT&E-approved test plan.
- DOT&E submitted a classified memorandum report to the Milestone Decision Authority on the results of the Block 2 test on May 9, 2016.
- The USD(AT&L) approved the DCGS-N Increment 2 Milestone B on September 19, 2016.

Assessment

- DOT&E evaluated the Block 2 system to be operationally effective and suitable, but not survivable against cyber threats to the system.
- Additional details can be found in DOT&E's May 2016 classified report.

Recommendations

- Status of FY15 Recommendations. The Navy addressed all previous recommendations.
- FY16 Recommendation.
  1. The Navy should remedy cyber vulnerabilities associated with DCGS-N per DOT&E's classified May 2016 report.

E-2D Advanced Hawkeye

Executive Summary

- In 3QFY16 DOT&E completed its assessment of the E-2D Advanced Hawkeye's first FOT&E period, OT-D1. The focus of OT-D1 was to evaluate the Initial Operational Capability hardware/software configuration, Delta System/Software Configuration (DSSC) Build 1. DOT&E concluded that OT-D1 showed the E-2D had no significant performance difference compared to IOT&E. OT-D1 was adequate to assess E-2D suitability and effectiveness for legacy E-2C missions. Unlike in IOT&E, OT-D1 also executed adequate E-2D carrier testing. An evaluation of E-2D's capability to perform the Theater Air and Mission Defense (TAMD) mission cannot be conducted until future FOT&E periods as that capability is still immature.
- DOT&E approved Change 1 to the E-2D Test and Evaluation Master Plan (TEMP) revision D. The change supports the second FOT&E period (OT-D2), DSSC Build 2, and addresses operational performance relevant to the E-2D system of systems, and E-2D cybersecurity testing,
- The Navy conducted E-2D developmental testing for DSSC-2 between 2QFY16 and 3QFY16. The developmental testing demonstrated DSSC-2 meets required technical performance parameters.

System

- The E-2D Advanced Hawkeye is a carrier-based airborne early warning and command and control aircraft.
- Significant changes to this variant of the E-2 include: upgraded engines, to provide increased electrical power and cooling relative to current E-2C aircraft; a strengthened fuselage, to support increased aircraft weight; replacement of the radar system, communications suite, and mission computer; and incorporation of an all-glass cockpit, which permits the co-pilot to act as a tactical fourth operator in support of the system operators in the rear of the aircraft.
- The radar upgrade replaces the E-2C mechanically scanned radar with a phased-array radar that has combined mechanical and electronic scan capabilities.
- The upgraded radar provides significant improvement in littoral and overland detection performance and TAMD capabilities.

- The E-2D Advanced Hawkeye Program includes all simulators, interactive computer media, and documentation to conduct maintenance, as well as aircrew shore-based initial and follow-on training.
- DSSC-1 included E-2D upgrades and updates to multiple systems such as the radar system, mission computer display, and communication systems. DSSC-2 includes further E-2D upgrades such as improvement in satellite communications, radar, and tracking systems. Future DSSC Builds will focus on the E-2D's Naval Integrated Fire Control – Counter Air (NIFC-CA) capabilities.

Mission

The Combatant Commander, whether operating from the aircraft carrier or from land, will use the E-2D Advanced Hawkeye to accomplish the following missions:

- Theater air and missile sensing and early warning
- Battlefield management, command, and control
- Acquisition, tracking, and targeting of surface warfare contacts
- Surveillance of littoral area objectives and targets
- Tracking of strike warfare assets

Major Contractor

Northrop Grumman Aerospace Systems – Melbourne, Florida

Activity

- The Navy conducted developmental testing for DSSC-2 from 2QFY16 to 3QFY16.
- Change 1 to the E-2D TEMP revision D supports the second FOT&E period (OT-D2), which is scheduled for 4QFY16. Change 1 to revision D E-2D focuses on DSSC-2 upgrades and also includes cybersecurity testing. DOT&E approved the Change 1 TEMP in August 2016.
- DOT&E provided cybersecurity guidance for the OT-D2 cybersecurity test plan and all subsequent test plans and TEMPs for future FOT&E periods.

- The Navy submitted the OT-D2 test plan and a separate cybersecurity test plan, which were both approved by DOT&E in 4QFY16. OT-D2 was completed in 1QFY17 and the operational test report is forthcoming.
- The Navy continues to correct deficiencies with E-2D Cooperative Engagement Capability performance with a plan to have deficiencies remedied in FY19 with fielding of DSSC Build 3.

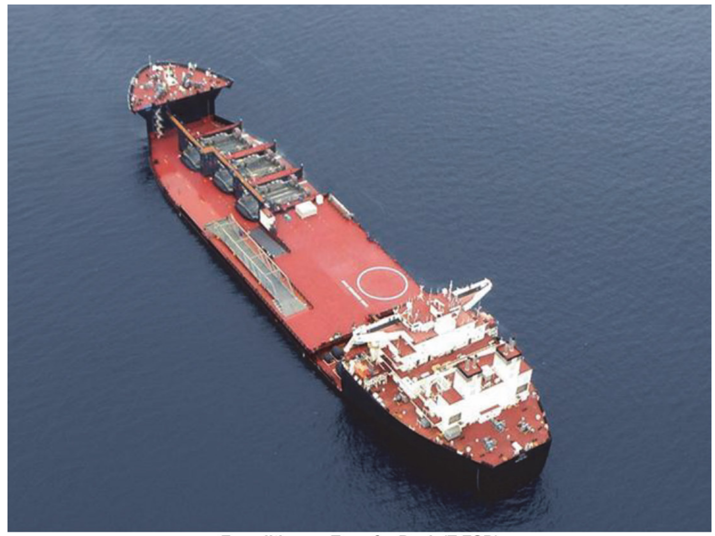
Assessment

- Following developmental testing for DSSC-2, the Navy concluded that DSSC-2 met the naval requirements for NIFC-CA capabilities. The Navy's Program Executive Officer – Tactical Aircraft Programs subsequently removed NIFC-CA Increment 1 from DSSC-2 for operational testing. The Navy plans to include the NIFC-CA From the Air capability in Increment 2 and include this capability with release to the fleet with DSSC-3 in FY19. Developmental testing demonstrated that the Increment 1 capability lacked sufficient military utility against modern threats. To date, NIFC-CA testing scope has been extremely limited. This limited scope has resulted in a lack of statistical confidence to assess this potential future capability.
- DOT&E's OT-D1 report in 3QFY16 showed that E-2D has no significant performance difference compared to IOT&E and has similar shortfalls on most radar reliability, availability, and weapon system metrics. OT-D1 was adequate to assess E-2D suitability and effectiveness for legacy E-2C missions. An evaluation on E-2D's capability to perform the TAMD mission cannot be made until future FOT&E periods as that capability is immature.
- E-2D's second FOT&E, OT-D2, was completed in 1QFY17. OT-D2 included a separate cybersecurity test plan which was also completed in 1QFY17. An operational test report is forthcoming.
- A full assessment of E-2D operational capabilities will require systematic updates and future operational testing.

Recommendations

- Status of Previous Recommendations. The Navy continues efforts to improve radar and mission system performance, improve radar and overall weapon system reliability and availability as recommended in FY15. However, these recommendations have not been resolved and thus the Navy should continue to address them.
- FY16 Recommendations. The Navy should:
  1. Incorporate all DOT&E guidance in its cybersecurity testing for OT-D2 and all subsequent FOT&E periods.
  2. Provide complete training on all components of the E-2D system and mission.
  3. As future DSSC updates occur, conduct FOT&E.

Expeditionary Transfer Dock (T-ESD) and Expeditionary Sea Base (T-ESB)



Expeditionary Transfer Dock (T-ESD)

Expeditionary Sea Base (T-ESB)

Executive Summary

- From June 2015 through August 2016, the Navy conducted the Expeditionary Sea Base's (T-ESB) Post-Delivery Test and Trials (PDT&T). DOT&E and the Navy's Commander, Operational Test and Evaluation Force (COTF) observed PDT&T events and collected data to be used in the T-ESB's operational assessment.
- In August 2016, the Navy conducted the T-ESB IOT&E, followed immediately by the Total Ship Survivability Trial (TSST).
- DOT&E will publish a combined IOT&E and LFT&E report assessing T-ESB in 2QFY17. The following preliminary assessment is based on observations during IOT&E and PDT&T. The T-ESB:
  - Is capable of hosting a helicopter squadron with four MH-53Es
  - Is capable of hosting all airborne mine countermeasure (AMCM) equipment, including the 7-meter rigid hull inflatable boats (RHIBs) required in the launch and recovery of all waterborne AMCM equipment
  - Is capable of launching, recovering, and maintaining MH-53E helicopters
  - Is capable of deploying all legacy AMCM equipment
  - Is capable of transiting the required 9,500 nautical miles at 15 knots while fully loaded with an AMCM helicopter squadron including all mine-sweeping equipment
  - Lacks enough space to concurrently accommodate personnel and embarked systems of an explosive ordnance disposal detachment and the MCM coordination staff while hosting an AMCM helicopter squadron (not included in the Joint Chiefs of Staff's requirement document)
  - Lacks Chemical, Biological, and Radiological (CBR) defense (not included in the Joint Chief of Staff's requirement document)
  - Has limited self-defense capability against any threat. Its self-defense capability against small boat attacks consists of 12 50-caliber gun stations capable of 360-degree coverage
- The T-ESB was designed to operate in a benign environment where there is low/negligible threat to the ship. However, MCM operations will require the ship to move closer to the MCM threat area. The lack of self-defense capability renders the ship totally dependent upon protection from other naval combatants and joint forces to be survivable in the intended operating environment.
- The Navy conducted the TSST aboard USNS *Lewis B. Puller* (T-ESB 3) August 8 – 9, 2016, in the Virginia Capes operating area. DOT&E's preliminary findings are related to limitations with the internal communication system, emergency lighting, ship egress, and watertight and non-watertight doors. DOT&E will finalize and publish the findings and recommendations in the combined IOT&E and LFT&E report.

System

- Expeditionary Transfer Dock (T-ESD) and T-ESB are both modified heavy-lift ships, based on the British Petroleum *Alaska*-class oil tanker that the Navy procured to use as logistics interfaces and mobile landing fields, respectively.
- The Navy developed the T-ESD to have the ability to operate from international waters in non-hostile areas, and persist for extended periods of time on station – providing a prepositioning force capability. The T-ESB was developed to provide AMCM support capability both unencumbered by geopolitical constraints to meet strategic goals.
- Military Sealift Command (MSC) serves as the ships' Life Cycle Manager.
- The Navy delivered two T-ESD ships (hulls 1 and 2), one T-ESB ship (hull 3, June 2015), and plans to deliver two more

T-ESB ships. Hull 4 will be delivered in February 2018, and hull 5 will be delivered in September 2019.

- The T-ESD:
  - Includes a vehicle-staging area (raised vehicle deck), vehicle transfer ramp, large mooring fenders, an emergency-only commercial helicopter operating spot, and three Landing Craft Air Cushion (LCAC) lanes/operating spots with wash-down and fueling services
  - Is equipped with a crane and work boat for the placing of fenders used for skin-to-skin operations with the Large Medium Speed Roll-on/Roll-off (LMSR) or Expeditionary Fast Transport (T-EPF) (formerly Joint High Speed Vessel)
  - Requires 34 MSC contracted mariners to operate and maintain the vessel
  - Is built to commercial standards
  - Is classified as a non-combatant
- The T-ESB:
  - Is built similar to the T-ESD to commercial standards. It includes a forward section called the forward house and an aft section called the aft house. The forward house includes military aviation facilities such as a hangar facility; workstations for operation planning; a command, control, communications, computers, and intelligence suite; ammunition magazines for ordnance stowage; and berthing for a total of 250 personnel.
  - During non-hostile periods when the ship is designated as a USNS, it carries 100 permanent military crew and 150 personnel from an embarked detachment. During hostile periods when the ship is designated a USS, it carries 101 permanent military crew and 149 personnel from an embarked detachment. The vessel also has a four-spot flight deck, helicopter fueling capability, and a fueling at-sea station. It houses 34 MSC civilian mariners in the aft house of the ship.
  - Has a mission deck below the flight deck with a man-rated crane for launch and recovery of manned boats, and legacy mine-hunting and mine-clearing equipment, which are used with the MH-53E helicopters during AMCM operations.
  - Has an aft knuckle boom crane rated for 10 metric tons in Sea State 3 (0.50 – 1.25 meters significant wave height) to transfer cargo from the pier to mission deck and/or to the flight deck. This crane is rated up to 8 metric tons to transfer ordnance from mission deck to flight deck or flight deck to mission deck.
  - Has fueling at-sea capability for diesel and JP-5 (jet propellant 5) fuel.
  - Has vertical replenishment capability.
  - Is classified as a non-combatant.
- The T-ESD and T-ESB designs inherently incorporate survivability features evaluated through the LFT&E program, to include:
  - Distributed firefighting equipment in the form of a fire main and aqueous film-forming foam and distributed damage control lockers/repair stations (containing fire hoses, firefighting ensembles, self-contained breathing apparatus, and flood repair kits).
  - Retractable bow thruster for station-keeping.
  - Emergency electrical power to selective ship loads by way of the Emergency Diesel Generator (EDG).
  - A carbon dioxide gaseous flooding system in the main engineering, EDG spaces, and spaces with high risk of fuel induced fires.
  - As a result of its more aviation focused mission, the T-ESB is equipped with an Aviation Crash Locker to handle shipboard aviation casualties and a seawater sprinkling system for protection to magazines and other high-risk spaces in the forward portion of the ship.

Mission
- Combatant Commanders will use the T-ESD to support Mobile Prepositioning Force (future) operations by facilitating at-sea transfer and delivery of prepositioned assets to units ashore. The T-ESD will act as a vessel interface between LMSR or T-EPF and LCAC vehicles and, in the future, Ship-to-Shore Connectors.
- Combatant Commanders will use the T-ESB to support AMCM operations, which includes hosting a squadron of four legacy MH-53E helicopters together with their mine-clearing equipment, or explosive ordnance demolition teams with their equipment.
- Special Operations Force (SOF) will use the T-ESB to support Helicopter Assault Force and Boat Assault Force operations, not concurrently with AMCM operations.

Major Contractors
- Base ship for both variants and T-ESB mission package: General Dynamics' National Steel and Shipbuilding Company (NASSCO) – San Diego, California
- T-ESD mission package: Vigor Marine LLC Shipbuilding – Portland, Oregon

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Activity
T-ESD
- There were no T-ESD test events in FY16.

T-ESB
- On December 8, 2015, DOT&E approved the T-ESB IOT&E test plan. The test plan adopted an integrated test approach where the Navy conducted developmental and operational testing concurrently, with each having its own set of metrics and data collection. All operational tests were conducted in accordance with the DOT&E-approved test plan.
- The first ship of the class, USNS *Lewis B. Puller* (T-ESB 3), launched in November 2014, completed builder trials in

April 2015, and acceptance trials in May 2015; and was delivered to the Navy in June 2015.

- T-ESB 3 transited from San Diego, California, to Norfolk, Virginia, from August to October 2015. COTF collected material availability data from the ship's crew during the transit.
- Personnel from the Naval Surface Warfare Center, Port Hueneme, California, conducted an Underway Replenishment Ship Qualification Trial in January 2016, off the coast of Norfolk, Virginia.
- Combat Direction Systems Activity personnel observed by COTF completed two phases of cybersecurity developmental testing: the first phase in November/December 2015, and the second phase in January/February 2016.
- Combatant Craft Division of Naval Surface Warfare Center Carderock Division completed two phases of craft launch and recovery testing, first in February 2016, and then again in May 2016.
- The Board of Inspection and Survey conducted a Final Contract Trial in April 2016.
- Naval Air Systems Command with aircraft and maintenance detachment provided by Helicopter Mine Countermeasure Squadron-15 (HM-15), conducted Aircraft Dynamic Interface Testing, including Vertical Replenishment operations, during April and June 2016.
- The Program Office, assisted by HM-15, conducted AMCM deployment test during PDT&T in June 2016.
- The Program Office, assisted by MSC's Afloat Training Team, completed the TSST aboard USNS *Lewis B. Puller* (T-ESB 3) August 8 – 9, 2016, off the coast of Norfolk, Virginia, in the Virginia Capes operating area. This event was preceded by pre-test system checks to verify system components and line-ups in November 2015 and January and May 2016.
- COTF personnel:
  - Observed a ship self-defense test contending crew-served weapons against high-speed maneuvering surface targets in May 2016 on USS *San Antonio* (LPD 17)
  - Conducted the cybersecurity Cooperative Vulnerability and Penetration Assessment during May and June 2016, and the cybersecurity Adversarial Assessment during July 2016
  - Conducted the IOT&E End-to-End Event in accordance with the DOT&E-approved test plan in August 2016, while underway in the Virginia Capes operating area
  - Conducted a critical systems maintenance review, consisting of targeted interviews with senior military and civilian crewmembers, onboard the ship while in port at Naval Station Norfolk during August 2016
  - Conducted a walk-through SOF review with the subject matter experts to assess the ship's ability to host light-package SOF missions onboard the ship, while in port at Naval Station Norfolk during August 2016
- The 1-year post-delivery guarantee period ended on June 11, 2016.

Assessment

T-ESD

- The results from earlier testing were reported in the July 6, 2015, DOT&E combined IOT&E and LFT&E report on Mobile Landing Platform with Core Capability Set (MLP (CCS)).

T-ESB

- T-ESB's preliminary findings are based on observations on USNS *Lewis B Puller* (T-ESB 3) during the PDT&T and IOT&E periods. DOT&E will provide the final assessment in the 2QFY17 combined IOT&E and LFT&E report.
  - Based on a 24-hour fuel endurance trial, DOT&E estimates T-ESB to have an un-refueled range of greater than 11,000 nautical miles, exceeding the 9,500-nautical mile requirement.
  - Out of the four helicopter operating spots on the flight deck, three are functional for landing and launching MH-53E helicopters while performing the AMCM mission. The fourth spot served as a parking space only, since it was fouled by a triple wide container used for AMCM equipment. Without this container, the fourth spot is fully functional.
  - The helicopter hanger is large enough to accommodate two folded or one spread MH-53E helicopters.
  - The ammunition magazines can accommodate AMCM ordnance such as the SeaFox mine disposal vehicle.
  - The mission deck size and tie down arrangement are sufficient to accommodate all supplies and equipment required for a four-helicopter MH-53E Squadron including all legacy mine-sweeping equipment.
  - The mission deck crane is effective for launching and recovering all AMCM equipment along with launching the 7-meter RHIBs used for deploying the AMCM equipment. The mission deck crane is also effective for launching and recovering the 11-meter RHIBs and 41-foot Combatant Craft Assault boats.
  - Cybersecurity test results and analysis will be provided in the classified annex to the 2QFY17 DOT&E combined IOT&E and LFT&E report.
  - The lack of air conditioning in the aircraft maintenance shops surrounding the hanger bay will limit work days for maintainers in high heat stress areas of the world.
  - Lacks enough space to concurrently accommodate personnel and equipment of an explosive ordnance detachment, the MCM staff required to coordinate the operations, and an AMCM helicopter squadron during the MCM operations. This may affect the MCM mission.
- The T-ESD and T-ESB are built to commercial standards and have survivability features to protect against typical commercial ship hazards such as groundings, collisions, raking, and fires. However, for missions that the ships will execute in the littorals close to threat areas, not having military survivability requirements introduce the following shortfalls:

  - Lack of a CBR defense capability, including countermeasure wash-down capability
  - Lack of anti-ship missile, torpedo, and naval mine defense capability
  - Self-defense capability is limited to crew-served weapons only
- The T-ESB was designed to operate in a benign environment where there is low/negligible threat to the ship. However, MCM operations will require the ship to move closer to the MCM threat area. The lack of self-defense capability renders the ship totally dependent upon protection from other naval combatants and joint forces to be survivable in the intended operating environment.
- T-ESB has very limited self-defense capability, which will force the Combatant Commander to place T-ESB outside the threat area. Alternately, the Combatant Commander will need to devote defensive units to support the mission. T-ESB is not outfitted to accommodate explosive ordnance teams or mine clearing coordination staffs while supporting AMCM.
- The T-ESB TSST identified limitations with the ships' communications systems that challenged the damage control effectiveness of both the Navy and MSC crew. Additionally, the trial revealed ship design deficiencies associated with emergency lighting, personnel egress, and the ships' watertight and interior joiner doors. The Navy is assessing the TSST data and will provide additional findings in their report due in FY17. DOT&E will finalize and publish findings and recommendations in the combined IOT&E and LFT&E report.
- If T-ESB is upgraded to add full SOF capability, an FOT&E event will be required to evaluate the added SOF capability. The final DOT&E IOT&E and LFT&E report will provide assessment based on the walk-through review that COTF conducted with existing SOF capability during the end-to-end test event.

Recommendations

- Status of Previous Recommendations: The Navy still needs to address the FY14 recommendation to re-evaluate the need for at-sea skin-to-skin operations between T-ESD and T-EPF. The Navy also still needs to address the following FY15 recommendations:
  1. Install a separate Ship Service Diesel Generator to minimize periods of under-loading of the Main Diesel Generators.
  2. Address the live fire issues identified in the classified annex to the July 2015 DOT&E combined IOT&E and LFT&E report on the T-ESD.
  3. Conduct a robust, self-defense test utilizing live ammunition and realistic targets in support of the T-ESB IOT&E.
- FY16 Recommendation.
  1. DOT&E will provide recommendations regarding test adequacy, effectiveness, suitability, and survivability of the T-ESB in the combined IOT&E and LFT&E report in FY17 after a more comprehensive analysis of all operational and live fire test data.

F/A-18E/F Super Hornet and EA-18G Growler

Executive Summary

- During FY16, the Navy released System Configuration Set (SCS) H10E for use in the F/A-18E/F Super Hornet and the EA-18G Growler fleets. Software upgrades for the Super Hornet included improved multi-sensor integration, aircrew displays, short-range tracking, and combat identification. For the Growler, SCS H10 added the Joint Tactical Terminal Receiver, enhanced combat identification capability, and expanded jamming assignments. SCS H10 included an initial capability allowing aircrew for both platforms to operate more easily in Air Traffic Control (ATC)-controlled airspace.
- The reliability of the APG-79 Active Electronically Scanned Array (AESA) radar improved during SCS H10 testing for the F/A-18E/F and EA-18G, demonstrating the highest reliability to date since introduction of the AESA in 2006. However, it failed to meet the program reliability requirement.
- SCS H10 built-in test (BIT) detection and isolation functions demonstrated strong performance, but a high BIT false alarm rate resulted in an unnecessary maintenance burden.
- The Super Hornet weapons system has demonstrated operational effectiveness and suitability in most, but not all, threat environments. Previous DOT&E classified reports have discussed the threat environments in which the Super Hornet is not effective.
- The EA-18G Growler weapons system equipped with SCS H10 demonstrated operational effectiveness and suitability with the same radar limitations as the Super Hornet. It also demonstrated degraded APG-79 performance when ALQ-99 pods radiated within the AESA frequency range.
- The Navy began operational testing of the next software upgrade, SCS H12, in October 2016. Planned improvements include another phase of multi-sensor integration improvements, enhanced ALQ-218 geolocation, Communication Countermeasures Set improvements, modifications to crew to aircraft interfaces and displays to manage aircrew workload, and additional capabilities to operate in ATC-controlled airspace.

System

F/A-18E/F Super Hornet

- The Super Hornet is the Navy's premier strike-fighter aircraft and is a more capable follow-on replacement to the F/A-18A/B/C/D and the F-14.
- F/A-18E/F Lot 25+ aircraft provide functionality essential for integrating all Super Hornet Block 2 hardware upgrades, which include:
  - Single pass multiple targeting for GPS-guided weapons
  - Use of off-board target designation
  - Improved datalink for target coordination precision
  - Implementation of air-to-ground target aim points
- Additional systems include:

  - APG-73 (Lots 21-24) or APG-79 radar (Lots 25+)
  - Advanced Targeting Forward Looking Infrared Systems
  - AIM-9 infrared-guided missiles and AIM-120 and AIM-7 radar-guided missiles
  - Multi-functional Information Distribution System for Link 16 tactical datalink connectivity
  - Joint Helmet-Mounted Cueing System
  - Integrated Defensive Electronic Countermeasures

EA-18G Growler

- The Growler is the Navy's land- and carrier-based, radar and communications jamming aircraft.
- The two-seat EA-18G replaces the four-seat EA-6B Prowler. The ALQ-218 receiver, improved connectivity, and linked displays are the primary design features implemented to reduce the operator workload in support of the EA-18G's two-person crew.
- The Airborne Electronic Attack (AEA) system includes:
  - Modified EA-6B Improved Capability III ALQ-218 receiver system
  - Advanced crew station
  - Legacy ALQ-99 jamming pods
  - Communication Countermeasures Set System
  - Expanded digital Link 16 communications network
  - Electronic Attack Unit
  - Interference Cancellation System that supports communications during jamming operations
  - Satellite receiver capability via the Multi-mission Advanced Tactical Terminal
- Additional systems include:
  - APG-79 AESA radar
  - Joint Helmet Mounted Cueing System
  - High-speed Anti-Radiation Missile
  - AIM-120 radar-guided missiles

System Configuration Set (SCS) Software

- Growler and Super Hornet aircraft include SCS operational software to enable major combat capabilities. All EA-18G

and Block 2 F/A-18E/F (production Lot 25+) use high-order language (HOL) "H-series" software, while F/A-18E/F prior to Lot 25 and all legacy F/A-18A/B/C/D aircraft use "X-series" software.
- The Navy released SCS H10 in October 2015 and began operational testing of SCS H12 in October 2016.
- The Navy released SCS 25X on legacy Hornet and older Super Hornet aircraft in October 2015.

Mission
- Combatant Commanders use the F/A-18E/F to:
  - Conduct offensive and defensive air combat missions.
  - Attack ground target with most of the U.S. inventory of precision and non-precision weapons.
  - Provide in-flight refueling for other tactical naval aircraft.
  - Provide the fleet with an organic tactical reconnaissance capability.
- Combatant Commanders use the EA-18G to:
  - Support friendly air, ground, and sea operations by countering enemy radar and communications
  - Jam integrated air defense systems
  - Support non-integrated air defense missions and emerging non-lethal target sets
  - Enhance crew situational awareness and mission management
  - Enhance connectivity to national, theater, and tactical strike assets
  - Provide enhanced lethal suppression through accurate High-speed Anti-Radiation Missile targeting
  - Provide the EA-18G crew with air-to-air self-protection with the AIM-120

Major Contractors
- The Boeing Company, Integrated Defense Systems – St. Louis, Missouri
- Raytheon Company – Forest, Mississippi
- General Electric Aviation – Evendale, Ohio
- Northrop Grumman Corporation – Bethpage, New York

Activity
- The Navy released SCS H10 to the F/A-18E/F and EA-18G fleets in 2016.
- The Navy began testing SCS H12 on both platforms in October 2016 in accordance with a DOT&E-approved test plan. Testing will continue into 2017.
- The Navy delivered SCS H10 improvements for the Super Hornet including improved multi-sensor integration, aircrew displays, short-range tracking, combat identification, and the ability to operate more easily in ATC-controlled airspace.
- The Navy delivered SCS H10 improvements for the Growler including the addition of the Joint Tactical Terminal Receiver, enhanced combat identification, expanded jamming assignments, and the ability to operate more easily in ATC-controlled airspace.
- The Navy completed testing and released SCS 25X to the fleet in 2016 for use in F/A-18 A-D and early lot F/A-18E/Fs that do not have HOL computers. The Navy plans to use the remaining non-HOL Super Hornets primarily for training.

Assessment
- Although capability enhancements in SCS H10 resulted in incremental changes in the ability of the Super Hornet to complete missions, DOT&E did not expect this software release to add significant mission capability. The F/A-18E/F remains operationally effective in some threat environments and ineffective in particular air warfare environments noted in classified reports. Though SCS H10 has begun to address some of those long-standing deficiencies in air warfare, the Super Hornet requires further improvements. Software false alarms in SCS H10 impose a maintenance burden on unit personnel.
- SCS H10 testing showed improved AESA reliability, and while it demonstrated the highest reliability to date since introduction of the AESA in 2006, it fell short of its reliability requirement. Although the AESA provides improved performance compared to the legacy mechanically-steered radar, DOT&E has assessed the radar as not operationally suitable since the 2006 IOT&E because of poor software stability and BIT performance. Fault identification and isolation functionality have improved, but the AESA false alarm rate remains high. Additionally, the F/A-18 has demonstrated interoperability deficiencies with on- and off-board sensor inputs.
- DOT&E continues to assess the EA-18G as operationally effective and suitable subject to the same threat limitations as the Super Hornet. The radar performance degradation occurs when ALQ-99 pods radiate in AESA frequencies, affecting Growler operational effectiveness.
- Because the Navy did not include an end-to-end multiple AIM-120 missile test during SCS H10, testing has been deferred to SCS H12 FOT&E. The Navy will not have successfully demonstrated that the AESA can support this required capability until this test is successfully completed.
- The Navy's F/A-18 fleet relies more heavily on Lot 25+ E and F aircraft compared to the Navy's operational test squadron, VX-9, which includes more F/A-18C and D aircraft and older E and F aircraft that lack HOL mission computers and APG-79 AESA radars, making test conditions less operationally representative.

Recommendations
- Status of Previous Recommendations. Per previous recommendations, the Navy should continue to improve the

APG-79 radar reliability, false alarm performance, and, for the EA-18G, geolocation timeliness with jammers off, and should continue to develop and characterize the full electronic warfare capability of the AESA radar. DOT&E continues to recommend that the Navy conduct an operationally representative end-to-end missile test to demonstrate APG-79 radar and system support for a multiple AIM-120 missile engagement. The Navy should continue to focus on improvements that will allow the Super Hornet and Growler to be operationally effective in all threat environments.

- FY16 Recommendation.
  1. The Navy should upgrade the Super Hornet aircraft used during operational testing to better reflect fleet composition in terms of number of aircraft with HOL mission computers and APG-79 radars.

Infrared Search and Track (IRST)

Executive Summary

- On November 5, 2015, the USD(AT&L) designated the Infrared Search and Track (IRST) program as an Acquisition Category (ACAT) I program and delegated milestone decision authority to the Navy.
- The Commander, Operational Test and Evaluation Force (COTF) conducted Operational Assessment 2 (OA 2) in November 2015. OA 2 included simulated air combat against a challenging, operationally realistic threat surrogate. The system continues to have difficulty with detection and tracking in an environment that reflects realistic fighter employment and tactics. DOT&E reported OA 2 results in a January 27, 2016, classified memorandum.
- Assistant Secretary of the Navy (ASN) for Research, Development, and Acquisition (RDA) held an IRST program review on January 27, 2016, and in a September 8, 2016, Acquisition Decision Memorandum (ADM), ASN (RDA) approved a restructured program that foregoes full-rate production of Block I sensors and proceeds directly to development of the Block II system. The Block I system will not be fielded and IOT&E did not begin in 2016 as planned.
- The Navy plans to hold the Block II Preliminary Design Review in May 2017 and begin IOT&E in 2020.

System

- The IRST system consists of a passive long-wave infrared receiver (IRR), a processor, inertial measurement unit (IMU), and environmental control unit (ECU). The IRR, processor, IMU, and ECU are housed within the Sensor Assembly Structure (SAS). The SAS attaches to the front of the Fuel Tank Assembly that is mounted to the aircraft on the BRU-32 bomb rack. The Navy designed the IRST to be flown on the F/A-18E/F and it will be built into a modified centerline fuel tank.
- The Navy developed Block I using components from the F-15K/SG IRR, which is based on the F-14 IRST design. Block I will be used to support testing and tactics development. Block II is being acquired through an Engineering Change Proposal contract as an engineering change to Block I. Block II will include improvements to the IRR and updated processors.
- The Navy intends to produce a total of 170 IRST systems. The 18 Block I low-rate initial production (LRIP) systems will be retrofitted to the Block II configuration and an additional 152 Block II systems will be acquired.

Mission

Commanders will use F/A-18E/F aircraft equipped with the IRST in a radar-denied environment to locate and destroy enemy forces. The IRST system is intended to allow the F/A-18E/F to operate and survive against existing and emerging air threats by enhancing situational awareness and providing the ability to acquire and engage targets beyond visual range.

Major Contractors

- The Boeing Company – St Louis, Missouri
- Lockheed Martin – Orlando, Florida

Activity

- The USD(AT&L) designated IRST as an ACAT IC program on November 5, 2015.
- COTF conducted OA 2 in November 2015. VX-9, with support from VX-31, conducted realistic engagements over the China Lake Range Complex and Point Mugu Sea Range. DOT&E reported results in a January 27, 2016, classified memorandum.
- ASN (RDA) held an IRST program review on January 27, 2016, to consider LRIP-2 and receive a program status update.
- Following the ASN (RDA) review, the Navy developed a new program plan, which foregoes full-rate production of Block I after the acquisition of the 18 LRIP units and proceeds directly to the development of the Block II system, which is expected to enter IOT&E in 2020. Under the new plan, the Block I LRIP units will not be fielded, but will be used for testing and tactics development until they can be retrofitted to the Block II configuration.
- In a September 8, 2016, ADM, ASN (RDA) approved Block I LRIP-2 (12 units) and entry into the Block II development phase.

- Based on the results of aeromechanical testing, Naval Air Systems Command (NAVAIR) issued a flight clearance in July that allowed flight test with the full envelope of flight conditions when the fuel tank is empty and excludes a small set of conditions when the tank has over 500 pounds of fuel (and an even narrower set of conditions with more than 1,500 pounds of fuel). The new flight clearance also clears the fuel tank for shore-based catapults and arrestments (with less than 230 pounds of fuel). Since the July flight clearance was issued, Boeing has released their carrier suitability report, which recommends IRST for unrestricted carrier operations. The Program Office provided the results to NAVAIR engineering, which are reviewing them, and will release an updated flight clearance if appropriate.
- The program has increased the scope of Integrated Test Phase IT-C1 to include testing IRST on aircraft software System Configuration Set (SCS) H14 and will extend the test phase through summer 2017. The objectives of this test phase are to characterize sensor performance (including testing algorithm enhancements intended to improve performance) and test integration of IRST with the F/A-18 weapons system. Testing also includes a progression of simulated AIM-120 shots on IRST tracks using captive carry missiles. The culminating live weapons shots planned for Block I were canceled.

Assessment

- The Key Performance Parameter (KPP) and the derived contract specification for detection and tracking describe only a narrow subset of the operational environments where the Navy will employ IRST. Meeting the KPP (with a narrow reading of the KPP requirement) does not ensure a useful combat capability. Much of developmental testing, however, was focused on verifying this contract specification.
- OA 2 included realistic operational conditions. The system tested in OA 2, while much improved from OA 1, could not reliably detect and track targets well enough to support weapons employment in an environment that reflects realistic fighter employment and tactics.
- Demonstrated reliability is below what was expected at this point in the flight test program. As of the time of DOT&E's OA 2 report, the cumulative Mean Time Between Operational Mission Failure (MTBOMF) was 4.1 hours; the reliability after incorporating known fixes was 19.5 hours. The MTBOMF requirement is 40 hours and the system was expected to have a projected reliability of 38 hours when entering IOT&E.
- Most of the failures are built-in test (BIT) false alarms that require a system reset and are therefore scored as an OMF.
- The Block II system has significant commonality with the Block I system. Block I will continue to fly between now and the start of Block II IOT&E. If the program keeps in place its reliability growth program, identifying and correcting failure modes, the reliability of components that Block II has in common with Block I should improve.
- The Block I system reliability growth plan was overoptimistic in its assessment of initial reliability. A new reliability growth plan is needed for Block II and care should be taken to determine a realistic initial reliability and growth rate. While reliability has grown with Block I and projected reliability at the time of OA 2 was 19.5 hours, new hardware and software might initially reduce Block II reliability. Achieving the desired reliability could require a design effort focused on the reliability of the BIT system in order to meet the 40-hour threshold requirement. The program should also consider reviewing the rationale for the current reliability threshold.
- The logistical impact of requiring a mechanical boresight procedure for Block II should be considered for the Block II sensor design.
- The new flight clearance is a significant improvement over the flight clearance used in OA 2. Given the rate at which fuel is consumed from the centerline fuel tank, these restrictions are effective for only a short period at the beginning of the mission profile and should not have an operational impact.
- Many of the Block I system's difficulties with detection and tracking seen in OA 1 and OA 2 did not require flight testing to uncover them, but could have been discovered earlier via analysis and modeling and simulation. The Navy expects that the Block II configuration (which includes sensor and aircraft hardware and software), will provide improved capability. This assumption should be tested as early as possible, prior to major decisions, via analysis and modeling and simulation if flight test data are not available. The program has a wealth of data and lessons learned that could be used to support such an effort.

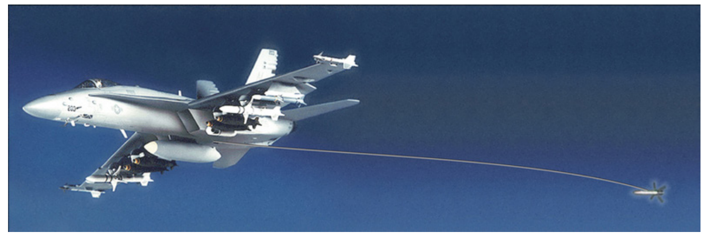
Recommendations

- Status of Previous Recommendations. The Navy should continue to address the two FY15 recommendations:
  1. Explicitly state detection and tracking requirements for the range of operational conditions in which the Navy expects to employ the system. The requirements document has not been updated. Testing, however, has included operationally realistic conditions and COTF and DOT&E have evaluated the system against the stated mission need.
  2. Improve detection and tracking performance prior to entry into IOT&E. The Navy has elected not to proceed beyond LRIP with Block I and will wait until the Block II sensor and SCS H16 aircraft software are available prior to entering IOT&E.
- FY16 Recommendations. The Navy should:
  1. Use modeling and simulation and analysis (including analysis of Block I data) to test the detection and tracking capability of the Block II system as early as possible, well prior to flight test. Document this strategy in the updated Test and Evaluation Master Plan.
  2. Future developmental testing should include more testing beyond specification compliance to ensure readiness to conduct operationally representative missions in operational testing and in combat.
  3. Correct issues seen in the Block I in-flight transfer alignment system or include the necessary logistical support for mechanical boresight in the Block II design.

Integrated Defensive Electronic Countermeasures (IDECM)

Executive Summary

- The Navy completed an Integrated Defensive Electronic Countermeasure (IDECM) Software Improvement Program (SWIP) operational assessment (OA) on September 30, 2015. Developmental testing of the SWIP program is ongoing, and integrated test missions flew in July and August 2016, at the Joint Pacific Alaska Range Complex (JPARC) at Eielsen AFB near Fairbanks, Alaska.
- The Navy's F/A-18 wingman radio frequency compatibility group that contains members from multiple Navy Program Offices continues to investigate and resolve deficiencies associated with the aircraft radar, which may be caused by other systems such as IDECM. The Navy has asked for significant funding to resolve the incompatibilities.
- DOT&E produced a classified report on the IDECM SWIP OA and the integrated testing at JPARC. The IDECM Block 4 hardware is effective and suitable on the F/A-18E/F, and not effective and not suitable on the F/A-18C/D because the system is unsafe due to environmental control system issues leading to cabin pressurization problems.
- The IDECM Block 4 with SWIP demonstrated inconsistent performance during integrated testing at the JPARC. However, the system demonstrated improved stability over previous developmental test flights.



System

- The IDECM system is a radio frequency, self-protection electronic countermeasure suite on F/A-18 aircraft. The system is comprised of on- and off-board components. The onboard components receive and process radar signals and can employ on- and/or off-board jamming components in response to identified threats.
- There are four IDECM variants: Block I (IB-1), Block II (IB-2), Block III (IB-3), and Block IV (IB-4). All the variants include an onboard radio frequency receiver and jammer.
  - IB-1 (fielded FY02) combined the legacy onboard receiver/jammer (ALQ-165) with the legacy (ALE-50) off-board towed decoy.
  - IB-2 (fielded FY04) combined an improved onboard receiver/jammer (ALQ-214) with the legacy (ALE-50) off-board towed decoy.
  - IB-3 (fielded FY11) combined the improved onboard receiver/jammer (ALQ-214) with a new (ALE-55) off-board fiber-optic towed decoy that is more integrated with the ALQ-214.
  - IB-4 with SWIP (currently in developmental test) replaces the onboard receiver/jammer (ALQ-214(V)3) with a lightweight, repackaged onboard jammer (ALQ-214(V)4 and ALQ-214(V)5). IB-4 also replaces the ALQ-126B to provide advanced, carrier capable jamming to the F/A-18C/D for the first time. IB-4 (without SWIP) fielded to three squadrons in FY15.
- IB-4 hardware will run enhanced onboard software known as SWIP. SWIP will give IDECM enhanced capabilities against modern threats, denying or delaying a weapons-quality track on the F/A-18.
- The F/A-18E/F installation includes off-board towed decoys. The F/A-18C/D installation includes only the onboard receiver/jammer components and not the towed decoy.

Mission

- Combatant Commanders will use IDECM to improve the survivability of Navy F/A-18 strike aircraft against radio frequency-guided threats while flying air-to-air and air to ground missions.
- The Navy intends to use IB-4's complex jamming capabilities to increase survivability against modern radar guided threats.
- IDECM SWIP provides a new deny/delay capability to enhance survivability against modern radio frequency threats.

Major Contractors

- ALE-55: BAE Systems – Nashua, New Hampshire
- ALQ-214: Harris – Clifton, New Jersey
- ALE-50: Raytheon Electronic Warfare Systems – Goleta, California

Activity

IB-4

- The Navy completed an OA for IDECM Block 4 hardware on September 30, 2015. Testing was adequate to assess effectiveness on the F/A-18E/F. However, due to a major safety issue on the F/A-18C/D, the Navy deferred testing on F/A-18C/D until the middle of FY-17.
  - All planned laboratory testing, including a dense emitter scenario and closed-loop hardware-in-the-loop testing was completed.
  - Follow-on testing is scheduled for 2017 to complete all remaining flight test points for both platforms.

IB-4 with SWIP

- The Navy completed integrated testing at a hardware-in-the-loop facility for the SWIP software.
  - Integrated testing at the JPARC tested the SWIP system against a modern threat in a more realistic threat environment than was previously possible. Further, while working in concert with the EA-18G and the ALQ-99 jamming pod, the Navy tested SWIP interoperability and effectiveness in the presence of support jamming.
  - Due to the integrated nature of the test, multiple configurations and software versions were tested at the JPARC.
- The Navy conducted all testing in accordance with a DOT&E-approved test plan.

Assessment

IB-4

- IDECM Block 4 is effective and suitable on the F/A-18E/F and unsafe and not suitable on the F/A18C/D, leading to a not effective evaluation. Testing was adequate to support DOT&E evaluation of the system.
  - IDECM Block 4 demonstrated the same capabilities as the legacy IDECM Block 3 system.
  - Environmental Control System (ECS) problems on multiple F/A-18C/D aircraft prevented completion of IDECM Block 4 testing. Since the root cause of the ECS issues has not been determined, IDECM Block 4 is unsafe on the F/A-18C/D. The Navy wrote technical orders to diagnose ECS problems on the F/A-18C/D, but each aircraft must be investigated individually to solve the problems. IDECM is therefore not suitable on the F/A-18C/D fleet writ large.

IB-4 with SWIP

- IDECM Block 4 with SWIP demonstrated little deny-delay capability at the JPARC against a modern threat. The IDECM program should optimize countermeasure techniques employed using SWIP and their effectiveness for the threats of interest.
- IDECM Block 4 with SWIP did not demonstrate consistent effectiveness against modern surface-to-air missile systems. Integrated test led to the discovery of stability problems with the SWIP software, some of which have potential fixes in the latest software, but system effectiveness is often unpredictable. On at least one occasion, the SWIP system produced no radio frequency output but all system indications showed that IDECM was working perfectly.

Recommendations

- Status of Previous Recommendations. The Navy addressed some previous recommendations; however, the following remain outstanding:

IDECM System

1. The Navy should develop hardware and/or software changes to provide pilots with correct indications of whether a decoy was completely severed. This recommendation does not apply to the F/A-18 C/D installation since that installation does not include a towed decoy.
2. The Navy should continue to improve maintenance data collection processes and reporting methods during developmental and integrated test for IDECM to support an adequate suitability assessment.
3. The Navy should ensure that the ALR-67(V)3 Radar Warning Receiver interface with IDECM is updated to allow for proper situational awareness when SWIP is in use.
4. The Navy should ensure that the SWIP software is consistent and produces effective output prior to fielding.

Electronic Warfare Warfighting Improvements

5. In coordination with the Defense Intelligence Agency, the Navy should update the warhead probability of kill data in requirements documents to confirm IDECM effects are sufficient to ensure aircraft survivability.
6. The Services should improve the fidelity of missile endgame analysis, to including warhead fuzing.

- FY16 Recommendations. The Navy should:

1. Fully resolve F/A-18C/D ECS issues before resuming any test flights on the F/A-18C/D.
2. Determine for each threat whether the current SWIP techniques or the original IDECM Block 3 or 4 baseline techniques provide the greatest survivability gains and field the most effective technique.

Joint Standoff Weapon (JSOW)

Executive Summary

- The Navy completed Joint Standoff Weapon (JSOW) C-1 operational testing and declared Initial Operational Capability (IOC) in FY16.
- DOT&E published a classified FOT&E report in early FY17. This report indicates:
  - Weapon accuracy against stationary land targets has been maintained and moving maritime target accuracy was demonstrated in seven developmental, integrated, and operational free flight test events.
  - JSOW C-1 Mean Flight Hours Between Operational Mission Failure exceeded the requirement value of 95 hours.
  - The Navy has reduced the complexity of the Pilot Vehicle Interface (PVI) in the F/A-18E/F H10 software. There remain minor PVI challenges that could prevent successful mission execution. These challenges can be effectively overcome with proper training prior to employment. The Navy is addressing these challenges in F/A-18E/F H12 Operational Flight Program, scheduled for release in FY17.
  - In operational testing, aircrew workload to employ the weapon increased due to display errors in target location on multiple displays and intermittent errors in the status of the weapon entering the datalink and during post-launch weapon control. The Navy implemented a fix and tested it post-IOC, eliminating these errors.
- Cybersecurity testing of the JSOW C-1 was insufficient to test the cybersecurity vulnerabilities of the weapon and support equipment.

System

- The AGM-154 JSOW family uses a common and modular weapon body capable of carrying various payloads. The JSOW is a 1,000-pound class, air-to-surface glide bomb intended to provide low observable, standoff precision engagement with launch and leave capability. All variants employ a tightly coupled GPS/Inertial Navigation System.
- AGM-154A (JSOW A) payload consists of 145 BLU-97/B combined effects submunitions.
- AGM-154C (JSOW C) utilizes an imaging infrared seeker and its payload consists of an augmenting charge and follow through bomb that can be set to detonate both warheads simultaneously or sequentially.

- AGM-154A and AGM-154C are fielded weapons and no longer under DOT&E oversight. AGM-154C-1 (JSOW C-1) adds moving maritime target capability and the two-way strike common weapon datalink to the baseline AGM-154C weapon.

Mission

- Combatant Commanders use aircraft equipped with JSOW A to conduct pre-planned attacks on soft point and area targets such as air defense sites, parked aircraft, airfield and port facilities, command and control antennas, stationary light vehicles, trucks, artillery, and refinery components.
- Combatant Commanders use aircraft equipped with JSOW C to conduct pre-planned attacks on point targets vulnerable to blast and fragmentation effects and point targets vulnerable to penetration such as industrial facilities, logistical systems, and hardened facilities.
- Combatant Commanders will use F/A-18 E/F aircraft equipped with JSOW C-1 to conduct attacks against moving maritime targets and aircrew will have the ability to retarget weapons post launch. JSOW C-1 will retain the JSOW C legacy capability against stationary land targets.

Major Contractor

Raytheon Company, Missile Systems – Tucson, Arizona

Activity

- The Navy concluded operational testing and declared IOC of the JSOW C-1 in June 2016.
- The Navy completed 166 captive flight test (CFT) runs versus stationary land targets and 160 CFT runs versus mobile maritime targets. However, due to range, target, and environmental limitations as well as a problem with the computer system used to collect the data, many of the planned target runs in the approved operational test plan design of experiments were not accomplished adequately to fully assess

weapon accuracy. The computer system that was used to collect and store the data was unable to produce complete data files for a substantial number of runs against both land and maritime targets. The end-game portions of many runs were missing, resulting in incomplete data files that allowed for the collection of reliability data but not weapon accuracy. The Navy, through follow-on analysis of captive carry test seeker video, was able to assess weapon seeker tracking, but not miss-distance data, for many of the CFT runs.

- The Navy, through follow-on analysis of captive carry test seeker video, was able to assess attack success, but not miss-distance data, on an additional 37 maritime target runs.
- In operational testing, the Navy successfully completed one free flight test event versus a stationary land target on October 21, 2015, and one free flight test versus a mobile maritime target on January 26, 2016.
- The Navy unsuccessfully attempted a free flight test versus a mobile maritime target on February 9, 2016.
  - This shot was designed to be a long-range Advanced Targeting Forward Looking Infrared (AT-FLIR) targeting pod cued shot with handover to a second aircraft for weapon control. Due to range weather limitations, the aircraft providing initial target location and in-flight target updates to the missile was artificially close to the target and passed a very small target location error to the missile to define its search area for the target. However, this aircraft also had an unknown AT-FLIR boresight error, which resulted in a large error in target location. This combination resulted in the target being outside of the missile's search area and a weapon miss. Due to this combination of errors, this event was considered a no-test.
  - A previous captive carry rehearsal of this event on the same sortie, with the aircraft at range providing the initial target location as designed, and without these errors, was assessed as successful.
- The Navy completed carrier suitability testing in February 2016, with 10 catapults and 10 arrestments with aircraft carrying two weapons. The weapons were tested for functionality with no discoveries after this testing.
- Post-IOC, the Navy operational units conducted a live fire Fleet Exercise, Valiant Shield 16, where seven JSOWC-1 weapons were successfully employed against a former Oliver Hazard Perry class frigate. All weapons dropped impacted the ship and achieved high order detonation.
- The Navy conducted cybersecurity testing in April 2016, in accordance with the DOT&E-approved Test and Evaluation Master Plan and operational test plan – except it did not conduct a complete threat representative Adversarial Assessment versus JSOW employment.

Assessment

- DOT&E published a classified FOT&E report in early FY17. This report indicates:
  - Significant amounts of unrecoverable data from captive carry runs, a no-test live fire event, and limited cybersecurity testing resulted in limited information to assess all aspects of JSOW C-1 effectiveness and survivability.
  - Weapon accuracy against stationary land targets has been maintained and moving maritime target accuracy was demonstrated in seven developmental, integrated, and operational free flight test events. .Although the data collected was adequate to demonstrate overall weapon accuracy, it was not adequate to test all the factor effects specified in the approved operational test plan. The additional analysis conducted by the Navy on captive carry test, while unable to gather miss-distance data, was useful in assessing weapon performance and likelihood of attack success.
  - JSOW C-1 Mean Flight Hours Between Operational Mission Failure exceeded the requirement value of 95 hours.
  - The Navy has reduced the complexity of the PVI in the F/A-18E/F H10 software. There remain minor PVI challenges that could prevent successful mission execution. These challenges can be effectively overcome with proper training prior to employment. The Navy has further reduced these challenges in F/A-18E/F H12 software, scheduled for release in FY17.
  - In operational testing, aircrew workload to employ the weapon increased due to display errors in target location on multiple displays, a persistent incorrect advisory of missing cryptographic key data, and intermittent errors in the status of the weapon entering the datalink and during post launch weapon control. The Navy implemented a fix to the Joint Tactical Information Distribution Network Library after the completion of operational testing. This fix was tested during Harpoon II+ testing and in Exercise Valiant Shield with the JSOW; these errors are no longer present.
- Cybersecurity testing of the JSOW C-1 was insufficient to fully test the cyber vulnerabilities of the weapon and support equipment.

Recommendations

- Status of Previous Recommendations. The Navy has partially addressed the previous recommendations. The Navy has demonstrated a reduction in software-driven failures during the extended integrated testing phase. While it has significantly reduced the complex PVI, its plan will not fully address this issue until the F/A-18E/F H12 software release, scheduled for FY17.
- FY16 Recommendations. The Navy should:
  1. Continue to reduce the PVI complexity between the JSOW C-1 and the F/A-18E/F to permit successful mission execution.
  2. Conduct a more complete Cooperative Vulnerability and Penetration Assessment to identify all JSOW and supporting equipment vulnerabilities and a threat-representative Adversarial Assessment, as required by the approved operational test plan.

LHA 6 New Amphibious Assault Ship (formerly LHA(R))

Executive Summary

- LHA 6 completed a 10-month Post Shakedown Availability (PSA) on March 25, 2016. The Navy implemented the changes necessary to incorporate the Joint Strike Fighter (JSF) and the MV-22 Osprey on LHA 6 and will include these changes into the LHA 7 construction plan. LHA 6 will conduct her maiden deployment in mid-2017 with a standard Marine Expeditionary Unit (MEU) Aviation Combat Element (ACE) that includes AV-8B Harrier aircraft. LHA 6 will not complete her operational evaluation of the ship's ability to support a complement of 20 JSF aircraft until FY19.
- The Navy conducted the first part of LHA 6 IOT&E phase OT-C5, which assesses the cybersecurity of the LHA 6. The Cooperative Vulnerability and Penetration Assessment (CVPA) was executed from August 15 – 29, 2016, with the Adversarial Assessment (AA) planned for February 2017. The Navy's Commander, Operational Test and Evaluation Force (COTF) conducted testing on 6 of 128 systems due to limited tester availability, and reported that Hull, Mechanical, and Electrical (HM&E) systems and the Navigation Sensor System Interface (NAVSSI) cannot be tested due to safety concerns.
- The Navy and Marine Corps Operational Test Agencies developed a plan to complete LHA 6 IOT&E phase OT-C4 – the amphibious warfare (AMW) phase – in conjunction with scheduled pre-deployment fleet exercises. The Navy's Program Office is also coordinating with fleet and Marine Corps leadership to conduct the Total Ship Survivability Trial (TSST) in conjunction with these fleet exercises.
- After the PSA, the Navy recommenced LHA 6 IOT&E with the OT-C2 test phase, which was conducted during the Rim of the Pacific multi-national exercise. No Critical Operational Issues were resolved during this phase of test, which was conducted to only provide supplemental data and to inform the Operational Test Agencies as they develop their methodology to execute OT&E in conjunction with the formal certifying fleet exercises in 2QFY17.
- LHA 6 IOT&E phase OT-C3, planned for January 2017, will include tests of the gun systems against the small boat raid and low slow flyer and a demonstration of the chemical warfare detection, protection, and recovery system.
- LHA 6 IOT&E phase OT-C4 will be conducted in April through June 2017. The test will serve as the assessment of the AMW mission areas and be performed in conjunction with the Amphibious Squadron (PHIBRON)/MEU Integration exercise (PMINT), Composite Training Unit Exercise, and conclude with the final Certifying Exercise. Integration of test needs, goals, and requirements is essential from the earliest stage (i.e., the PMINT initial planning conference).

System

- LHA 6 is the lead ship of this new class of large-deck amphibious assault ships designed to support a notional mix of fixed- and rotary-wing aircraft consisting of 12 MV-22 Ospreys, 6 F-35B JSFs (Short Take Off/Vertical Landing variant), 4 CH-53Es, 7 AH 1s/ UH 1s, and 2 embarked H-60 Search and Rescue aircraft, or a load out of 20 F-35Bs and 2 embarked H-60 Search and Rescue aircraft. Key ship features and systems include the following:
  - A greater aviation storage capacity and an increase in the size of the hangar bay is required to accommodate the enhanced aviation maintenance requirements for the MEU ACE with F-35B and MV-22. Additionally, two maintenance areas with high-overhead clearance have been incorporated in the hangar to accommodate maintenance on MV-22s in the spread configuration (wing spread, nacelles vertical, and rotors spread).
  - The ship does not have a well deck. All personnel and equipment transfer to the beach must be done by aviation units.
  - Shipboard medical spaces were reduced by approximately two thirds compared to contemporary LHDs to accommodate the expanded hangar bay.
- The LHA 6 combat system for defense against air threats and small surface craft includes the following major components:
  - The Ship Self-Defense System (SSDS) MK 2 Mod 4B supporting the integration and control of most other combat system elements
  - The ship's AN/SPS-48E and AN/SPS-49A air search radars and the AN/SPQ-9B horizon search radar
  - USG-2 Cooperative Engagement Capability real-time sensor netting system

- The Rolling Airframe Missile and the Evolved Seasparrow Missile (ESSM), with the NATO Seasparrow MK 9 Track Illuminators
- The AN/SLQ-32B(V)2 electronic warfare system with the Nulka electronic decoy-equipped MK 53 Decoy Launching System
- The Phalanx Close-In Weapon System Block 1B and the MK 38 Mod 2 Gun Weapon System

- Two marine gas turbine engines, two electric auxiliary propulsion motors, and two controllable pitch propellers provide propulsion. Six diesel generators provide electric power.
- Command, control, communications, computers, and intelligence (C4I) facilities and equipment support Marine Corps Landing Force operations. The Navy will not install the Consolidated Afloat Networks and Enterprise Services (CANES) on the LHA 6 before FY22, but the LHA 7 design and beyond will deploy with CANES incorporated.
- In addition to the self-defense features discussed above, the ship has the following survivability features:
  - Improved ballistic protection for magazines and other vital spaces as well as the inclusion of some shock hardened systems/components intended to enhance survivability.
  - Various installed and portable damage control, firefighting, and dewatering systems intended to support recoverability from peacetime shipboard fire and flooding casualties and from battle damage incurred during combat.
- The Navy will introduce a Flight 1 variant of the LHA(R) program with the third ship, LHA 8. It will have a well deck for deploying surface connectors to move troops and equipment ashore, a modified flight deck, and reduced island intended to enable an aviation support capability similar to that of LHA 6.

Mission

The Joint Maritime Component Commander will employ LHA 6 to:

- Serve as the primary aviation platform within an Amphibious Ready Group with space and accommodations for Marine Corps vehicles, cargo, ammunition, and more than 1,600 troops
- Serve as an afloat headquarters for an MEU Amphibious Squadron, or other Joint Force commands using its C4I facilities and equipment
- Accommodate elements of a Marine Expeditionary Brigade when part of a larger amphibious task force
- Carry and discharge combat service support elements and cargo to sustain the landing force

Major Contractor

Huntington Ingalls Industries, Ingalls Shipbuilding Division – Pascagoula, Mississippi

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Activity

- LHA 6 completed her PSA on March 25, 2016. The 10-month long PSA, held from May 2015 until March 2016, prevented any significant testing through the availability. The principal tasks accomplished during PSA were the design modifications to the flight deck to account for the deck strengthening, heat-resistant material improvements, and lighting positioning to accommodate the JSF F-35B and benefit MV-22 Osprey operations. The flight deck changes have been included in the LHA 7 design currently under construction at Huntington Ingalls shipyard.
- Since completing her PSA, the Navy recommenced LHA 6 IOT&E with the OT-C2 test event, conducted from June 29 through August 3, 2016. The test was conducted during the Rim of the Pacific multi-national exercise. No Critical Operational Issues were resolved during this phase of test. The exercise was conducted to provide supplemental data and to develop a methodology on how best to accomplish testing in conjunction with the formal certifying fleet exercises to be conducted in 2QFY17.
- The Navy conducted the LHA 6 cybersecurity testing CVPA from August 15 – 29, 2016, and the AA is planned for February 2017. COTF conducted testing on 6 of 128 systems, but did not perform testing on HM&E systems due to safety concerns. The Navy did not permit any hands-on manipulation of HM&E or NAVSSI systems; the Navy plans to construct a stand-alone laboratory environment to conduct testing of such shipboard systems in high fidelity representative test environments without the risk of corrupting them..
- The Navy is developing an LHA(R) Test and Evaluation Master Plan (TEMP) Revision B to address design modifications to LHA 8, including the addition of the well deck and changes to the flight deck, the island configuration, the combat system, medical spaces, fuel tanks, and supporting spaces. Evolutions of Marine Corps aircraft, surface connectors, and vehicles will also be considered.
- The Navy has stated it is not planning to execute the Advanced Mine Simulation System (AMISS) trial, which would be used to establish the mine susceptibility of the LHA 6, as agreed to in the DOT&E-approved TEMP Revision A. To date, the Navy has not presented a valid alternative to conducting the AMISS trial.

Assessment

- Because LHA 6 does not have a well-deck, it will rely exclusively on air assets to move forces ashore. The Navy and Marine Corps are in the process of adjusting their tactics to be consistent with the capabilities of LHA 6. In particular, the aircraft mix and equipment load-out used on an LHD with a well deck is unlikely to enable combat power to be massed rapidly ashore from LHA 6. The Navy and Marine Corps to date have not finalized the tactics that will be required for IOT&E.

- The LHA 6 TSST, which contributes to the survivability assessment of the ship, was planned to occur during the AMW event consistent with execution of an efficient test program. The Navy has rescheduled the test to occur before the LHA 6 pre-deployment exercises in March/April 2017 to ensure the presence of an operationally representative load-out aboard the ship during the TSST. The Navy has coordinated with the fleet and Marine Corps leadership to ensure the TSST is conducted in an operationally realistic manner.
- Results of testing completed to date continue to indicate that LHA 6 has some ship self-defense capability against older ASCM threats. LHA 6 ship self-defense performance against newer ASCM threats remains undetermined pending completion of the Probability of Raid Annihilation modeling and simulation test bed tests for IOT&E in late 2017.
  - The Navy initiated the Fire Control Loop Improvement program (FCLIP) to correct some combat system deficiencies related to self-defense against ASCMs and has the potential to mitigate some of the vulnerabilities.
  - The Navy has completed Phase 1 of the FCLIP. What was formally known as FCLIP Phase 2 and 3 are now merged into FCLIP Phase 2, which is not funded. Absent full funding of FCLIP, significant deficiencies will remain in the ability of the ship to defend itself against threats proliferating worldwide.
- DOT&E does not agree that the Navy's proposed modeling and simulation-based approach to assessing the mine susceptibility of LHA 6 is adequate. The Navy should plan to execute the AMISS trial as agreed to in the DOT&E-approved TEMP Revision A.

Recommendations

- Status of Previous Recommendations. The Navy:
  1. Has not fully resolved the recommendation to correct systems engineering deficiencies related to SSDS MK 2-based combat systems and other combat system deficiencies so that LHA 6 can satisfy its Probability of Raid Annihilation requirement.
  2. Has not yet resolved the MK 29 launcher system motor failures due to the additional weight of the ESSM.
  3. In conjunction with the Marine Corps, finalize the tactics, techniques, and procedures for LHA 6 prior to the phase of IOT&E in which they will be used.
  4. Has neither planned nor resourced the mine susceptibility trial for the LHA 6 using the AMISS.
- FY16 Recommendations. The Navy should:
  1. Conduct cybersecurity testing of HM&E and Navigation systems, which was deferred due to safety concerns, in a laboratory to understand the systems' vulnerabilities.
  2. Fully fund and execute all phases of the FCLIP.
  3. Execute the AMISS trial as agreed in TEMP Revision A.

Littoral Combat Ship (LCS)

***Freedom* Variant (LCS 1)**

***Independence* Variant (LCS 2)**

Executive Summary

- Over the last year, DOT&E published four reports on the LCS program:
  - An assessment of the results of operational testing of the *Freedom*-variant seaframe equipped with the Increment 2 surface warfare (SUW) mission package (December 2015)
  - A response to satisfy Congressional reporting requirements in the National Defense Authorization Act (NDAA) for FY16 (January 2016)
  - An early fielding report that provided DOT&E's interim assessments of operational effectiveness and suitability of the *Independence*-variant LCS equipped with the mine countermeasures (MCM) mission package (June 2016)
  - An assessment of the results of operational testing of the *Independence*-variant seaframe equipped with the Increment 2 SUW mission package (November 2016)
- The ability of LCS to perform the bulk of its intended missions (SUW, MCM, and anti-submarine warfare (ASW)) depends on the effectiveness of both the host seaframe and the installed mission packages. To date, despite LCS having being in service since 2008, the Navy has not yet demonstrated effective capability for LCS equipped with the MCM, SUW, or ASW mission packages.
  - As one of the results of a failed technical evaluation period in 2015, the Navy canceled the Remote Minehunting System (RMS), a core component of the MCM mission package. Therefore, the MCM mission package will be unable to meet the Navy's minehunting requirements until replacement systems can demonstrate operationally effective and suitable capabilities, which will not occur before 2020. Mine neutralization and sweeping systems also have yet to demonstrate operationally effective and suitable capabilities in the MCM mission package.
  - The ASW mission package continues to undergo development and is not expected to be ready for operational testing on the first seaframe until 2018 at the earliest.
  - The Increment 2 SUW mission package, following a 2014 operational test aboard a *Freedom* variant and a 2016 operational test aboard an *Independence* variant, has demonstrated only modest ability to aid the ship in defending itself against small swarms of small boats, and the ability to support maritime security operations. The Navy has not yet demonstrated in an operational test that an LCS equipped with this mission package has an offensive capability, such as in an escort mission (a traditional frigate role), nor the capability to defend itself against threat-representative numbers and tactics of attacking small boats. The Navy believes it will meet the original LCS SUW requirements with the introduction of Increment 3 of the SUW mission package, scheduled to begin operational testing in FY18.
  - In September 2016, the Navy announced actions being taken to implement the recommendations of the LCS review team established in February. LCS program changes will reportedly include semi-permanent installation of mission package systems in the seaframes, dedicating specific ships to specific missions. The Navy originally designed LCS from the outset as a "seaframe" into which interchangeable mission packages could be installed. The change represents a departure from the Navy's original concept that intended to provide the Maritime Component Commander with the flexibility to interchange modular capability on any LCS seaframe, as required by the mission. Twenty-four of the planned 28 ships will form into six divisions with three divisions on each coast – *Independence* variants on the west coast and *Freedom* variants on the east coast. Each division of four ships will have a single warfare focus and the crews and mission module detachments will be combined.
- In response to conditions that the NDAA for FY16 placed on the availability of LCS program funding, the Navy successfully completed a partial update of the LCS Test and Evaluation Master Plan (TEMP) to support future operational test and evaluation of the seaframes and mission packages.

Congress required the update to support planning of the needed testing of the Increment 3 SUW mission package, the ASW mission package, to reflect the significant changes to the program's air defense plans, as well as MCM mission package development and composition. DOT&E approved the TEMP change pages submitted by the Navy in March 2016. The Navy is now working to complete a full revision of the TEMP.

- **Live Fire.**
  - The LCS 4 Total Ship Survivability Trial (TSST), conducted in January 2016, exposed weaknesses in the *Independence*-variant design. While the shock-hardened auxiliary bow thruster would have provided limited post-shock propulsion, much of the ship's mission capability would have been lost because critical support systems (such as chilled water) are not designed for reconfiguration and isolation of damage caused by the initial weapons effects or caused by the ensuing fire and flooding.
  - In June and July 2016, the Navy conducted a reduced severity shock trial on USS *Jackson* (LCS 6), executing three shots of increasing severity, ending at 50 percent of the maximum design level rather than 67 percent as done on other ship classes.
    - The Navy argued the reduced severity approach taken for LCS 6 was necessary because it lacked specific test data and a general understanding of how the non-hardened systems would respond to shock. To further mitigate potential equipment damage and personnel injury, some mission systems were removed, other equipment was modified to improve its shock resistance, and construction deficiencies were corrected.
    - The electrical distribution system remained operable or was restored to a limited or full capability prior to the ship's return to port after each shot.
    - Most non-hardened components and systems, including the SeaRAM air defense system, remained operable or were restored to a limited or full capability prior to the ship's return to port after each shot. The Navy is still analyzing the structural response data.
    - DOT&E will release a more comprehensive report in 2017 upon complete analysis of the trial data.
  - Based on the LCS 6 shock trial lessons learned, the Navy conducted a shock trial aboard USS *Milwaukee* (LCS 5) from August 29 through September 23, 2016, starting the trial at more traditional severity levels. However, the Navy stopped the LCS 5 trial after the second shot due to concerns with the shock environment, personnel, and equipment. The Navy did not view the third LCS 5 shock event as worthwhile because of concerns that shocking the ship at the increased level would significantly damage substantial amounts of non-mission-critical equipment, as well as significantly damage a limited amount of hardened, mission-critical equipment, thereby necessitating costly and lengthy repairs.
    - DOT&E cannot adequately assess the survivability of the *Freedom* variant to underwater shock threats, although the behavior of the ship was better than expected throughout the two executed events.
    - Most non-hardened components and systems, including electrical power generation systems and the RAM air defense system, remained operable or were restored to a limited or full capability prior to the ship's return to port after each shot.
    - By not executing the 2/3 level shot, the Navy could not validate the overly conservative assumptions made for the underwater threat shot in the LCS 3 TSST.
    - DOT&E will release a more comprehensive classified report in 2017 upon complete analysis of the trial data.
- **Air Defense.**
  - In June 2016, the Navy responded to DOT&E's August 2015 memorandum that advised the Navy to adopt an alternative test strategy for air defense testing given the Navy's inability to obtain the intellectual property necessary to develop high-fidelity models of the ships' radars. In its response, the Navy indicated that it does not plan to test the current configuration of the *Freedom* variant's air defense system. Instead, the Navy plans to replace the *Freedom* variant's Rolling Airframe Missile (RAM) system with the SeaRAM system starting on LCS 17 and follow-on ships of that variant and will conduct the appropriate testing of that system at the appropriate time. The Navy plans to backfit SeaRAM onto the earlier ships of that variant (LCS 1 through 15) in the 2020-2025 time period. Thus, there will be a 5-10 year gap during which the effectiveness of the deployed *Freedom* variants' air defense system will remain unknown and untested, leaving sailors without knowledge of the capabilities and limitations of their systems should they come under attack.
  - Also in June 2016, the Navy postponed indefinitely its plans to conduct the first of four live fire test events aboard the self-defense test ship to examine the effectiveness of the *Independence* variant's SeaRAM air defense system, citing initial modeling predictions that predicted poor performance in the planned test event scenario. In July 2016, the LCS Program Executive Officer sent a letter to the Navy's Surface Warfare Director (N96) stating that the *Independence* variant's air warfare testing directed by the extant TEMP cannot be executed at current funding levels. DOT&E expects that the *Independence* variant will have been in service nearly 10 years by the time that air defense testing is complete, which at the time of this report, is not anticipated before FY20.
- **Surface Warfare.** While equipped with the Increment 2 SUW mission package, LCS 4 participated in three engagements with small swarms of small boats in the 2015-2016 operational test period. LCS 4 failed the Navy's reduced requirement for interim SUW capability, failing to defeat each of the small boats before one penetrated the prescribed keep-out zone in two of the three events. Although LCS eventually destroyed or disabled all of the attacking boats in these events, the operational test results suggest that the Increment 2 SUW mission package provides the crew with a moderately

enhanced self-defense capability (relative to the capability of the seaframe's 57 mm gun alone), but not an effective offensive capability. In all three events, the ship expended an inefficiently large quantity of ammunition from the 57 mm gun and the two mission package 30 mm guns, while contending with azimuth elevation inhibits that disrupted or prevented firing on the targets. In one event, frequent network communication faults disrupted the flow of navigation information to the gun systems, further hindering the crew's efforts to defeat the attacking boats. LCS 4's failure to defeat this relatively modest threat routinely under test conditions raises questions about its ability to deal with more realistic threats certain to be present in theater, and suggests that LCS will be unsuccessful operating as an escort (a traditional frigate role) to other Navy ships.

- **Seaframe Suitability.** DOT&E has now evaluated both seaframe variants to be not operationally suitable because many of their critical systems are unreliable, and their crews do not have adequate training, tools, and documentation to correct failures when they occur. No matter what mission equipment is loaded on either of the ship variants, the low reliability and availability of seaframe components, coupled with the small crew size, imposed significant constraints on mission capability. During this last year, the seaframes encountered multiple problems with main engines, waterjets, communications, air defense systems, and cooling for the combat system. Unless corrected, the critical operational suitability problems highlighted in this report as well as multiple DOT&E test reports will continue to prevent the ship and mission packages from being operationally effective.
- **Mine Countermeasures.** After canceling the RMS program, the Navy announced its intention to evaluate alternatives to the RMS such as an unmanned surface craft towing improved minehunting sensors and the Knifefish unmanned undersea vehicle (UUV). Although the Navy intended to accelerate development of Knifefish pre-planned product improvements, that effort was not funded. The Navy abandoned plans to conduct operational testing of individual MCM mission package increments and delayed the start of the LCS MCM mission package IOT&E on the first seaframe until late FY20. The Navy also delayed the IOT&Es of the LCS-based airborne mine countermeasures (AMCM) systems that it had expected to complete in FY16 during the operational test of the LCS with the first increment of the MCM mission package.
- **Over-the-Horizon Missile.** The Navy is preparing to add an over-the-horizon anti-ship missile capability to in-service LCS seaframes before they deploy, as soon as FY17. To date, the Navy has completed two structural test firing events from an *Independence*-variant seaframe using two different candidate missile systems. These tests were conducted to determine whether the installed missile systems carry any risk of damaging the ship's structure. A Naval Strike Missile was fired from LCS 4 in September 2014, and a Harpoon Missile was fired from LCS 4 during 2016's Rim of the Pacific (RIMPAC) exercise. The Navy has not conducted any further developmental testing of either missile system, and neither missile has been exercised during an LCS operational test.
- **Cybersecurity.** In early 2016, the Navy made substantial changes to the LCS 4's networks, calling the effort "information assurance (IA) remediation," to correct many of the deficiencies in network security in the baseline *Independence* variant's total ship computing environment. The Navy's IA remediation corrected some of the most severe deficiencies known prior to the test period. However, testing revealed that several problems still remain which will degrade the operational effectiveness of *Independence*-variant seaframes until the problems are corrected. The Navy plans a second phase of IA remediation to correct additional network deficiencies.

System

Seaframes

- The LCS is designed to operate in the shallow waters of the littorals that limit the access of larger ships.
- The Navy is currently procuring two LCS seaframe variants:
  - The *Freedom* variant (odd-numbered ships) is a semi-planing monohull design constructed of steel (hull) and aluminum (deckhouse) with two steerable and two fixed-boost water jets driven by a combined diesel and gas turbine main propulsion system.
  - The *Independence* variant (even-numbered ships) is an aluminum trimaran with two steerable water jets driven by diesel engines and two steerable water jets driven by gas turbine engines.
- Common design specifications include:
  - Sprint speed in excess of 40 knots, draft of less than 20 feet, and an unrefueled range in excess of 3,500 nautical miles at 14 knots
  - Accommodations for up to 98 personnel
  - A common Mission Package Computing Environment for mission package control using Mission Package Application Software installed when a mission package is embarked
  - A Multi-Vehicle Communications System to support simultaneous communications with multiple unmanned off-board vehicles
  - Hangars sized to embark MH-60R/S and Vertical Take-off Unmanned Aerial Vehicles (VTUAVs)
  - MK 110 57 mm gun (BAE/BOFORS)
- The variants include the following damage control features:
  - Ballistic protection for magazines and other vital spaces
  - Various installed and portable damage control, firefighting, and dewatering systems intended to support recoverability from shipboard fire and flooding casualties
- The designs have different core combat systems to provide command and control, situational awareness, and self defense against anti-ship cruise missiles (ASCMs) and surface craft.
  - *Freedom* variant: COMBATSS-21, an Aegis-based integrated combat weapons system with a TRS-3D (AN/SPS-75) air and surface search radar (ASR) (Airbus, France); Rolling Airframe Missile (RAM) system supported by elements from the Ship Self Defense System (Raytheon) (one 21-cell launcher); a Terma Soft

Kill Weapon System (Denmark); and a DORNA EOD gunfire control system with an electro optical/infrared sensor (Navantia, Spain) to control the MK 110 57 mm gun. In 2013 the Navy announced that, starting with LCS 17, future *Freedom*-variant ships will be fitted with SeaRAM, instead of RAM, as their air defense system. The Navy is also developing plans to backfit SeaRAM on earlier *Freedom* seaframes between 2020 and 2025. In the interim, the Navy has accepted the operational risk associated with continued operation of *Freedom* seaframes with the RAM air defense system, and does not plan to operationally test this configuration.

- *Independence* variant: Integrated Combat Management System derived from the Thales TACTICOS system (The Netherlands) with a Sea Giraffe (AN/SPS-77) ASR (SAAB, Sweden); one MK 15 Mod 31 SeaRAM system (Raytheon) (integrates the search, track, and engagement scheduler of the Phalanx Close-in Weapon System with an 11-round RAM launcher assembly); Automatic Launch of Expendables (ALEX) System (off-board decoy countermeasures) (Sippican, U.S.), and SAFIRE (FLIR, U.S.) for 57 mm gun fire control.

- Commencing with LCS 7 and LCS 10, the Navy plans to incorporate changes needed for compatibility with the ASW mission package in future seaframes. The Navy has not yet addressed the plan for backfitting these changes in earlier seaframes.
- The Navy is preparing to add an over-the-horizon anti-ship missile capability to in-service LCS seaframes before they deploy, as soon as FY17. To date, the Navy has completed two structural test firing events from an *Independence* variant seaframe using two different candidate missile systems: the Naval Strike Missile System (Kongsberg/Raytheon) and the Harpoon weapon system (Boeing).
- The Navy originally planned to acquire 55 LCSs, but reduced the planned procurement to 52 ships in 2013. In a February 24, 2014, memorandum, the Secretary of Defense announced that no new contract negotiations beyond 32 ships would go forward and directed the Navy to submit alternative proposals to procure a more capable and lethal small surface combatant, generally consistent with the capabilities of a Frigate. In December 2015, the Secretary of Defense directed that the total procurement of LCS and the improved small surface combatant variant (now called a Frigate) be truncated to 40 ships. The Secretary also directed that the LCS program down-select to a single variant and transition to the Frigate no later than FY19. The Navy plans to acquire the last 12 ships in the Frigate configuration, for which the two prime contractors are developing proposals.

Mission Packages

- LCS is designed to host a variety of individual warfare systems (mission modules) assembled and integrated into interchangeable mission packages. The Navy currently plans to field MCM, SUW, and ASW mission packages. A mission package provides the seaframes with capability for a single or "focused" mission. Multiple individual programs of record involving sensor and weapon systems and off-board vehicles make up the individual mission modules. Summarized below is the current acquisition strategy for the incremental development of each mission module. Although the Navy had been planning to field four increments of the MCM mission package following associated phases of operational testing, the program has recently decided to integrate and field new capabilities whenever they are ready. The Navy also deferred IOT&E of the MCM mission package until mine hunting and sweeping systems are mature enough to complete end-to-end mine clearance requirements throughout most of the water column.

SUW Mission Package

- Increment 1 included:
  - Gun Mission Module (two MK 46 30 mm guns)
  - Aviation Module (embarked MH-60R/S). Because of a shortage of MH-60R helicopters, the Navy is substituting the less-capable MH-60S helicopter, which does not have a radar.
- Increment 2 added:
  - Maritime Security Module (two 11-meter rigid-hull inflatable boats (RHIBs) with associated launch and recovery equipment)
- Increment 3 will add:
  - Surface-to-Surface Missile Module (SSMM) Increment I, employing the AGM 114L-8A Longbow HELLFIRE missile
  - One MQ-8B or MQ-8C Fire Scout VTUAV to augment the Aviation Module
- Increment 4, if fielded, would add:
  - SSMM Increment II (replacing Increment I) to provide a longer range surface engagement capability

MCM Mission Package

- The current version of the mission package (formerly described as Increment 1) includes:
  - Remote Minehunting Module, consisting of two Remote Multi-Mission Vehicles (RMMVs) (version 6.0) and three AN/AQS-20A sensors.
  - Aviation Module consisting of an MH-60S Block 2B or subsequent AMCM helicopter outfitted with an AMCM system operator workstation and a tether system.
  - Near Surface Detection Module, consisting of one Airborne Laser Mine Detection System (ALMDS) and an embarked spare.
  - Airborne Mine Neutralization Module, consisting of one Airborne Mine Neutralization System (AMNS) unit and an embarked spare. The current version of AMNS does not include a near-surface mine neutralization capability.
- The composition of the future (circa FY20-25) MCM mission package is unsettled. In the wake of the Navy's Technical Evaluation of the current mission package in 2015, an independent review team recommended that the Navy cancel plans to procure additional RMMVs and instead evaluate other alternatives. The Navy subsequently canceled the RMS program but funded refurbishment of a

small number of the existing RMMVs. Although the Navy may still employ the existing RMMVs in some capacity, planning for developmental and operational testing of the mission package is proceeding under the assumption that the future minehunting capability will be provided by one or two unmanned surface vessels towing an AN/AQS-20C or AN/AQS-24C minehunting sensor and a pair of Knifefish UUVs. Both minehunting solutions are under development.

- In addition to the selected minehunting system and the AMCM systems ALMDS and AMNS, for which the Navy plans to declare Initial Operational Capability (IOC) in FY17, the future MCM mission package will likely include:
  - Coastal Mine Reconnaissance Module, consisting of the Coastal Battlefield Reconnaissance and Analysis (COBRA) Block I, Block II, or Block III system and one MQ-8B or MQ-8C VTUAV for daytime unmanned aerial tactical reconnaissance to detect and localize mine lines and obstacles in the beach zone (Blocks I and II) and the surf zone (Block II). The Navy also expects the Block II system to add improved beach zone detection capability against small mines and add nighttime capability. As currently envisioned, Block III will add the capability to detect buried mines in the beach zone and surf zone. The Navy expects the Block I system to reach IOC in FY17. The Navy expects Block II to reach IOC in FY22; the Block III IOC date has not yet been established.
  - An Unmanned Mine Sweeping Module, consisting of the Unmanned Influence Sweep System (UISS) to detonate acoustic-, magnetic-, and combined acoustic/magnetic-initiated volume and bottom mines. The Navy is developing an unmanned surface vehicle (USV) based on the UISS surface craft that can host the minesweeping system or tow a minehunting sensor. The Navy expects UISS to reach IOC early in FY19.
  - The Barracuda Mine Neutralization System (MNS), which the Navy expects to provide a near-surface mine neutralization capability. If successful, it will also augment AMNS in other portions of the water column. The Navy plans to deploy Barracuda from LCS using the USV as well as manned and unmanned aircraft and expects the system to be ready to begin developmental testing in FY22.
  - Buried Minehunting Module, consisting of two Knifefish UUVs, battery-powered, autonomous underwater vehicles, employing a low frequency, broadband, synthetic aperture sonar to detect and classify volume and bottom mines in shallow water. The Navy plans for Knifefish to reach IOC in FY18.
  - Pre-planned product improvements (P3I) to ALMDS are currently unfunded. When funding becomes available, the Navy also plans to commence developmental testing of an alternate AMNS fiber-optic cable material designed to reduce the incidence of breakage.
- The Navy is planning to use Expeditionary MCM units – consisting of Explosive Ordnance Disposal personnel equipped with legacy MCM systems and experimental systems deployed to theater – to augment LCSs equipped with MCM mission packages. In particular, the Navy envisions Expeditionary MCM forces, aboard LCSs or other ships, as a gap-filler in missions for which LCS MCM mission package capabilities do not yet exist.

ASW Mission Package

- Torpedo Defense and Countermeasures Module (Lightweight Tow torpedo countermeasure)
- ASW Escort Module (Multi-Function Towed Array and Variable Depth Sonar)
  - The Navy expects to select the vendor for these systems in FY17 and conduct the first operational test of the ASW mission package in late FY18.
- Aviation Module (embarked MH-60R and MQ-8B or MQ-8C Fire Scout VTUAV)

Mission

- The Maritime Component Commander will employ LCS to conduct MCM, ASW, or SUW tasks depending on the mission package installed in the seaframe. Because of capabilities inherent to the seaframe, commanders can employ LCS in a maritime presence role in any configuration. With the Maritime Security Module, installed as part of the SUW mission package, the ship can conduct Maritime Security Operations, including Visit, Board, Search, and Seizure of ships suspected of transporting contraband.
- In September 2016, the Navy announced actions being taken to implement the recommendations of the LCS review team established in February. LCS program changes will reportedly include semi-permanent installation of mission package systems in the seaframes, dedicating specific ships to specific missions. The Navy originally designed LCS from the outset as a "seaframe" into which interchangeable mission packages could be installed. The change represents a departure from the Navy's original concept that intended to provide the Maritime Component Commander with the flexibility to interchange modular capability on any LCS seaframe, as required by the mission. Twenty-four of the planned 28 ships will form into six divisions with three divisions on each coast – *Independence* variants on the west coast and *Freedom* variants on the east coast. Each division of four ships will have a single warfare focus and the crews and mission module detachments will be combined.
- The Navy can employ LCS alone or in company with other ships. The Navy's Concept of Operations (CONOPS) for LCS anticipates that the ship's primary operational role will involve preparing the operational environment for joint force assured access to critical littoral regions by conducting MCM, ASW, and SUW operations, possibly under an air defense umbrella as determined necessary by the operational commander. However, the latest CONOPS observes, "The most effective near-term operational roles for LCS to support the maritime strategy are theater security cooperation and maritime security operations supporting deterrence and maritime security."

Major Contractors
- *Freedom* variant
  - Prime: Lockheed Martin Maritime Systems and Sensors – Washington, District of Columbia
  - Shipbuilder: Marinette Marine – Marinette, Wisconsin
- *Independence* variant
  - Prime for LCS 2 and LCS 4: General Dynamics Marine Systems Bath Iron Works – Bath, Maine
  - Prime for LCS 6 and subsequent even numbered ships: Austal USA – Mobile, Alabama
  - Shipbuilder: Austal USA – Mobile, Alabama
- Mission Packages
  - Mission Package Integration contract awarded to Northrop Grumman – Los Angeles, California

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Activity

LCS Program

- In December 2015, DOT&E published an assessment of the results of operational testing of the *Freedom*-variant seaframe equipped with the Increment 2 SUW mission package.
- In January 2016, DOT&E responded to the reporting requirement in section 123 of the NDAA for FY16, which directed DOT&E to report to Congress and the Secretary of Defense on the current CONOPS and expected survivability attributes of each of the seaframes. This report was an update to similar reporting requirements in both the NDAAs for FY14 and FY15. DOT&E tailored this report to address changes to previous assessments due to the additional testing conducted following the previous years' submissions.
- In February 2016, the Chief of Naval Operations and the Assistant Secretary of the Navy for Research, Development, and Acquisition established a panel headed by the Commander, Naval Surface Forces to review the LCS program, including the crewing, operations, training, and maintenance of the ships.
- In response to conditions that the FY16 NDAA placed on the availability of LCS program funding, the Navy successfully completed a partial update of the LCS TEMP to support future OT&E of the seaframes and mission packages. Congress required the update to support planning of the needed testing of the Increment 3 SUW mission package, the ASW mission package, to reflect the significant changes to the program's air defense plans, as well as MCM mission package development and composition. DOT&E approved the change pages to the TEMP in March 2016. Additional updates are required to complete a revision to the TEMP, including developmental and integrated testing plans, changes to reflect the Navy's evolving plans for the MCM mission package, air defense testing of the seaframes, and plans for providing seaframes with an over-the-horizon missile capability.
- In April 2016, DOT&E provided USD(AT&L) an assessment of the capabilities and limitations of LCS ships and mission packages to support USD(AT&L)'s FY16 annual in-process review of the LCS program. That report summarized DOT&E's current assessment of both LCS variants, including an evaluation of the seaframes' cybersecurity, air defense, surface self-defense, reliability, and availability, and known survivability shortfalls. The report also provided a preliminary assessment of recent developmental and operational test results in advance of the formal submission of operational test and early fielding reports for the SUW and MCM mission packages, respectively.
- In June 2016, DOT&E submitted an early fielding report to the Congress in response to the Navy's plan to deploy the *Independence*-variant LCS equipped with the MCM mission package prior to the conduct of operational testing. The classified report provided DOT&E's interim assessments of operational effectiveness and operational suitability of the *Independence*-variant LCS employing the MCM mission package consisting of the RMS, MH-60S, ALMDS, and AMNS.
- In September 2016, the Navy announced actions being taken to implement the recommendations of the LCS review team established in February. LCS program changes will reportedly include semi-permanent installation of mission package systems in the seaframes, dedicating specific ships to specific missions. The Navy originally designed LCS from the outset as a "seaframe" into which interchangeable mission packages could be installed. The change represents a departure from the Navy's original concept that intended to provide the Maritime Component Commander with the flexibility to interchange modular capability on any LCS seaframe, as required by the mission. Twenty-four of the planned 28 ships will form into six divisions with three divisions on each coast – *Independence* variants on the west coast and *Freedom* variants on the east coast. Each division of four ships will have a single warfare focus and the crews and mission module detachments will be combined. The Navy also plans to establish "maintenance execution teams" staffed with LCS sailors in each division to assist ship crews with preventive and corrective maintenance. One of the ships in each division will be a dedicated training platform; it will not normally deploy overseas and will be staffed by a single crew of experienced LCS sailors. The Navy plans to adopt the blue-gold crewing model (two crews for every one ship) for selected ships instead of the current 3-2-1 crewing plan, which provides three crews for every two ships to keep one of those ships forward deployed. The Navy also plans to dedicate the

first four LCSs for experimentation, test, and evaluation activities vice routinely deploying them as part of the normal ship deployment rotation.

- In November 2016, DOT&E published an assessment of the results of operational testing of the *Independence*-variant seaframe equipped with the Increment 2 SUW mission package.

Seaframe Test Activities

- *Freedom* Variant:
  - During high-speed operations aboard LCS 5 in December 2015, a software failure resulted in damage to the high-speed clutches connecting the gas turbine engines to the combining gears, contaminating the lubricating oil system and damaging the combining gears. Repairs to the clutches and combining gears sidelined the ship for about 3 months.
  - In January 2016, during diesel engine testing aboard LCS 3 at the Changi Naval Base in Singapore, combining gears were damaged when they were operated without lubrication. After a lengthy repair period, the ship departed Singapore for San Diego, California, on August 22, 2016, having been out of service for more than 6 months.
  - In June 2016, the Navy responded to DOT&E's August 2015 memorandum that advised the Navy to adopt an alternative test strategy for air defense testing given the Navy's inability to obtain the intellectual property necessary to develop high-fidelity models of the ships' radars. The Navy's response indicated the Navy does not plan to test the current configuration of the *Freedom* variant's air defense system. Instead, the Navy plans to install the SeaRAM system on LCS 17 and beyond and will conduct the appropriate testing of that system at the appropriate time. The Navy plans to backfit SeaRAM onto the LCS 1-15 hulls in the 2020-2025 time period. This plan reveals a 5-10 year gap where the effectiveness of the deploying *Freedom* variants' air defense system remains unknown and untested.
  - The Navy reported that LCS 1, serving as an Afloat Forward Staging Base, demonstrated the ability to conduct Expeditionary MCM operations during the biennial Rim of the Pacific (RIMPAC) exercise in July 2016. DOT&E has not yet been provided details on these exercises.
  - During the same time period, LCS 1 returned to port multiple times to effect repairs, including decontamination of the lube oil system to remove seawater. Following LCS 1's participation in RIMPAC, the Navy reported that an investigation of the ship's propulsion plant revealed significant damage to at least one of the engines caused by rust and seawater and that it will be necessary to replace or rebuild the engine.
  - The Navy conducted a two shot shock trial aboard USS *Milwaukee* (LCS 5) from August 29 through September 23, 2016.
- *Independence* Variant:
  - The Navy executed a Total Ship Survivability Trial (TSST) aboard USS *Coronado* (LCS 4) from January 25 – 28, 2016.
  - From June 7 to July 17, 2016, the Navy conducted a three shot reduced-severity shock trial of USS *Jackson* (LCS 6) off the eastern coast of Florida.
  - From September 2015 until July 2016, the Navy performed blast and fire testing on the Multi-Compartment Surrogate (MCS) at Aberdeen Proving Grounds, Maryland to assess the vulnerability of the welded-aluminum ship structures under internal blast loading and fire exposure. The Navy will also use these data to update the modeling and simulation tools used in the survivability evaluation of the *Independence* variant.
  - Because of changes to the ship's air defense system, SeaRAM, and additional modifications to the ship's combat system and networks (referred to as IA remediation), the Navy conducted additional testing of the Increment 2 version of the SUW mission package and *Independence*-variant seaframe from March through June 2016. These test events included:
    - Previously deferred developmental test events
    - Air defense testing to examine radar tracking performance against subsonic aerial drones
    - Cybersecurity testing
    - A single self-defense live-fire event and multiple tracking events to confirm that the changes did not degrade SUW performance
  - In December 2015, the Navy conducted the first operationally realistic live-fire event aboard the self-defense test ship, where the SeaRAM system was successful at defeating a raid of two GQM-163 supersonic targets.
  - In June 2016, LCS 4 conducted its second shipboard live fire of the ship's SeaRAM system against a single subsonic aerial drone. The live-fire demonstration was not designed to be an operationally realistic test of the ship's capability, and the aerial drone's flight profile and configuration were not threat representative. These tests provide no insight into SeaRAM's effectiveness against threats that LCS is likely to encounter, but they confirmed that SeaRAM is able to at least target and launch RAM missiles – a necessary but not sufficient testing milestone.
  - During the 2015-2016 operational testing aboard LCS 4, the Navy conducted several non-firing events to examine components of the *Independence* variant's air defenses. These included non-firing radar tracking events against subsonic ASCM drones (June 2016), and non-firing tracking events against Learjet aircraft equipped with ASCM seeker simulators ES-3601 (to test the electronic support measures (ESM) system) (September 2015). The Navy failed to execute a test of the ship's capability to track tactical aircraft in both clear and jamming environments. Such a test was scheduled to occur during

the FY16 operational test events; it is now rescheduled for January 2017.
- In June 2016, the Navy postponed indefinitely its plans to conduct the first of four live fire test events aboard the self-defense test ship to examine the effectiveness of the *Independence* variant's SeaRAM air defense system, citing initial modeling predictions that predicted poor performance. In July 2016, the LCS Program Executive Officer sent a letter to the Navy's Surface Warfare Director (N96) stating that *Independence* air warfare testing directed by the extant LCS TEMP cannot be executed at current funding levels.
- The Navy is preparing to add an over-the-horizon anti-ship missile capability to in-service LCS seaframes before they deploy, as soon as FY17. To date, the Navy has completed two structural test firing events from an *Independence*-variant seaframe using two different candidate missile systems. These tests were conducted to determine if the installed missile systems carry any risk of damaging the ship's structure. A Naval Strike Missile was fired from LCS 4 in September 2014, and a Harpoon Missile was fired from LCS 4 during the July 2016 RIMPAC exercise. The Navy has not conducted any further developmental testing of either missile system, and neither missile has been exercised during an LCS operational test.
- LCS 4 deployed to the western Pacific following participation in RIMPAC, but returned to Pearl Harbor under escort in late August because of a propulsion system casualty that resulted in the failure of two high-speed flexible couplings. LCS 4 was supposed to replace LCS 3 as the rotationally deployed LCS in Singapore. The Navy evaluated the damage and determined this casualty was not a result of human error, but rather a material deficiency. The Navy completed the necessary repairs to the two high-speed flexible couplings and LCS 4 resumed its deployment in late-September.
- After operating out of Pensacola, Florida, for most of FY15, LCS 2 returned to San Diego in February and has remained in port in a maintenance status for the majority of FY16, to include the conduct of a planned dry-docking selected restricted availability.

MCM Mission Package Activity

- In October 2015, the Navy delayed the IOT&E of the *Independence*-variant LCS equipped with the first increment of the MCM mission package pending the outcome of an independent program review, including an evaluation of potential alternatives to the RMS. The Navy chartered the review in response to an August 21, 2015, letter from Senators John McCain and Jack Reed, Chairman and Ranking Member of the Senate Armed Services Committee, expressing concerns about the readiness to enter operational testing given the significant reliability problems observed during a Technical Evaluation in 2015.
- In early 2016, following the completion of the independent review, the Navy:
  - Concluded that reliance on shore-based test metrics provided a false sense of RMMV maturity and contributed to the RMS progressing to sea-based test events prematurely.
  - Cancelled the RMS program and halted further RMMV procurement.
  - Announced its intention to field existing RMMVs following overhauls intended to mitigate high impact failure modes.
  - Indicated a desire to accelerate development of Knifefish UUV pre-planned product improvements, which are funded in the FY18-23 Knifefish budget.
  - Revealed initial plans (subsequently dashed by lack of funding for Knifefish improvements) to evaluate alternatives to the RMS, including an unmanned surface craft towing either the AN/AQS-20C or AN/AQS-24C minehunting sensor and an improved version of the Knifefish UUV already in development.
  - Abandoned plans to conduct operational testing of individual MCM mission package increments and delayed the start of LCS MCM mission package IOT&E until at least FY20.
  - Announced plans to delay IOT&E of the LCS-based AMCM systems (MH-60S with ALMDS and the MH-60S with AMNS) and declare an IOC for these systems in early FY17.
- In May 2016, DOT&E provided comments on the Navy's draft Capability Development Document for the Barracuda Mine Neutralization System. The Navy approved the Barracuda Mine Neutralization Capability Development Document in September 2016.
- In FY16, the Navy continued development of the COBRA Block I system, and conducted developmental testing of the system from a modified U.S. Army UH-1H "Huey" helicopter and MQ-8B airframes. The Navy expects to complete operational testing of the COBRA Block I system in 2017, including a demonstration of LCS integration and an assessment of potential cybersecurity vulnerabilities.
- The Navy continued development of UISS and plans to commence developmental testing in FY17. As part of the initial effort to identify two suitable test sites for future operational testing, the Navy employed a prototype system to characterize the magnetic properties of two environments in FY16. Since the results of these events indicate the two environments the Navy examined are not magnetically diverse, additional environmental characterization will be necessary to ensure that future operational testing spans a representative portion of the system's expected operating regime.
- Throughout 2016, the Navy continued to develop the mine-like Navy Instrumented Threat Target (NAVITTAR), which is a key resource for future developmental and operational testing of the UISS and a potential training asset for the fleet. Although the Navy is developing instrumented targets to imitate a variety of threat mines, the pace of NAVITTAR development and production

raises considerable doubts about whether both moored and bottom targets will be available in sufficient quantities to support the developmental and operational testing of UISS planned in FY17 and FY18. The Navy also employed early NAVITTARs to collect environmental characterization data, but observed multiple incidents in which an instrumented target failed to collect the expected data, raising additional doubts about the adequacy of this critical test resource.

- The Navy continued to develop pre-planned product improvements for the AN/AQS-20 sonar in FY16. The Navy's plans to commence realistic AN/AQS-20C developmental and operational testing are unsettled because of limited availability of two potential tow platforms; existing RMMVs are not reliable but the Navy does not expect to make the initial, limited-quantity USVs compatible with the AN/AQS-20C until late FY18. In testimony to the Senate Armed Services Committee in December, the Navy announced that two RMMVs will be groomed and one will be overhauled. These RMMVs will then be used to continue AN/AQS-20 sonar testing, conduct data collection, and support user evaluation until the first USV is available.
- During FY16, the Knifefish program focused on hardware qualification testing and limited at-sea contractor testing in preparation for future developmental and operational testing. The Knifefish contractor is fixing failures identified in contractor testing. Contingent on adequate program funding, the Navy expects to continue developmental testing (DT), followed by an operational assessment in FY17. The Navy plans to start Knifefish IOT&E in FY18.
- In 2016, the Navy reallocated funding intended to support near-term ALMDS pre-planned product improvement development. The Navy also reported that the improved system would not be available to the LCS MCM mission package until at least FY21, thus indicating it will not be available in time to support the planned LCS MCM mission package IOT&E (in FY20).
- In September 2016, the Navy announced that it plans to use fleet exercises to gather additional data to characterize previously unknown attributes of the AMCM systems it plans to IOC in FY17. For ALMDS, the Navy expects to characterize the system's probability of detection and classification as a function of mine spacing and water depth. For AMNS, the Navy expects to characterize performance of the system against buried mines.
- The Navy is considering various LCS MCM mission package configurations that could be optimized to support mine hunting or mine sweeping operations but it has not established a concept of operations for using one or more of these LCS MCM mission package configurations to support MCM missions.

SUW Mission Package Activity

- In March 2016, DOT&E published a partial assessment of the radar-equipped MQ-8B's performance based on the Navy's Quick Reaction Assessment (QRA) conducted in 2015. The Navy deployed the MQ-8B as part of the SUW mission package on LCS 4 during its brief 2016 deployment; however, the air vehicle has never been operationally tested in conjunction with the SUW mission package on any LCS, so its capabilities and limitations in realistic environments are largely unknown.
- In June 2016, DOT&E published an operational assessment of the MQ-8C based on the testing conducted in November 2015. This report evaluated the MQ-8C sensor and air vehicle performance, but did not include an evaluation of the MQ-8C's ability to contribute to LCS missions or its interoperability with LCS and the SUW mission package. Operational testing of the MQ-8C and the mission package is planned for FY18.
- The Navy began developmental testing of the Increment 3 SUW mission package, completing initial Longbow HELLFIRE missile firing events from a barge in December 2015 and August 2016. The Navy planned to conduct the first structural test firing from an LCS fitted with a Surface-to-Surface Mission Module (SSMM) in September 2016, but that test was postponed until FY17. The Navy hopes to conduct ship-based developmental testing in 2017 in anticipation of Increment 3 operational testing in early FY18 aboard a *Freedom*-variant LCS.

ASW Mission Package Activity

- The Navy did not conduct any at-sea testing of the ASW mission package in FY16. The Navy continued its efforts on a weight reduction program for the components of the mission package, including the handling system and support structures for the variable depth sonar and multifunction towed array. The Navy anticipates downselecting to a single vendor for the variable depth sonar in FY17 and beginning a test program soon thereafter.
- In September 2015, the Navy completed a formal study that identified capability gaps in currently available torpedo surrogates and presented an analysis of alternatives for specific investments to improve threat emulation capability. The Navy has since taken the following actions to address the identified capability gaps:
  - The Navy received approximately $1.0 Million through an FY16 Resource Enhancement Project (REP) proposal and is currently in development of a threat-representative high-speed quiet propulsion system.
  - The Navy submitted an FY17 REP proposal for $6.2 Million to develop a General Threat Torpedo (GTT) that will expand upon the propulsion system under development and provide representation of threat torpedoes in both acoustic performance and tactical logic.

Assessment

Program

- The Navy's original plans to field multiple increments of each mission package as systems mature have changed. The Navy now plans to field a single increment of the ASW mission package. The fourth increment of the SUW mission package is not funded and the Navy intends to complete the SUW mission package with the introduction of the SSMM in Increment 3. Plans for the MCM mission package are uncertain with the recent cancelation of the RMS program and the continued development of multiple other minehunting and neutralization systems.

- The Navy completed initial phases of operational testing in FY14 for the *Freedom* variant with an embarked Increment 2 SUW mission package, and in FY16 for the *Independence* variant with an embarked Increment 2 SUW mission package. The final phases of operational testing will not be completed until the full mission package capability is available. The Navy expects to complete those final phases of operational testing of the ASW and SUW Increment 3 mission packages in FY18.
- The Navy was successful in articulating adequate operational test designs in an update to the LCS TEMP for the SUW, ASW, live fire, and air defense systems. In addition, despite uncertainty in MCM mission package plans, the Navy was also able to develop a high-level strategy for future MCM testing. However, the TEMP does not yet include plans for developmental or integrated testing of these systems, which should be added before testing begins.

Seaframes

- DOT&E has now evaluated both seaframe variants to be not operationally suitable because many of their critical systems are unreliable, and their crews do not have adequate training, tools, and documentation to correct failures when they occur. No matter what mission equipment is loaded on either of the ship variants, the low reliability and availability of seaframe components, coupled with the small crew size, imposed significant constraints on mission capability. During this last year, problems with main engines, waterjets, communications, air defense systems, and cooling for the combat system occurred regularly and required test schedules to be revised or operations to be conducted with reduced capability (e.g., conducting MCM missions without operational air defense systems). These reliability problems are often exacerbated because, by design, the ship's force is not equipped to conduct extensive repairs; problems cannot be corrected quickly due to the need to obtain vendor support, particularly when several vendor home bases are at disparate overseas locations. The inability of the ship to be ready at all times to reach maximum speed, keep its main air defense system in operation, and to cool its computer servers are substantially detrimental to the ships' ability to defend themselves in time of war, much less conduct their assigned missions in a lengthy, sustained manner.
- The Navy has not conducted any of the planned live-fire air defense test events planned as part of the Enterprise Air Warfare Ship Self Defense TEMP or recently updated LCS TEMP. After multiple years of delays, the Navy had planned to conduct the first of those events on the self-defense test ship in FY16, but postponed the test indefinitely because of anticipated poor performance predicted by pre-test modeling and analysis of the planned test event scenario. Without these tests, an adequate assessment of the *Independence*-class probability of raid annihilation requirement is not possible. DOT&E expects that the *Independence* variant will have been in service nearly 10 years by the time that air defense testing is complete, which at the time of this report is not anticipated before FY20.
- The Navy has identified it is not satisfied with the *Freedom* variant's radar and RAM system for defense against ASCMs. The Navy plans to replace the RAM system with SeaRAM, which is the system installed on the *Independence* variant. The Navy does not plan to test the existing *Freedom*-variant air defense systems installed on LCS 1 through 15. DOT&E assesses this to present a high risk for deploying crews, given that many *Freedom*-variant ships will deploy between now and 2020 when backfits of the SeaRAM system on those hulls are scheduled to begin.
- Neither LCS variant has been operationally tested to evaluate its effectiveness against unmanned aerial vehicles and slow-flying aircraft. Although the Navy had planned to test the *Independence* variant's capability to defeat such threats in FY15, the testing was canceled in part due to range safety requirements that would have precluded operationally realistic testing. DOT&E concurred with this decision because proceeding with an unrealistic test would have been a needless waste of resources.
- In the report to Congress responding to the NDAA for FY16, DOT&E noted that the envisioned missions, use of unmanned vehicles, and operating environments have shifted relative to the original LCS vision. DOT&E concluded that the current plan to employ LCS as a forward-deployed combatant, where it might be involved in intense naval conflict, appears to be inconsistent with its inherently poor survivability in those same environments.
- The ability of LCS to perform the bulk of its intended missions (SUW, MCM, ASW) depends on the effectiveness of the mission packages. To date, the Navy has not yet demonstrated effective capability for the MCM, SUW, or ASW mission packages. The Increment 2 SUW mission package has demonstrated some modest ability to aid the ship in defending itself against small swarms of fast-inshore attack craft (though not against threat-representative numbers and tactics), and the ability to support maritime security operations.
- The intentionally small crew size has limited the mission capabilities, combat endurance, maintenance capacity, and recoverability of the ships. The core crew of *Independence* seaframes does not include sufficient watchstanders qualified to operate the seaframe combat system to maintain an alert posture for extended periods of time. During normal peacetime operations, the combat systems can be overseen by a single combat system manager (CSM), but in any elevated threat environment the manning plan calls for two CSMs to stand watch together to reduce overtasking. Since the ship's crew includes only three qualified CSMs,

the ship cannot maintain this alert posture for extended periods, such as might be required when transiting through contested areas, or escorting a high-value unit.

- In September 2016, the Navy released new plans to change the crewing structure. The Navy plans to phase out the 3-2-1 crewing construct and transition to a Blue/Gold model similar to the one used in crewing Ballistic Missile submarines. Originally, core crews and mission module crews were intended to move from hull to hull independently of one another; core crews will now merge with mission module crews and focus on a single warfare area – either SUW, MCM, or ASW. DOT&E does not yet have sufficient information to assess whether the new crewing model will solve the problems observed in the testing of both variants and whether ships will continue to be heavily dependent on Navy shore organizations for administrative and maintenance support.

- *Freedom* Variant Seaframe (LCS 1 and 3):
  - DOT&E's FY15 annual report as well as the comprehensive classified report issued in December 2015 described DOT&E's assessment of the *Freedom* variant. The Navy did not conduct any additional testing or perform any modifications to the seaframe in 2016 that would affect these assessments.
- *Independence* Variant Seaframe (LCS 2 and 4):
  - Although not all aspects of operational effectiveness and suitability could be examined during the 2015/16 operational test, that testing identified shortcomings in cybersecurity, air defense, surface self-defense, reliability, maintainability, and other operations, which are detailed in the DOT&E November 2016 classified report. DOT&E will issue an operational test report following the testing of the final increment of the SUW mission package to support acquisition decision making regarding the Full-Rate Production decision for the SUW mission package and other aspects of the LCS program.
  - **Air Defense.**
    - In the Navy-conducted non-firing radar tracking events against subsonic ASCM drones, the Sea Giraffe radar provided LCS crews with only limited warning to defend itself against ASCMs in certain situations.
    - In the Navy-conducted testing of the *Independence* variant's ES-3601 ESM system, the Navy used Learjet aircraft equipped with ASCM seeker simulators to represent the ASCM threats. The ES-3601 detected the presence of the ASCM seekers in most instances but did not reliably identify certain threats. Classified results are contained in DOT&E's operational test report of November 2016.
    - In the developmental test events evaluating the ship's capability to detect, track, and engage so-called low slow flyers (LSFs) (unmanned aerial vehicles, slow-flying fixed-wing aircraft, and helicopters), the only sensor used to provide tracking information for engaging LSFs with the 57 mm gun was the SAFIRE electro-optical/infrared system. The test events demonstrated that SAFIRE was unable to provide reliable tracking information against some targets. Furthermore, the safety standoff requirements on Navy test ranges were so severe that they precluded meaningful live-fire gun engagements against these targets. Because of these problems and constraints, the program decided to cancel all subsequent live-fire events, including those scheduled for operational testing, conceding that the *Independence* variant is unlikely to be consistently successful when engaging some LSFs until future upgrades of SAFIRE can be implemented. Future testing against LSFs will not be possible until the Navy finds a solution to the severe safety constraints that preclude engaging realistic targets.
    - Although the Navy has postponed indefinitely its plans to conduct live-fire testing of the LCS air defense systems, the Navy has conducted some initial testing of the SeaRAM system, as it is employed aboard Arleigh Burke destroyers. In the Navy-conducted live-fire event aboard the self-defense test ship, the SeaRAM system was successful at defeating a raid of two GQM-163 supersonic targets. Although a stressing event, these targets were not representative of the threats they were attempting to emulate. The Navy does not currently have an aerial target that is capable of emulating some modern ASCM threats. During this test, SeaRAM employed the RAM Block 2 missile, which is different than the current LCS configuration that employs the RAM Block 1A missile. However, if the Navy decides to deploy LCSs with the Block 2 missile, then this test and others planned are germane to an LCS evaluation, however incomplete. DOT&E and the Navy continue to conduct test planning to optimize the available resources and ensure that LCS's air defense testing reflects the capabilities of deploying LCSs.
  - **Surface Self-Defense.** The Navy conducted seven test events (four integrated test events and three dedicated operational test events), each consisting of a single attacking small boat. LCS was required to defeat the boat before it reached a prescribed keep-out range. LCS failed to defeat the small boats in two of the events.
    - The 57 mm gun demonstrated inconsistent performance even in benign conditions, which raises doubts about the ship's ability to defend itself without the SUW mission package installed. The inaccuracy of the targeting systems, the difficulty in establishing a track on the target, and the requirement to hit the target directly when using the point-detonation fuze combine to severely impair effective employment of the gun, and limit effective performance to dangerously short ranges. The Navy has not conducted any testing to determine how well the ship will perform when faced with an attack in a realistic cluttered maritime environment including both neutral

and hostile craft; the Navy has also not conducted operational testing to determine how well the ship (without the SUW mission package) will perform against multiple attacking boats. Nevertheless, given the performance observed during operational testing, the combination of faster threats, multiple threats, threats with longer-range standoff weapons, cluttered sea traffic, or poor visibility is likely to make it difficult for LCS (without the SUW mission package) to defend itself.

- The ship's electro-optical/infrared camera, SAFIRE, is the primary sensor for targeting the 57 mm gun. The system suffers from a number of shortcomings that contribute to inconsistent tracking performance against surface and air targets, including a cumbersome human-systems interface, poor auto-tracker performance, and long intervals between laser range finder returns. These problems likely contributed to the poor accuracy of the 57 mm gun observed during live-fire events, though the root cause(s) of the gun's inaccuracy has not been determined definitively.
- Both of the failures of the surface self-defense test events were caused by MK 110 57 mm gun malfunctions. During the first presentation, the Proximity Fuze Programmer failed, causing all rounds to be fired in the default proximity mode, which then exploded in midair. The crew was unable to repair the failure and continued to fire the gun during the event until the target broached the minimum safety range. Technicians subsequently repaired the gun on July 7, 2015. The second failed event occurred on July 18 when the 57 mm gun jammed during the event. With the assistance of a civilian gun system technician, the crew downloaded the remaining ammunition, cleared the jam, and restored the gun to "single-sided" operation in about 4 hours by consolidating good components. Until repaired on August 7, 2015, the gun was limited to firing 60 rounds, rather than its normal 120, before reloading.
- On two occasions, the shock caused by firing the 57 mm gun unseated network cards, disabling the steering controls on the bridge and forcing the crew to steer the ship from an alternate location. On another occasion, gunfire shook network cables loose, disabling the 57 mm gun. Although the ship was able to recover from these failures within a few minutes and continue the engagement, these types of interruptions have the potential to prolong the ship's exposure to an advancing threat, as was observed during testing.
- In the most recent of the seven live fire test events the Navy conducted against a single-boat target, the crew employed the 57 mm differently than it had in previous live-fire events, and defeated the attacking boat with less ammunition and at a slightly longer range than in previous events. One event does not provide conclusive evidence that the ship can be effective in these scenarios, and such performance was never observed during the swarm-defense test events. Nevertheless, these results are encouraging and suggest that the Navy should examine tactics and alternative gun employment modes, including different projectile fuze settings, as a means to enhance LCS's currently limited capabilities.

- **Missions of State.** LCS 4 completed six mock Missions of State during the 2015 test period requiring the launch and recovery of two 11-meter rigid hull inflatable boats (RHIBs). Although the ship demonstrated the capability to meet Navy requirements for the timely launch of two 11-meter RHIBs to support effective Visit, Board, Search, and Seizure operations in Sea State 2 and below, the time needed to recover the boats aboard ship often exceeded the Navy requirement because of problems with the surface tow cradle and the twin-boom extensible crane (TBEC). Testing revealed operational deficiencies and safety concerns. Observers reported that flaws in the design of the surface tow cradle used in conjunction with the watercraft launch, handling, and recovery system and other problems limit safe launch, internal movement, and recovery of boats to Sea State 2 and below. The cumbersome multi-step boat launch/recovery process has several "single points of failure" – including the surface tow cradle, TBEC, the Mobicon straddle carrier, and a forklift – that increase the likelihood of delays and the possibility of mission failure. The failure of any of these components can halt boat operations and could leave a boat stranded at sea, which happened once during operational testing.
- **Endurance and Speed.** LCS 4 met its transit range requirement, demonstrating a fuel usage rate that enables it to travel more than 4,200 miles at 14 knots if called upon to do so (threshold 3,500 miles). LCS 4 failed its sprint speed requirement of 40 knots, demonstrating a maximum sustained speed of only 37.9 knots in calm waters. It fell just short of its sprint range requirement (1,000 miles at maximum speed), demonstrating fuel burn rates at maximum speed that would enable it to travel 947 miles. LCS 4 has long-standing problems with her ride control system hardware, including interceptors, fins, and T-Max rudders, that affect the ship's maneuverability at high speeds. The ship also had reported recurring problems with frequent clogging of the gas turbine engine fuel oil conditioning module pre-filters and coalescers, and found it difficult to maintain high speed for prolonged periods. The crew found it necessary to station extra operators in the machinery room (normally an unmanned space) to change fuel filters and manually control the fuel oil heaters to keep the gas turbine engines in operation during these high-speed runs.
- **Cybersecurity.** In early 2016, the Navy made substantial changes to the LCS 4's networks, calling

the effort "information assurance (IA) remediation," to correct many of the deficiencies in network security on the baseline *Independence* variant's total ship computing environment. Previous testing on LCS 2 in 2015 revealed several deficiencies in network protection such as the lack of proper settings and access controls, poor network segmentation, and lack of intrusion detection capabilities. The Navy designed and implemented the IA remediation program to mitigate or eliminate such vulnerabilities and was successful in eliminating some of the deficiencies that placed the ship at risk from cyber-attacks conducted by nascent (relatively inexperienced) attackers.

- DOT&E found that the Navy's testing, which included a Cooperative Vulnerability and Penetration Assessment (CVPA) and an Adversarial Assessment in 2016 on LCS 4, was inadequate to fully assess the LCS 4's survivability against cyber attacks originating outside of the ship's networks (an outsider threat). The testing was adequate to determine that some deficiencies remain when attacks occur from an insider threat, however, it was not adequate to determine the full extent of the ship's cybersecurity vulnerability or the mission effects of realistic cyber-attacks. Because of the imminent deployment of LCS 4, the Navy did not allow cybersecurity testers to make changes to the configuration of network components, as a cyber aggressor would almost certainly attempt to do to gain a foothold on the system. Testing was also impeded by electrical work, test site disruptions, and frequent network configuration changes because the test was conducted during a maintenance period. Because of these changes and the installation of systems (including the Harpoon missile and MQ-8B Fire Scout and its control system) after the test completed, DOT&E is uncertain whether an operationally representative configuration of the system was tested. Lack of physical access to many systems imposed by test artificialities, restrictions on the test team, and inadequate test preparation also limited the conduct of the test. The duration of Adversarial Assessment was reduced to less than half the original plan because of the delays experienced during the CVPA. Finally, DOT&E found that the Navy Operational Test Agency's threat emulation used for this test was lacking and did not meet the standards necessary for a robust cybersecurity examination. In July 2016, DOT&E issued guidance on cybersecurity test methods to all of the Service operational test agencies, in part due to the inadequacies in threat emulation observed in the LCS cybersecurity testing.
- Although the Navy's IA remediation corrected some of the most severe deficiencies known prior to the test period, the testing revealed that several problems still remain which will degrade the operational effectiveness of *Independence*-variant seaframes until the problems are corrected. The Navy reported that the second phase of IA remediation intended to correct additional network deficiencies has been installed on all follow on ships; however, DOT&E is unaware of the plans to test these changes on future ships, or whether these changes will correct the problems observed during the LCS 4 test.

- **Operational Suitability.** The *Independence* variant (with or without a mission package) is not suitable for SUW missions or MCM missions, and will remain that way until the Navy can reduce the failure rates of mission-essential equipment and correct the deficiencies that require workarounds and unsustainable manning. Unless corrected, the critical operational suitability problems highlighted below will continue to prevent the ship and mission packages from being operationally effective.
- **LCS 2 Reliability and Availability.** Although not tested in 2016, DOT&E's June 2016 early fielding report on the LCS 2 equipped with the MCM mission package delineated the suitability of the *Independence* variant. The type and severity of the failures observed on LCS 4 were also observed on LCS 2 during the 2015 Technical Evaluation period for the MCM mission package, suggesting that the reliability and availability problems observed are inherent to the *Independence*-variant seaframe, rather than isolated to one hull. The MCM mission package places different and greater demands on seaframe equipment than does the SUW mission package. The frequency of seaframe failures observed on the LCS 2 seaframe with the MCM mission package was greater than that observed on LCS 4 with the SUW mission package; implying the frequency of *Independence* variant seaframe failures and associated availability are likely mission package dependent (i.e., mission dependent). The following are the most significant seaframe equipment problems observed during the 2015 Technical Evaluation period.
  - Recurring failures of the main propulsion diesel engines and their associated water jet assemblies hindered test operations throughout the test period. LCS 2 was unable to launch and recover RMMVs on 15 days because of four separate propulsion equipment failures involving diesel engines, water jets, and associated hydraulic systems and piping. These failures would also have limited the ship's capability to use speed and maneuver to defend itself against small boat threats.
  - LCS 2 experienced multiple air conditioning equipment failures and was unable to supply enough cooling to support the ship's electronics on several occasions. One or more of the ship's three chilled water units was either inoperative or operating at reduced capacity for 159 days (90 percent of the period).

- LCS 2 experienced failures of critical systems such as the SeaRAM air defense system (four failures and a total downtime of 120 days), the ship's 57 mm gun (inoperative for 114 days), the SAFIRE electro-optical/infrared system (inoperative for 25 days), and the Sea Giraffe radar (multiple short outages) that were not repaired immediately because they did not preclude continuation of MCM testing in an environment devoid of air and surface threats. These failures would not have been ignored in a contested location; and many of these failures left the ship defenseless against certain threats for days at a time. Had these failures occurred in theater, the repair efforts would have affected MCM operations, likely forcing the ship off-station to effect repairs and/or embark technicians since the crew does not have the requisite training, parts, or documentation to effect repairs themselves.
- Similar to LCS 4, LCS 2 experienced several Ship Service Diesel Generator failures during the period, but was never without at least two of four generators operable (sufficient to power all combat loads, but which leaves the ship with no redundancy in the event of another failure).
- A Mobicon straddle carrier failure left the ship unable to conduct waterborne MCM operations for a period of 4 days until a technician could travel from Australia to diagnose the problem and make needed adjustments. This episode demonstrated the crew's paucity of documentation, training, and diagnostic equipment.
- Failure of a power conversion unit that supplied 400-Hertz power to the mission bay deprived the ship of MCM mission capability for 20 days while the ship was in port undergoing repairs. The ship also lost the capability to supply 400-Hertz power to the aircraft hangar, where it is needed to conduct pre-mission checks on the MH-60S and AMCM systems. The Navy never determined the cause of the near-simultaneous failures of the two power conversion units, although technicians considered them related.

- **LCS 4 Reliability and Availability.** The mission-essential equipment for conducting SUW on LCS 4 had poor reliability, with a failure that caused a partial loss of capability approximately every day and a complete loss of mission capability every 11 days on average. Based on these failure rates, LCS has a near-zero chance of completing a 14-day mission (the length of time LCS can operate before resupply of food is required) or a 30-day mission (the length of time prescribed by Navy requirements documents) without experiencing an operational mission failure. When averaged over time, and accounting for both planned and unplanned maintenance downtimes, the ship was fully mission capable for SUW missions 24 percent of the 2015 test period, and was fully or partially mission capable 66 percent of the time. The following are the most significant seaframe equipment problems observed during the 2015-2016 developmental and operational test periods.
  - LCS 4 suffered numerous failures of its propulsion systems, including the diesel engines, gas turbines, and steerable waterjets. The most debilitating problems occurred during the first developmental testing period in May and June 2015, when a combination of failures left the ship with only one working engine for 19 days. Following the July 2015 in-port maintenance period, the reliability of the propulsion systems improved, but single engines and waterjets continued to fail, and LCS spent 40 days of the 136-day test period with one or more engines inoperative or degraded. During the 2016 test periods, observers continued to report failures to the diesel engines and gas turbines that limited the ship's speed.
  - LCS 4 was seldom able to keep all three air conditioning units fully operational. In one case, the systems were unable to supply enough cooling to support the ship's electronics for a 2-week period. The Navy recognized that the commercial off-the-shelf chilled-water air conditioning systems installed in LCS 2 and LCS 4 had serious reliability problems and, working with the shipbuilder, sourced the air conditioning systems on LCS 6 and follow-on *Independence* seaframes from a different manufacturer. Since the LCS program has not replaced the air conditioning systems on LCS 2 and LCS 4, those systems are still exhibiting severe reliability problems.
  - LCS 4 experienced several Ship Service Diesel Generator failures during the periods of observation, but was never without at least two of four generators operable (sufficient to power all combat loads, but which leaves the ship with no redundancy in the event of another failure). Problems with electrical switchboards added to the difficulties, as certain combinations of diesel generators would not share load, reducing the redundancy in the system. Observers recorded four load sheds, which automatically severed power to non-essential systems, and in one case, caused key combat systems to shut down.
  - During the 2015 test events, LCS 4 experienced numerous instances in which the flow of navigation data (heading, pitch, and roll) to the combat system was disrupted for short periods, which disabled the Sea Giraffe radar and the 57 mm gun and degraded SeaRAM's performance. The worst recorded instance occurred during the September 2015 live fire gun event when the flow of navigation data was interrupted 34 times, leading to a loss of all tracking information and the inability to fire the 57 mm gun

for nearly 30 minutes. These outages significantly affected the crew's ability to defeat targets and contributed to the ship's failure to defeat all targets before they entered the keep-out zone. The problem defied early troubleshooting efforts and persisted into early 2016; however, observers did not report any navigation data outages after testing resumed in 2016, indicating that the Navy may have corrected the problem during installation of the IA remediation upgrades and other system changes. The Navy reported that the first instances of navigation data outages observed in 2015 were attributable to a cabling failure; and that the root cause of the failure was determined and corrected permanently. The Navy determined that the navigation data outages observed in 2016 were caused by the IA upgrade that had been recently installed in LCS 4 in early 2016; and the outages were remedied by reverting the network core switches back to the pre-IA upgrade routing protocol.

  - The *Independence* variant's primary air defense system, SeaRAM, suffered from poor reliability and availability before, during, and after operational testing aboard LCS 4. Failures caused seven long periods of downtime (greater than 48 hours) between May 16, 2015, and June 18, 2016. Each repair required the delivery of replacement components that were not stocked aboard the ship, and most required assistance from shore-based subject matter experts. These failures left the ship defenseless against ASCMs, and would likely have forced it to return to port for repairs if it had been operating in an ASCM threat area. In addition, the SeaRAM aboard LCS 4 had five short (less than 5 minute) outages during live and simulated engagements against aerial targets, each of which might have resulted in an inbound ASCM hitting the ship. The SeaRAM aboard LCS 2 has also suffered from several long-lived failures.
  - The ship's ride control system, used for high-speed maneuvering, did not appear to be fully functional at any time during developmental or operational testing in FY15 and FY16.

SUW Mission Package

- While equipped with the Increment 2 SUW mission package, LCS 4 participated in three engagements with small swarms of fast-inshore attack craft (small boats). LCS 4 failed the Navy's reduced requirement for interim SUW capability, failing to defeat each of the small boats before one penetrated the prescribed keep-out zone in two of the three events. Although LCS eventually destroyed or disabled all of the attacking boats in these events, the operational test results suggest that the Increment 2 SUW mission package provides the crew with a moderately enhanced self-defense capability (relative to the capability of the 57 mm gun alone) but not an effective offensive capability. In all three events, the ship expended an inefficiently large quantity of ammunition from the 57 mm gun and the two mission package 30 mm guns, while contending with azimuth elevation inhibits that disrupted or prevented firing on the targets. In one event, frequent network communication faults disrupted the flow of navigation information to the gun systems further hindering the crew's efforts to defeat the attacking boats. SAFIRE is a likely contributor to the observed 57 mm gun performance and large ammunition expenditure during surface engagements, and its cumbersome user interface contributed to the workload of already-overtasked watchstanders. LCS 4's failure to defeat this relatively modest threat routinely under test conditions raises questions about its ability to deal with more realistic threats certain to be present in theater, and suggests that LCS will be unsuccessful operating as an escort (a traditional frigate role) to other Navy ships. Additional details about the LCS gun performance and the factors and tactics that contribute to the ship's effectiveness are discussed in DOT&E's November 2016 classified report.
- The Navy has begun work on developing and testing the SSMM, the core component of the Increment 3 mission package. Operational testing in 2015 and 2016 revealed that the ship's radar, the only sensor available to provide initial targeting information to the Longbow HELLFIRE missiles employed from the SSMM, demonstrated performance limitations that might hinder its ability to support missile employment against small boat swarms. The Navy intends to conduct additional developmental testing to better understand these limitations; and the results of these tests will be used to inform future decisions by the Navy to modify missile targeting algorithms and tactics, as needed to overcome the limitations. The Navy plans to demonstrate the ability to meet the original LCS requirements for SUW swarm defense during operational testing of the Increment 3 mission package in FY18.

MCM Mission Package

- DOT&E concluded in a June 2016 early fielding report, based exclusively on the testing conducted before 2016, that an LCS employing the current MCM mission package would not be operationally effective or operationally suitable if called upon to conduct MCM missions in combat. The primary reasons for this conclusions are:
  - Critical MCM systems are not reliable.
  - The ship is not reliable.
  - Vulnerabilities of the RMMV to mines and its high rate of failures do not support sustained operations in potentially mined waters.
  - RMMV operational communications ranges are limited.
  - Minehunting capabilities are limited in other-than-benign environmental conditions.
  - The fleet is not equipped to maintain the ship or the MCM systems.
  - The AMNS cannot neutralize most of the mines in the Navy's threat scenarios.
- In the same early fielding report, DOT&E concluded that the current versions of the individual systems that

comprise the current MCM mission package, specifically the RMS and the MH-60S AMCM helicopter equipped with ALMDS or AMNS, would not be operationally effective or operationally suitable if called upon to conduct MCM missions in combat.

- Although the Navy has implemented some corrective actions to mitigate the problems observed in earlier testing, the substantive unclassified details of DOT&E's assessment are unchanged from the FY15 edition of this report. DOT&E's classified June 2016 early fielding report provides additional detail.
- Developmental MCM Systems. The Navy is continuing to develop the COBRA Block I, Knifefish, and UISS programs and has not yet conducted operational testing of these systems. However, early developmental testing or contractor testing of COBRA Block I and Knifefish have revealed problems that, if not corrected, could adversely affect the operational effectiveness or suitability of these systems, in operational testing planned in FY17 or FY18, and subsequently the future MCM mission package. In addition to the problems observed in early testing of developmental systems, DOT&E used lessons learned from earlier testing of the RMS to identify problems that are likely to affect the upcoming phases of Knifefish and UISS operational testing.
  - During developmental testing of COBRA Block I in early FY16, test data revealed that the system's probability of detection is low against small mines and mines emplaced in some environmental conditions. Thus, without improvements, the capability of the current system will likely be limited in some operationally realistic threat scenarios. Operational testing, planned for 2017, will characterize the COBRA Block I capability against a broader range of operationally realistic conditions.
  - For the Knifefish UUV program, the Navy's developmental efforts are currently focused on system design and have not yet tested Knifefish integration with either LCS seaframe variant. The Navy needs to test battery charging, off-board communications, maintainability, launch and handling equipment and procedures, and the ability of the crew to recover the vehicle reliably while employing the proposed grappling hook capture device to support Knifefish operations on both LCS variants. In addition, it is not yet known how Knifefish operations will be affected by concurrent LCS MCM activities, making operationally realistic testing of the Knifefish UUV in the combined MCM mission package essential.
  - The Knifefish vehicle's low frequency broadband sonar is designed to detect bottom, moored, and buried mines. After early contractor testing revealed that sonar transmitter elements were failing prematurely, the Naval Research Laboratory recommended operating the elements at a significantly lower voltage to extend their operational life. While this change will likely improve the sonar's reliability, the reduction of the sonar's transmitting power will also likely reduce the range at which the sonar can detect objects. Although the operational implications of these changes are not yet known, the actions taken to mitigate reliability problems could negatively affect the assessment of operational effectiveness in the upcoming operational assessment.
  - Knifefish contractor testing in October uncovered a UUV structural failure mode during launch in which the vehicle broke in half during launch from a test ship. The contractor analyzed the failure and suspects it was caused by a combination of factors including the wave height encountered during launch, the vehicle position on the launch ramp, and the launch ramp geometry. The contractor is considering options to address this failure mode such as redesigning the launch ramp and restricting launches to lower sea states.
  - The UISS contractor delivered the first engineering development unit only recently and has not yet conducted testing of a production representative system. The Navy will need to consider integration challenges that include off-board communications, maintainability, launch and handling equipment and procedures, and the ability of the crew to recover the system safely and reliably. Although the Navy plans to characterize UISS performance in dedicated minesweeping scenarios during the initial phases of LCS-based testing, operationally realistic testing of the system in the combined MCM mission package is also essential.
  - Currently, LCS sailors do not possess an organic, in-situ means to measure environmental characteristics that are important to plan UISS minesweeping missions. Although the Navy is working on a solution that it hopes to make available by 2020, the lack of this capability may affect the LCS crew's ability to employ UISS effectively in upcoming operational testing that will characterize minesweeping performance over the range of conditions expected in potential threat scenarios.
- Current Navy plans for developing, integrating, and testing mine hunting and mine sweeping systems in the LCS MCM mission package are not adequately funded to mature the MCM capabilities to meet mission requirements.

ASW Mission Package

- The current threat torpedo surrogates have significant limitations in their ability to represent threat torpedoes. As such, operational assessment of each LCS variant with ASW mission package using these test articles will not fully characterize the ship's capability to defeat incoming threat torpedoes. The proposed development of a General Threat Torpedo (GTT) addresses many of DOT&E's concerns; however, the GTT's capability to support realistic operational testing depends on future Navy decisions to procure a sufficient quantity of GTTs.

LFT&E

- Neither LCS variant is expected to be survivable in high intensity combat because the requirements accept the risk of abandoning the ship under circumstances that would not require such an action on other surface combatants. Although the ships incorporate capabilities to reduce their susceptibility to attack, previous testing of analogous capabilities in other ship classes demonstrates it cannot be assumed LCS will not be hit in high-intensity combat. As designed, the LCS lacks the redundancy and the vertical and longitudinal separation of vital equipment found in other combatants. Such features are required to reduce the likelihood that a single hit will result in loss of propulsion, combat capability, and the ability to control damage and restore system operation.
- LCS does not have the survivability features commensurate with those inherent in the USS *Oliver Hazard Perry*-class Guided Missile Frigate (FFG 7) it is intended to replace. The FFG 7 design proved to retain critical mission capability and continue fighting after receiving a significant hit.
- The LCS 4 Total Ship Survivability Trial (TSST) exposed weaknesses in the *Independence*-variant design.
  - While the auxiliary bow thruster provided a limited means to recover propulsion, much of the ship's mission capability would have been lost because of the primary weapon damage or the ensuing fire and flooding.
  - Damage to chilled water system piping caused an unrecoverable loss of several vital systems because of equipment overheating. The chilled water system's lack of cut-off valves does not allow for isolation of damaged sections.
  - There is a lack of sufficient separation between the two damage control repair stations (DCRS). The Mission Bay Fire scenario resulted in the loss of both DCRS (one from the primary weapon effects and the second due to the spread of smoke as a result of the proximity to the fire boundary). The rescue and assistance locker located in the Helicopter Hangar is not outfitted with DCRS equipment exacerbating the damage control capability shortfalls.
  - Installed damage control systems, such as Aqueous Film Forming Foam (AFFF) and Main Drainage, are designed with motor-operated valves co-located in the compartments that the systems are supposed to protect. As a result, the crew could not access these valves to reconfigure the damaged systems when remote operation was compromised by loss of power or data.
- The Navy conducted a reduced severity shock trial on USS *Jackson* (LCS 6), executing three shots of increasing severity, ending at 50 percent of the maximum design level. The Navy decided not to test up to the standard 2/3 design level due to concerns the ship would suffer a large amount of damage to non-shock hardened mission-critical equipment.
- In addition to reducing the shot severity, the Navy took several protective measures to reduce the risk of equipment damage and personnel injury to include:
  - Removed some equipment before the trial or between shots, such as the Tactical Common Data Link antenna and racks, the navigational radar, and the 57 mm gun.
  - Replaced some rigid pipes with flexible connections.
  - Replaced some existing bolts with higher strength material.
  - Added cable slack in some locations.
  - Rerouted some ducts and pipes and modified ship structure to increase shock excursion space around equipment.
  - Strengthened some bulkheads where heavy equipment was attached.
  - Repaired missing and undersized foundation welds.
  - Tied life rafts to the ship to make sure they did not self-deploy during the shots.
- A preliminary assessment of the LCS 6 shock trial demonstrated that:
  - The Navy assumptions regarding the performance of non-hardened when exposed to underwater shock are overly conservative. The Navy assumed that these components and systems would become inoperable while the shock trial demonstrated most non-hardened components and systems remained operable or were restored to a limited or full capability prior to the ship's return to port on each shot.
  - The ship maintained electrical power generation through all three shots, to include the Non-Vital Ship Service Diesel Generators.
  - The SeaRAM system remained operable through all three shots.
  - The main gun survived shot one, but the Navy removed it for the later shots, conceding that severe damage was likely. The actual gun survivability/firing capability at higher shock severities cannot be assessed.
  - The auxiliary propulsion bow thruster remained operable through all three events.
  - The trimaran ship design displayed unique structural behaviors not seen in mono-hull ships. The attenuation of the shock loading above the keel invalidated the Navy approach of using a target keel velocity as the metric to determine shot shock severity and confidence in the pertinent M&S tools to capture the shock trial phenomena. Despite achieving a target keel velocity, the majority of the LCS 6 deck mounted equipment did not experience the shock severity intended by the Navy.
- Based on the LCS 6 shock trial lessons learned, the Navy conducted a shock trial aboard USS *Milwaukee* (LCS 5) from August 29 through September 23, 2016, starting the trial at more traditional severity levels. However, the Navy stopped the LCS 5 trial after the second shot, thereby not executing the planned third shot due to concerns with the shock environment, personnel, and equipment. The Navy

did not view the third LCS 5 shock event as worthwhile because of concerns that shocking the ship at the increased level would significantly damage substantial amounts of non-mission critical equipment, as well as significantly damage a limited amount of hardened, mission critical equipment, thereby necessitating costly and lengthy repairs.
- The electrical distribution system remained operable or was restored to a limited or full capability prior to the ship's return to port after each shot.
- Most non-hardened components and systems, including the RAM air defense system, remained operable or were restored to a limited or full capability prior to the ship's return to port after each shot.
- By not executing the 2/3 level shot, the Navy could not validate the overly conservative assumptions made for the underwater threat shot in the LCS 3 TSST.
- DOT&E will release a more comprehensive classified report in 2017 upon complete analysis of the trial data.

Recommendations

- Status of Previous FY15 Recommendations.
  - With respect to the MCM mission package and the cancellation of the RMS program, the Navy appears to have accepted the recommendation to shift to a performance-based test schedule rather than continuing a schedule-driven program. The LCS program needs ample time and resources to correct the numerous serious problems with the MCM mission package.
  - The Navy did not accept DOT&E's recommendation to obtain the intellectual property rights needed to develop high-fidelity digital models of the AN/SPS-75 (TRS-3D) and AN/SPS-77 (Sea Giraffe) radars for the Probability of Raid Annihilation Test Bed (a model used to evaluate the effectiveness of the LCS's air defenses). Although the Navy did respond to DOT&E's August 2015 memorandum, it appears that testing of the *Freedom*-variant's current configuration of air defense systems will be eliminated entirely, as LCS 17 and follow-on *Freedom* seaframes will be equipped with SeaRAM. This will leave the air defense capabilities of LCS 1 through 15 untested until the Navy backfits SeaRAM, which is not scheduled to begin until 2020.
  - The Navy has not yet accepted or addressed DOT&E's recommendation to improve the shock resistance of mission-critical electronics in the *Independence*-variant LCS. Until this problem is addressed, LCS is likely to experience a disruption in operations during 57 mm gun engagements and other shock-inducing activities/events.
  - The Navy has not yet formally addressed DOT&E's recommendation to work with the vendor to develop changes and improvements to SAFIRE, which are needed to improve the human-machine interface, reduce the time required to develop a new track, improve tracking, and correct other performance issues noted in FY15 testing. DOT&E reiterates this recommendation and suggests that the Navy also consider replacing the SAFIRE system with a more capable targeting system – one that is more user friendly and enables more accurate and effective gunfire for both air defense and SUW missions.
  - The Navy has begun to correct the causes of *Independence*-variant seaframe problems that disrupted gunnery engagements and other operations, however, several problems still remain that will preclude effective gun employment. The debilitating problem of the intermittent loss of navigation data appears to have been corrected; however, the Navy has not yet corrected the 30 mm gun azimuth-elevation inhibits, and the 57 mm gun's azimuth-dependent range errors. Azimuth-elevation inhibit errors or gun turret-drive errors occur intermittently and are of short durations, and prevent the gunner from firing during an engagement. During testing these errors frequently interrupted engagements at key moments. The Navy developed tactics, techniques and procedures that are now in use to mitigate the problem. The Navy is investigating the root cause of this disruptive error.
  - Despite the cancellation of the RMMV program, DOT&E's recommendation to re-engineer the communications system remains germane, as there is still a need for reliable line-of-sight and over-the-horizon communications between LCS and off-board vehicles. DOT&E recommends continued work to ensure the components of the MCM mission package can communicate reliability and operate over-the-horizon to enable LCS to have an effective MCM capability.
  - The Navy has not yet addressed DOT&E's recommendation to devise a safe method to realistically test the ships' ability to counter LSF threats. The Navy should coordinate with test range authorities to examine the feasibility of reducing the safety standoff restrictions; without changes, no meaningful test of LCS's capability against these threats can be conducted.
  - The Navy's recent change to the LCS concept of employment, which changes the crewing structure, training, and operational deployment of the class partially addresses DOT&E's recommendation to provide LCS crews with better training, technical documentation, test equipment, and tools, along with additional spares to improve the crews' self-sufficiency. It is not yet clear whether these changes will fully address the recommendation and will eliminate the maintenance problems DOT&E has articulated in multiple test reports.
  - The Navy and LCS program are improving their organic expertise with LCS systems; however, the Navy continues to maintain an outsized reliance on equipment vendors and overseas contractors, especially for the maintenance and repair of some critical mission equipment. DOT&E continues to recommend reducing this reliance on outside vendors to ensure crews and the Navy's in-service engineering agent can fully support LCS repair and maintenance activities.
  - As DOT&E recommended, the Navy is investigating options for re-engineering the recovery of watercraft;

however, no solutions have been found to correct the problems with RMMV recovery nor has the Navy demonstrated the ability to recover other vehicles like the Knifefish UUV.
- The Navy has not made progress on developing tactics to mitigate system vulnerabilities to mines, mine collision, and entanglement hazards, and other surface and underwater hazards.

- FY16 Recommendations. Since December 2015, DOT&E issued three operational test reports for the LCS program, each of which contained multiple recommendations for the Navy's consideration that focus on the improvements needed to achieve operational effectiveness, suitability, and survivability, and to improve future testing. A selection of these recommendations is provided below.

Cybersecurity

1. After implementing changes to correct the deficiencies found in the LCS 4 cybersecurity test, conduct a full cybersecurity test, including a Cooperative Vulnerability and Penetration Assessment and Adversarial Assessment. This testing should be conducted on a ship that has received the second phase of IA remediation and should examine the Increment 3 SUW mission package configuration. Future tests should include a range of malicious activities from stealthy to noisy to gain data needed to characterize the ship's detect and react capabilities and should not be conducted during a ship maintenance period (since this contributed to the inadequacy of the LCS 4 test events).
2. Ensure that vulnerabilities identified on one ship are remedied on all ships.
3. Schedule and conduct a comprehensive cybersecurity assessment of the MH-60S helicopter with ALMDS and with AMNS.
4. Expand future cybersecurity testing to include custom malware for system-specific operating systems and an examination of supervisory control and data acquisition systems and programmable logic controllers. Provide a stable ship configuration that accurately reflects the intended deployment configuration and allows for temporary changes to enable testers to examine mission-critical systems and evaluate the mission effects of cyber-attacks.

Seaframes

5. Develop a plan for integration of the MCM mission package with the *Freedom*-variant seaframe, including launch and recovery of MCM watercraft, and schedule early developmental testing to identify implementation challenges.
6. Improve reliability of mission systems and seaframe support systems to reduce logistics support requirements, crew workload, and unplanned downtime during MCM operations.
7. Improve the performance of the 57 mm gun system to increase the effective range and simplify targeting to enable faster and more lethal performance over a broader engagement range.
8. Improve the air-search radar on both seaframes to support earlier detections of ASCMs and tactical aircraft in both clear and jammed environments. Early detection increases the likelihood of survival against attack.
9. Increase the number of qualified Combat Systems Managers (CSMs) on the *Independence*-variant to provide additional operators for the seaframe sensors and guns.
10. Improve the reliability of the engineering systems, including diesel and gas turbine engines, steerable water jets, ride-control systems, and air conditioning equipment.
11. Determine the root cause of the *Independence* variant's fuel oil service system problems that occur during high-speed operations that made it necessary to station additional operators in the machinery room to replace Fuel Oil Conditioning Module pre-filters and control the fuel oil heaters manually.
12. Adequately fund the Air Warfare Ship Self-Defense Enterprise so that adequate testing of the LCS air defense systems can occur.
13. Improve the reliability and availability of SeaRAM.
14. Implement the equipment shock hardening measures employed on LCS 5 and 6 during the shock trial on all ships and survivability improvement findings/recommendations developed as a result of the two shock trial series.
15. Implement the survivability improvement recommendations developed by the LCS 4 TSST team. Most importantly, redesign the *Independence* variant's chilled water system to enable isolation of damaged sections.
16. Reevaluate LCS susceptibility to influence mines by conducting at-sea trials with the Advanced Mine Simulation System.

SUW Mission Package

17. Consider developing multi-ship tactics or build additional capability into future mission packages to enable LCSs, operating in surface action groups, to more effectively counter small-boat swarms that are more threat-representative.
18. Improve the 30 mm gun system's accuracy and expand the guns' effective range so that crews are not limited to a narrow region of success. Without improvements, LCS crews are unlikely to be successful against realistically sized small-boat swarms.

MCM Mission Package

19. Limit procurement of ALMDS, AMNS, and AN/AQS-20A systems, which have significant operational performance limitations that negatively affect LCS MCM mission capability until much needed performance improvements are developed, tested, and proven effective in testing representative of realistic LCS mine-clearance operations. Suspend further use of RMMV v6.0 until completing a comprehensive reliability-centered analysis, correcting

high impact failure modes, and testing repairs in an operationally realistic environment.

20. Given the cancelation of the RMS program, accelerate the development the most promising minehunting alternatives, including the USV with a towed AN/AQS-20C or AN/AQS-24C sensor and the Knifefish UUV with pre-planned product improvements.
21. Avoid overreliance on shore-based testing of mission package systems, which often results in unwarranted confidence in system performance in a maritime environment.
22. Fully resource the development of improvements to the ALMDS and AMNS (or alternative systems such as Barracuda). For ALMDS, efforts should focus on reducing the incidence of false contacts and eliminating the need for multi-pass search tactics. For mine neutralization systems, efforts should focus on reducing the incidents of fiber-optic communications losses, developing the ability to neutralize near-surface mines, and operating in high-current environments.
23. Demonstrate through end-to-end testing that the systems included in future mission packages can achieve the area search rate and detection/classification performance needed to support LCS effectiveness in timely and sustained minehunting and clearance operations. Testing should avoid segmented evaluations of individual components of the mission package.
24. Demonstrate viability of multi-ship LCS MCM Concept of Operations (CONOPS) that address operational concerns such as data sharing, contact management, asset scheduling, and mutual interference when multiple ships operate together to accelerate mine-clearance timelines and, since no planned version of the LCS MCM mission package is expected to perform all MCM functions, develop and demonstrate CONOPS for combined LCS and legacy MCM operations.
25. Accelerate development and production of the Navy Instrumented Threat Target (NAVITTAR) to ensure that sufficient resources are available to support planned developmental and operational testing of UISS and the MCM mission package. Implement a reliability improvement program to mitigate the high failure rate of NAVITTARs observed in early testing.
26. Characterize the magnetic properties of additional U.S. test ranges to identify a second suitable location to execute UISS operational testing.
27. To mitigate the risk of poor operational performance in the LCS MCM mission package, the Navy should demonstrate UISS integration aboard LCS in developmental testing prior to the initial phases of LCS-based operational testing, planned in FY18.
28. Provide adequate funding for developing, integrating, and testing mine hunting and mine sweeping systems in the LCS MCM mission package to mature the MCM capabilities to meet mission requirements.

ASW Mission Package

29. Acquire a sufficient quantity of GTTs, when developed, to characterize the capability of each LCS variant with ASW mission package to defeat threat torpedoes during operational assessment.

Future Operational Testing

30. Develop an operationally realistic, cost-effective alternative for training and testing of small-boat defense operations such as an accreditable, operator-in-the-loop simulation that incorporates tactical computing hardware and software and realistic threat presentations.
31. Provide adequate resources to conduct the full complement of test scenarios prescribed by the recently updated TEMP
32. Complete an update to the LCS TEMP to ensure that future tests, including integrated testing and plans for testing the over-the-horizon missile, are clear and resourced appropriately.
33. Fund development of test targets and ranges to adequately test LCS MCM systems, and then maintain and employ these assets to facilitate MCM operator training and proficiency after fielding.

MH-60S Multi-Mission Combat Support Helicopter

Executive Summary

- In FY16, in conjunction with delays in the Littoral Combat Ship (LCS) mine countermeasures (MCM) mission (MCM) package, the Navy delayed IOT&E of the MH-60S equipped with the Airborne Laser Mine Detection System (ALMDS) and the Airborne Mine Neutralization Systems (AMNS) until at least FY21. Since the Navy plans to declare Initial Operational Capability (IOC) of these systems in early FY17 and deploy them by FY18, prior to the completion of operational testing, DOT&E issued an early fielding report in June 2016. The report concluded that the MH-60S Airborne Mine Countermeasures (AMCM) helicopter equipped with ALMDS or AMNS would not be operationally effective or operationally suitable if called upon to conduct MCM missions in combat. The primary reasons for these conclusions are:
  - The combined AMCM systems are not reliable.
  - The ALMDS minehunting capabilities are limited in other-than-benign environmental conditions.
  - The AMNS cannot neutralize most of the mines in the Navy's threat scenarios.
  - The fleet is not equipped to maintain the ALMDS or the AMNS.
- DOT&E issued a classified FOT&E report in April 2014 that assessed the MH-60S Multi-spectral Targeting System (MTS) Automatic Video Tracker (AVT) does not adequately meet surface warfare (SUW) requirements. Currently, there are no prospective remediation modifications planned to address the system deficiencies that would likely enable it to meet SUW requirements. The Navy has shifted its focus to the long-term replacement for the HELLFIRE missile, the Joint Air-to-Ground Missile (JAGM), which employs a different guidance system that would obviate the need to correct the MTS AVT deficiencies.
- The Digital Rocket Launcher (DRL) with Advanced Precision Kill Weapon System (APKWS) II rockets, installed in response to an urgent operational need request, provides additional SUW capability to the MH-60S, but presents technical and operational risks that should be addressed for improved performance. Fielding the JAGM would also address the major shortcomings of the DRL with APKWS II.
- The Navy is currently procuring the Helmet Display and Tracking System (HDTS) on the MH-60S based solely on developmental testing. Current plans are to field the system without conducting operational testing.

System

- The MH-60S is a medium lift ship-based helicopter manufactured in three variants (blocks) that are derived from the Army UH-60L Blackhawk.
- All three blocks share a common cockpit, avionics, flight instrumentation, and power train with the MH-60R.
- Installed systems differ by block based on mission:
  - Block 1, Fleet Logistics – precision navigation and communications, maximum cargo or passenger capacity.
  - Block 2A/B, AMCM System – AMCM system operator workstation; a tether/towing system, two AMCM systems that the Navy plans to IOC in FY17 – ALMDS for detection and classification of near-surface mines and AMNS for neutralization of in volume and bottom mines – and a third system in early development, the Barracuda Mine Neutralization System, which the Navy expects to provide a near surface mine neutralization capability. The draft Capability Development Document hints that the Navy will integrate Barracuda with the MH-60S prior to the planned IOC in FY22. Any Block 2B or subsequent aircraft (e.g., Block 3 A/B aircraft) can be an AMCM aircraft.
  - Block 3A, Armed Helicopter – 20 mm Gun System, forward-looking infrared with laser designator, crew served side machine guns, dual-sided HELLFIRE air-to-ground missiles, the 2.75-inch family of rockets, and defensive electronic countermeasures.
  - Block 3B, Armed Helicopter – adds a tactical datalink (Link 16) to Block 3A capabilities.

Mission

The Maritime Component Commander can employ variants of MH-60S to accomplish the following missions:

- Block 1 – Vertical replenishment, internal cargo and personnel transport, medical evacuation, Search and Rescue, and Aircraft Carrier Plane Guard.
- Block 2 – Detection, classification, identification, and/or neutralization of sea mines, depending on the specific AMCM systems employed on the aircraft.
- Block 3 – Combat Search and Rescue, Surface Warfare, Aircraft Carrier Plane Guard, Maritime Interdiction Operations, Special Warfare Support, and detection, classification, identification, and/or neutralization of sea mines, depending on the specific AMCM systems employed on the aircraft.

Major Contractors

- Sikorsky Aircraft Corporation – Stratford, Connecticut
- Lockheed Martin Mission System and Sensors – Owego, New York

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Activity

- In October 2015, the Navy delayed IOT&E of the *Independence*-variant LCS equipped with the first increment of the MCM mission package and its MH-60S AMCM systems pending the outcome of an independent review.
- In early 2016, following the completion of the independent review, the Navy announced plans to delay IOT&E of the LCS-based AMCM systems and declare an IOC for these systems in early FY17.
- In May 2016, DOT&E provided comments on the Navy's draft Capability Development Document for the Barracuda Mine Neutralization System. The Navy approved the Barracuda Mine Neutralization Capability Development Document in September 2016.
- In June 2016, DOT&E submitted an early fielding report to the Congress in response to the Navy's plan to deploy the *Independence*-variant LCS equipped with the MCM mission package, including the MH-60S with ALMDS and with AMNS, prior to the conduct of operational testing. The classified report, which does not support the Full-Rate Production decision, provided DOT&E's interim assessments of operational effectiveness and operational suitability of the *Independence*-variant LCS employing the MCM mission package and the AMCM systems.
- In 2016, the Navy reallocated funding intended to support near-term development of ALMDS pre-planned product improvements. The Navy also reported that the modified system would not be available to the LCS MCM mission package until at least FY21, thus indicating it will not be available in time to support the planned LCS MCM mission package IOT&E.
- In September 2016, the Navy announced that it plans to use fleet exercises to gather additional data to characterize previously unknown attributes of the AMCM systems it plans to IOC in FY17. For ALMDS, the Navy expects to characterize the system's probability of detection and classification as a function of mine spacing and water depth. For AMNS, the Navy expects to characterize performance of the system against buried mines.

Assessment

- The MH-60S AMCM helicopter, equipped with ALMDS or with AMNS, would not be operationally effective or operationally suitable if called upon to conduct MCM missions in combat. The primary reasons for these conclusions are:
  - The combined AMCM systems are not reliable.
  - The ALMDS minehunting capabilities are limited in other-than-benign environmental conditions.
  - The AMNS cannot neutralize most of the mines in the Navy's threat scenarios.
  - The fleet is not equipped to maintain the ALMDS or the AMNS.
- Since each LCS relies on a single helicopter to support all airborne MCM operations, MH-60S and AMCM mission kit reliability are critical factors affecting the timeliness of LCS-based MCM operations. Nonetheless, the Navy established a reliability requirement for the MH-60S (20.3 hours MTBOMF) but neglected to establish any requirements for the AMCM mission kit or for the combined AMCM system.
  - Based on data from combined developmental and integrated testing and operational assessments since 2011, MH-60S reliability is 26.3 hours MTBOMF, which exceeds the Navy's threshold requirement with high confidence. During the same period of testing, the average AMCM mission kit reliability is 24.5 hours MTBOMF; thus, its OMFs occur at approximately the same rate as MH-60S OMFs. The average reliability of the combined MH-60S AMCM helicopter is 12.7 hours MTBOMF, significantly less than the requirement for MH-60S reliability.
  - Mission kit reliability varies based on the AMCM mission configuration. On average, mission kit reliability is 59.1 hours MTBOMF during ALMDS missions and 19.0 hours MTBOMF during AMNS missions. The differing results are not surprising, since the MH-60S uses the AMCM tow cable and winch during AMNS missions but does not need these components during ALMDS missions. When the results are further merged with MH-60S reliability results, which vary little by mission

type, the combined MH-60S AMCM helicopter reliabilities are 16.9 hours MTBOMF during ALMDS missions and 10.7 hours MTBOMF during AMNS missions. Thus, the probability that the MH-60S and its mission kit can complete three 2.5-hour flights on any given day without experiencing a failure, which might be required during MCM operations, is 64 percent for ALMDS missions and 50 percent for AMNS missions. Those probabilities fall to 41 percent and 25 percent, respectively, for six 2.5-hour sorties on 2 consecutive days. Consequently, the probability of a single LCS sustaining high operating tempo AMCM missions is low.
  - Since no operational testing of an AMCM-equipped MH-60S has occurred onboard an LCS, the LCS MCM TECHEVAL is the best source of data to assess the ability of ship and crew to sustain MH-60S AMCM operations. During the FY15 TECHEVAL, the MH-60S and its associated AMCM mission kit experienced nine problems that interrupted or delayed LCS MCM activities, nearly the same as the now canceled Remote Minehunting System (RMS). Operationally, the flight crew would have incurred at least one additional MH-60S AMCM delay because of an AMNS destructor launch failure that would have required aircrew to jettison the launch and handling system if live (explosive) neutralizers (operational assets) had been employed. Because of these problems, LCS 2 demonstrated sustained MH-60S AMCM operations lasting more than 1 week just once during TECHEVAL. Although the LCS Design Reference Mission suggests the MH-60S will operate daily in intervals of 10 to 12 days over several months, LCS 2 conducted MH-60S operations for 2 days or less on nine occasions during TECHEVAL before needing essential maintenance that in many cases required the ship or helicopter to return to port for spare parts or repairs.
- Although the Navy has taken action to mitigate ALMDS reliability problems observed in early testing, the system continues to experience occasional failures and, more often, nuisance faults that affect LCS AMCM operations. Over multiple periods of testing completed since 2012, system reliability has averaged 30.9 hours MTBOMF, exceeding the Navy's requirement of 25 hours MTBOMF. DOT&E did not include less-critical faults that interrupted missions only briefly or reduced the ALMDS search rate by 50 percent (because one or two of the four receivers were not functioning properly) in this calculation. However, a strict interpretation of the requirements document would count each of these faults as an additional OMF that would further reduce the reported reliability. Considering only the phases of testing completed after the Navy implemented an engineering change to mitigate the most common failure modes, ALMDS pods have experienced only one OMF in 74.4 hours of operations. However, each of the pods employed during this time completed less than 20 hours of lasing operations after the prime contractor groomed the system for testing. DOT&E cannot assess that the system is meeting its reliability requirement with confidence until it can verify that performance observed in these short periods is representative of sustained operations.
  - The further combined results of MH-60S, AMCM mission kit, and ALMDS reliability suggest the integrated AMCM system experiences 1 OMF every 11.9 flight hours. Although the high failure rate of the combined system would make it difficult to sustain LCS-based operations, ALMDS pods have generally not been the primary source of mission downtime during stateside testing. Testers have also minimized ALMDS downtime during stateside testing by pre-positioning replacement systems to make them readily available in the event of a failure. This arrangement has produced high ALMDS availability results because testers assumed the system was available when at least one pod was operational, as opposed to recording uptime and downtime for each unit involved in the test. In the near-term, this approach is viable because the Navy has procured more ALMDS pods than deployable MCM mission packages; however, unless the Navy updates its ALMDS acquisition strategy to acquire additional units, it might not realize the same level of availability while operating more than a handful of MCM mission packages.
  - Commander Task Force (CTF) 52 monitored the availability of individual ALMDS pods deployed to the Navy's Fifth Fleet area of responsibility in 2014 and reported that pods demonstrated an average operational availability of 62 percent compared to the Navy's requirement of 80 percent. Although the pods did not include the Navy's reliability improvements, root cause analysis determined that even if the Navy had implemented the engineering changes prior to deployment, they would not have prevented several failures responsible for significant downtime. CTF 52 also concluded that the lack of in-theater repair capability negatively affected ALMDS operational availability because of the need to transport pods to the contractor's facility in Melbourne, Florida, for intermediate- and depot-level repair. By eliminating transit time from the calculation, CTF 52 showed that ALMDS operational availability would improve to approximately 75 percent if a repair capability equal to that of the contractor's facility were available in theater.
- The Navy established two reliability requirements for the AMNS that address the system's LHS and neutralizer separately. The Navy's threshold requirements are 24 hours MTBOMF for the LHS and 0.85 for neutralizer reliability. Assessing compliance with the former requirement is challenging because the AMNS Capability Production Document does not define LHS operating time. Although the Navy often equates LHS operating time with MH-60S flight time, DOT&E limits its assessment of LHS operating time to the period during which the aircrew employs the system (e.g., from initial deployment to final retrieval).
  - AMNS LHS reliability and neutralizer launch data show that on average, the LHS experiences one OMF for every 6.4 hours of operation and 17 neutralizer launches. Even if DOT&E used flight hours as the basis for its reliability

calculation, LHS reliability would still be well short of the Navy's threshold. Moreover, the combined results of MH-60S, AMCM mission kit, and AMNS reliability suggest that the integrated AMCM system experiences one OMF every seven neutralizer launches and 5.9 flight hours, on average, during AMNS operations. By either measure, system reliability precludes timely and sustained operations.

  - Neutralizer reliability is measured by the percentage of neutralizers launched that function as designed (i.e., give the operator an opportunity to identify and neutralize a mine) and is a component of the AMNS metric for probability of successful attack run. AMNS neutralizer reliability varies with environmental conditions, but is 65 percent, on average. Although the FY15 TECHEVAL produced the highest numerical result for neutralizer reliability, one should not attribute the change in the point estimate of neutralizer reliability to improvements in the underlying system. Instead, the combination of more favorable environmental conditions and the Navy's decision to avoid neutralizing most bottom targets, which had the highest incidence of failures in earlier testing, most likely led to the change in estimated performance between the operational assessment and the TECHEVAL. In addition to failures of the aircraft, mission kit, and LHS that delay completion of AMNS operations, multiple attempts to identify and neutralize the same contact (because of low neutralizer reliability) further extend AMNS and LCS MCM mission timelines.

- The ALMDS does not meet Navy detection/classification requirements. In particular, the system does not meet the Navy's requirements for minimum probability of detection and classification in all depth bins or the average probability of detection and classification in all conditions over a region of the water column that extends from the surface to a reduced maximum depth requirement. When the system and operator detect and classify a smaller percentage of mines than predicted by fleet planning tools, the MCM commander will likely underestimate the residual risk to transiting ships following clearance operations. To mitigate this uncertainty, the Navy might find it necessary to conduct follow-on minesweeping operations. However, the Navy does not plan to include the mechanical minesweeping capability that would be required in the MCM mission package. In some conditions, the system also generates a large number of false classifications (erroneous indications of mine-like objects) that can delay near-surface minehunting operations until conditions improve or slow mine clearance efforts because of the need for additional search passes to reduce the number of false classifications. In very favorable conditions, such as those observed during LCS MCM mission package TECHEVAL in FY15, detection performance meets the Navy's requirements and tactics, techniques, and procedures have been successful in reducing false classifications to the Navy's acceptable limits.
- The current increment of the AMNS has a system design limitation that prevents damage to the helicopter and is essential for the safety of aircrew. The current increment of the AMNS cannot neutralize mines that are moored above the system's prescribed operating ceiling, which will preclude neutralizing most of the mines expected in some likely threat scenarios; thus, alternative means, such as an Explosive Ordnance Disposal Team provided by another unit must be used to complete mine clearing. Within its operating range, AMNS performance is frequently degraded by the loss of fiber-optic communications between the aircraft and the neutralizer. The system has experienced loss of fiber-optic communications in a wide range of operationally relevant conditions, including those that are relatively benign. Although the Program Office has stated that it intends to develop an improved AMNS to extend its depth range and potentially improve performance in coarse bottom conditions and higher currents, none of these efforts are funded, and the Navy is considering needed Barracuda Mine Neutralization System capabilities that will compensate for shortfalls in AMNS operational performance.
- Consistent with the concept of operations, the LCS is reliant on shore-based support for assistance with diagnosis and repair of MCM mission systems including ALMDS and AMNS. The mission package detachment lacks the wherewithal to handle anything beyond relatively uncomplicated preventive maintenance and minor repairs. Thus, when ALMDS and AMNS failures occur, the Navy assumes that in most cases these systems will be replaced by embarked or shore-based spares.
- The MH-60S, as well as ALMDS and AMNS integrated on an LCS-based MH-60S have not completed cybersecurity testing.
- DOT&E's June 2016 early fielding report provides additional classified detail on MH-60S AMCM performance.
- DOT&E's classified April 2014 FOT&E report noted that the upgraded MH-60S MTS software showed some improved tracking performance compared to prior operational testing, but the MTS still did not meet its requirement for tracking. Additionally, the SUW mission capability of the MH-60S helicopter equipped with MTS and the HELLFIRE missile was not tested throughout the operational mission environment. Although the Navy is pursuing replacement of the AGM-114 HELLFIRE missile with the JAGM, which would obviate the need to correct the MTS deficiencies, the Milestone C decision for procuring JAGM is scheduled for late FY17 at the earliest. MTS tracking risks should be addressed as soon as possible. Failing to do so has left the Navy with a significant current capabilities gap in SUW that remains unaddressed. Should the JAGM fail to perform to requirements, this capabilities gap would continue to the foreseeable future with no alternative solution forthcoming.
- During FY14, a Quick Reaction Assessment of the MH-60S equipped with the DRL and APKWS II rockets demonstrated additional SUW capability for the MH-60S but identified technical and operational risks that should be addressed for improved mission performance. The preceding discussion on JAGM is also germane for the DRL with APKWS II.

Recommendations

- Status of Previous Recommendations. The Navy has partially addressed the FY11 recommendation to investigate solutions and correct the ALMDS False Classification Density and reliability deficiencies prior to IOT&E. The Navy has partially addressed the FY12 recommendation to assess corrections made to resolve previously identified MTS deficiencies by conducting FOT&E. The Navy has not acted or has yet to complete action on FY13, FY14, and FY15 recommendations:
  1. Complete comprehensive survivability studies for MH-60S employing the 20 mm Gun System and 2.75-inch Unguided Rockets.
  2. Conduct comprehensive live fire lethality testing of the HELLFIRE missile against a complete set of threat-representative small boat targets.
  3. Correct the tracking deficiencies in the MTS and conduct appropriate FOT&E in order to satisfactorily resolve the SUW Critical Operational Issue.
  4. Complete comprehensive IOT&E on the 2.75-inch Unguided Rocket and APKWS II to resolve the SUW Critical Operational Issue not resolved in limited assessments of system performance provided in Quick Reaction Assessments against small boat threats.
  5. Test the SUW mission capability of the MH-60S helicopter equipped with MTS and the HELLFIRE missile throughout the operational mission environment in FOT&E and LFT&E.
  6. Complete vulnerability studies for MH-60S employing the LAU-61G/A DRL armed with APKWS II rockets.
  7. Conduct comprehensive lethality testing of the LAU-61G/A DRL armed with APKWS II rockets against a complete set of threat-representative small boat targets.
  8. Correct AMCM mission kit reliability issues that limit AMNS mission availability identified during the operational assessment.
  9. Develop corrective actions to eliminate early termination fiber-optic communications losses observed in the AMNS operational assessment.
  10. Conduct AMNS medium current testing from MH-60S.
  11. Provide LCS with a mine neutralization capability in water depths above the current AMNS operating ceiling.
- FY16 Recommendations. The Navy should address the prior recommendations and consider the following actions:
  1. Conduct a comprehensive LCS-based cybersecurity assessment of the MH-60S helicopter with ALMDS and with AMNS.
  2. Limit procurement of ALMDS and AMNS, which are not meeting the Navy's original requirements and negatively affect LCS MCM capability, until much needed performance improvements are developed, tested, and proven effective in testing representative of realistic LCS mine-clearance operations.
  3. Fully resource the development of improvements to the ALMDS and AMNS (or alternative systems such as Barracuda). For ALMDS, efforts should focus on improving probability of detection over all required depths and relevant operating conditions, reducing the incidence of false contacts, and eliminating the need for multi-pass search tactics. For mine neutralization systems, efforts should focus on reducing the incidents of fiber-optic communications losses, developing the ability to neutralize near-surface mines, and operating in high-current environments.
  4. Avoid overreliance on shore-based testing, which often results in unwarranted confidence in system performance that may not be achieved during shipboard operations.
  5. Demonstrate through end-to-end testing that the systems included in future mission packages can achieve the area search rate and detection/classification performance needed to support LCS effectiveness in timely and sustained minehunting and clearance operations. Testing should avoid segmented evaluations of individual components of the mission package.

Mine Resistant Ambush Protected (MRAP) Family of Vehicles (FoV) – Marine Corps

Executive Summary

- In FY16, the Marine Corps completed live fire testing of the Mine Resistant Ambush Protected (MRAP) Cougar Category (CAT) II A1 with the Seat Survivability Upgrade (SSU). Preliminary analysis of the data indicates that the upgraded seats provide improved survivability over previous variants; the SSU provides force protection at the MRAP Capability Production Document (CPD) 1.1 objective level. DOT&E will provide a more comprehensive force protection/survivability evaluation in a final report in FY17.
- The program integrated approximately 100 SSU kits on CAT II A1 vehicles out of a planned total of 300.
- The Marine Corps is planning to retrofit all retained Cougar variants with egress upgrades, which will include power-assisted front and rear doors, redesigned rear steps, and a reconfigured exhaust system.
- In FY16, the Marine Corps completed live fire testing of the egress upgrades. The Cougar's power-assisted front doors did not function as designed post-event against CPD 1.1 objective-level threats; the vehicle's doors jammed during live fire testing. The program is investigating the vehicle structure to determine an appropriate solution.

System

- The MRAP Family of Vehicles (FoV) consists of medium-armored, all-wheel drive, tactical wheeled vehicles designed to provide protected mobility for personnel in a threat environment. Relative to the High Mobility Multi-purpose Wheeled Vehicle, MRAPs provide improved crew protection and vehicle survivability against current battlefield threats, such as IEDs, mines, small arms fire, rocket-propelled grenades, and explosively formed penetrators.
- The Marine Corps is retrofitting Cougar CAT II A1 vehicles with an SSU for improved survivability. The SSU integrates energy attenuating seats into the rear crew compartment and reconfigures the Automatic Fire Extinguishing System and internally stowed equipment.
- The Marine Corps is assessing egress upgrades to the Cougar FoV. The egress upgrade consists of new power-assisted front and rear doors, redesigned rear steps, and a reconfigured exhaust system.
- The Marine Corps will retain 2,500 MRAP vehicles in its enduring fleet: 68 Buffalo, 1,727 Cougar (CAT I, CAT II, and Ambulance), and 705 MRAP – All Terrain Vehicle. The Marine Corps will remain the Primary Inventory Control Activity for all Cougar platforms, including those vehicles divested to the Navy and Air Force.

Mission

Commanders will employ Marine units equipped with the MRAP Cougar to conduct mounted patrols, convoy protection, reconnaissance, communications, and command and control missions to support combat and stability operations in highly-restricted rural, mountainous, and urban terrain.

Major Contractor

General Dynamics Land Systems – Ladson, South Carolina

Activity

- The program completed the Cougar CAT II A1 with SSU live fire testing at Aberdeen Test Center (ATC), Maryland, in June 2016 in accordance with the DOT&E-approved test plan.
- The program completed five live fire egress test events along with exploitation testing, on a range of Cougar variants, at ATC from June through August 2016. These tests were completed in accordance with the DOT&E-approved test plan.
- In FY16, the program integrated approximately 100 SSU kits on CAT II A1 vehicles out of a planned total of 300.
- The program is investigating solutions to the floor and hull to further improve Cougar CAT II A1 survivability/force protection by modifying the structural response of the vehicle. The effort is using modeling and simulation to select potential designs.

Assessment

- The preliminary analysis of live fire test data indicate the Cougar CAT II A1 with the SSU provides force protection at the MRAP CPD 1.1 objective level. The upgraded seats demonstrated improved protection over previous variants against underbody mines while not degrading performance relative to other previously tested threats such as fragmenting IEDs, indirect fire, small arms fire, rocket-propelled grenades, and explosively-formed penetrators. DOT&E will provide a more comprehensive force protection/survivability evaluation in a final report to Congress in FY17.
- The Cougar's power-assisted doors did not function as designed post-event against CPD 1.1 objective-level threats. The vehicle's doors jammed during live fire testing. The program is investigating the vehicle structure to determine an appropriate the solution.

Recommendations

- Status of Previous Recommendations. The program has addressed the previous recommendation regarding upgrading the seats in the Cougar A1 vehicles.
- FY16 Recommendations.
  1. The Marine Corps should implement a fix to the front door problem encountered during egress upgrade testing at the contract threshold level, and conduct a follow-on event to verify threshold-level performance.

MK 54 Lightweight Torpedo and Its Upgrades Including High Altitude Anti-Submarine Warfare Capability

Executive Summary

- The Navy continued development of hardware and software updates to the MK 54. The new version, designated the MK 54 Mod 1 torpedo, is scheduled to begin OT&E in FY20.
- The Navy started the MK 54 Mod 1 development in FY07 and in-water developmental testing in November 2015. The Navy has completed 16 of the planned 80 MK 54 Mod 1 developmental test firings and obtained valid test data from 11. In February 2016, the Navy paused the second of six in-water developmental test events to search for two lost test torpedoes. The Navy updated its developmental test plans and resumed the in-water developmental test program in October 2016.
- In February 2016, the Navy completed a Milestone C acquisition decision for the MK 54 Mod 1 without a Navy-approved Capability Development Document or an approved Test and Evaluation Master Plan (TEMP). The Navy approved the MK 54 Mod 1 Capability Development Document on September 26, 2016.
- The High-Altitude Anti-Submarine Warfare Weapons Capability (HAAWC) program, designed to deliver the MK 54 torpedo from the cruising altitude of a P-8A aircraft, began initial contractor flight testing and initial P 8A Poseidon Flight Clearance safety testing in FY16. The Navy has not approved a requirements document yet for the HAAWC.
- Based on data collected in the Navy's scaled MK 54 warhead tests executed in FY16, it is assessed the MK 54 will remain not effective even with the Mod 1 fixes. Details supporting this assessment will be provided in a classified LFT&E report that will be issued in FY17.

System

- The MK 54 Lightweight Torpedo is the primary anti-submarine warfare (ASW) weapon used by U.S. surface ships, fixed-wing aircraft, and helicopters. The MK 54 must interoperate and be compatible with the analog or digital combat control systems and software variants installed on all ASW fixed-wing and helicopter aircraft, and on the surface ship combat control system variants used for torpedo tube or ASW rocket-launched torpedoes.
- The MK 54 combines the advanced sonar transceiver of the MK 50 torpedo with the legacy warhead and propulsion system of the older MK 46. MK 46 and MK 50 torpedoes are converted to an MK 54 via an upgrade kit.
- The Navy designed the MK 54 to operate in shallow-water environments and in the presence of countermeasures. The MK 54 sonar processing uses an expandable, open architecture system. It combines algorithms from the MK 50 and MK 48 torpedo programs with commercial off-the-shelf technology.

- The Navy has designated the MK 54 torpedo to replace the MK 46 torpedo as the payload section for the Vertical Launched Anti-Submarine Rocket for rapid employment by surface ships.
- The MK 54 Block Upgrade (BU) was a software upgrade to the MK 54 baseline torpedo designed to provide a small, shallow draft target capability and to correct deficiencies identified during the 2004 MK 54 IOT&E.
- The Navy is developing the MK 54 Mod 1. The MK 54 Mod 1 hardware upgrades the torpedo's sonar array from 52 to 112 elements, providing higher resolution. Associated software upgrades are designed to exploit these features to improve target detection and enhance false target rejection as well as correct previously identified deficiencies.
- The HAAWC will provide an adapter wing-kit to permit long-range, high-altitude, GPS-guided deployment of the MK 54 by a P-8A Multi-mission Maritime Aircraft. A follow-on capability to receive in-flight targeting updates via Link-16 from the P-8A is expected to be added in a later program phase. In-flight updates will not be available in the baseline HAAWC kit.

Mission

Commanders employ naval surface ships and aircraft equipped with the MK 54 torpedo to conduct ASW:

- For offensive purposes, when deployed by ASW aircraft and helicopters
- For defensive purposes, when deployed by surface ships
- In both deep-water open ocean and shallow-water littoral environments
- Against fast, deep-diving nuclear submarines and slow-moving, quiet, diesel-electric submarines

Major Contractors

- Raytheon Integrated Defense Systems – Tewksbury, Massachusetts
- Progeny Systems Corporation – Manassas, Virginia
- Boeing Company – St. Charles, Missouri
- Northrop Grumman – Annapolis, Maryland

Activity

- During FY16, the Navy continued development of new MK 54 Mod 1 torpedo front-end hardware and tactical software to address the performance shortfalls identified with the MK 54 (BU). The Navy plans to begin the MK 54 Mod 1 OT&E in FY20.
- The Navy began MK 54 Mod 1 development in FY07 and started in-water developmental testing in November 2015. The Navy's developmental test plan called for firing 80 MK 54 torpedoes in 6 separate test events covering both deep and shallow water scenarios, between September 2014 and May 2016. During the November 2015 test event, the Navy fired 10 MK 54 Mod 1 torpedoes in deep water scenarios and obtained valid test data from 8 torpedoes. During the February 2016 test event, the Navy fired 6 of the 10 planned MK 54 Mod 1 torpedoes before pausing the in-water test event to search for two lost test torpedoes. The Navy updated its developmental test plans and resumed the in water developmental test program in October 2016.
- In February 2016, the Navy completed a Milestone C acquisition decision for the MK 54 Mod 1 without a Navy-approved Capability Development Document or an approved TEMP. DOT&E continues to work with the Navy's Operational Test and Evaluation Force and the Program Office to develop an adequate MK 54 Mod 1 operational test program within the constraints of the available test target surrogates. The Navy approved the MK 54 Mod 1 Capability Development Document on September 26, 2016, but that document did not address the HAAWC program that has started testing. The Navy is developing a separate requirements document to address that program.
- In FY15, DOT&E participated in the Navy's Torpedo Target Strategy Working Group to identify and develop test target surrogates for the MK 54. The Navy proposed a short-term strategy that utilizes three separate torpedo targets, each appropriate for specific limited scenarios. However, the Navy did not fund the short-term strategy and has not developed a long-term target strategy.
- In FY15 and FY16, DOT&E funded and participated in two Resource Enhancement Program projects to develop critical assets for torpedo operational testing. One project develops the Submarine Launched Modular 3-inch Device (SLAM-3D) as a threat-representative surrogate torpedo countermeasure. The second project is an update to the Weapons Assessment Facility (WAF) hardware-in-the-loop modeling and simulation testbed located at the Naval Undersea Warfare Center in Newport, Rhode Island. The project is intended to improve the WAF for developing and testing torpedoes by improving the modeling of the ocean environment and improving target models.
- In FY16, Boeing continued contractor testing of the HAAWC wing kits for employing the MK 54 torpedo from the P-8A at medium to high altitudes. The Navy started initial integration testing and initial flight clearance safety testing of the HAAWC into the P-8A Poseidon aircraft.
- As a result of increased HAAWC program cost estimates and reduced funding, the Navy transferred sponsor organizational responsibilities within the Navy staff and is revising performance thresholds, which it is documenting in a draft HAAWC Capabilities Production Document.
- The HAAWC program has not yet developed a comprehensive test strategy and does not have an approved TEMP. The HAAWC program is scheduled to begin OT&E in FY19. DOT&E continues to work with the Navy to develop an adequate operational test strategy.
- In September 2015, the Navy conducted a small-scale test of the warhead to characterize hull deformation as a function of weapon standoff. The Navy has not delivered the final report on this test series. The results of the small-scale test were used to plan a large-scale test executed in late FY16, which the Navy performed at Aberdeen Test Center, Underwater Explosion Test Facility, using a scaled MK 54 warhead against a threat-representative target. The primary objective of this testing was to demonstrate weapon lethality by quantifying the extent of damage and hull rupture to the target hull.

Assessment

- In FY14, DOT&E assessed that the MK 54 torpedo is not operationally effective as an offensive ASW weapon. During operationally challenging and realistic scenarios, the MK 54 (BU) demonstrated below threshold performance and exhibited many of the same failure mechanisms observed during the IOT&E. Torpedo mission kill performance against targets employing operationally realistic evasion tactics was below requirement thresholds. Performance was further degraded when considering crew performance for targeting and employing the MK 54 (BU) and the Navy's assessment of the warhead. The Navy designed the MK 54 Mod 1 upgrade to improve the MK 54's hit performance in these test scenarios.

- DOT&E also reported the MK 54 (BU) torpedo was operationally suitable and met the same reliability and availability requirements as the baseline torpedo. However, MK 54 (BU) operational testing identified shortfalls with the employing platforms' tactics and tactical documentation, and interoperability problems with some platform fire control systems. The Navy initiated immediate actions to address these shortfalls and has reported the training and tactics shortfalls are fixed for the MK 54 (BU). DOT&E plans to evaluate the effectiveness of the employing platforms' tactics, documentation, and interoperability during the MK 54 Mod 1 OT&E.
- Some MK 54 (BU) operational realistic scenarios were not assessed due to the unavailability of target surrogates and the Navy's safety regulations for shooting against manned submarine targets. Due to resource constraints, the Navy has not developed adequate set-to-hit surrogate targets and test articles. Because of these test limitations, the Navy will not be able to assess MK 54 Mod 1 performance in all important operationally realistic scenarios. DOT&E plans to conduct set-not-to-hit testing with manned submarines and limited set-to-hit testing with available target surrogates to assess if the MK 54 Mod 1 improves hit performance and corrects MK 54 (BU) shortfalls. These test limitations will result in an upper bound estimate of MK 54 hit performance but are acceptable for Mod 1 testing given past performance shortfalls. However, the Navy must fund efforts to resolve these test limitations.
- The Navy intends the MK 54 Mod 1 to improve MK 54 (BU) effectiveness with a new 112-element hydrophone front end, new processors, and new software designed to improve detection, classifier, and tracker performance. Completed developmental testing demonstrated performance results similar to the MK 54 (BU); however, to date, the Navy has conducted most developmental testing using simple structured scenarios where the MK 54 previously demonstrated satisfactory performance. These simple developmental test scenarios are good regression testing that yield significant recorded test data; however, little data were obtained to assess MK 54 performance in challenging, operationally realistic scenarios. The Navy is planning additional in-water developmental testing to assess more challenging operational scenarios.
- Based on data collected in the Navy's scaled MK 54 warhead tests executed in FY16, it is assessed the MK 54 will remain not effective even with the Mod 1 fixes. Details supporting this assessment will be provided in a classified LFT&E report that will be issued in FY17.

Recommendations

- Status of Previous Recommendations. The following previous recommendations remain outstanding. The Navy still needs to:
  1. Conduct operationally realistic mobile target set-to-hit testing scenarios. The Navy has not developed a mobile target surrogate for set-to-hit testing. The Navy investigated possible surrogates; however, the proposals are unfunded.
  2. Propose alternatives to minimize or eliminate the test and safety limitations that minimize operational realism in MK 54 testing.
  3. Complete development of the MK 54 Mod 1 TEMP.
  4. The Navy should evaluate and incorporate the 11 recommendations in DOT&E's MK 54 (BU) OT&E report to improve the effectiveness of the MK 54. Significant unclassified recommendations include:
     - Improve the target detection localization and track performance of ship and aircraft crews that employ the MK 54. While improving the sensor system capability on ships and aircraft is a longer range goal, updating the MK 54 employment tactics, training, and documentation could immediately improve overall crew proficiency and ASW effectiveness. The Navy has reported it has made progress in updating its tactics and documentation, but there has been no testing yet to verify the deficiencies have been resolved.
     - Improve the MK 54's effective target search and detection capability. The MK 54 should be able to effectively search the area defined by typical fire control solution accuracy and crew employment and placement errors.
     - Reduce the complexity of the MK 54 employment options and required water entry points in existing tactical documentation. The Navy has reported it has made progress in updating its tactics and documentation, but there has been no testing yet to verify the deficiencies have been resolved.
- FY16 Recommendations. The Navy should:
  1. Complete the development and approval of the HAAWC requirements and TEMP.
  2. Utilize developmental test scenarios that stress the MK 54 Mod 1 in scenarios where improvements are desired. When possible, these scenarios should be operationally realistic.
  3. Initiate recommendations that will be provided in the FY17 MK 54 LFT&E report.

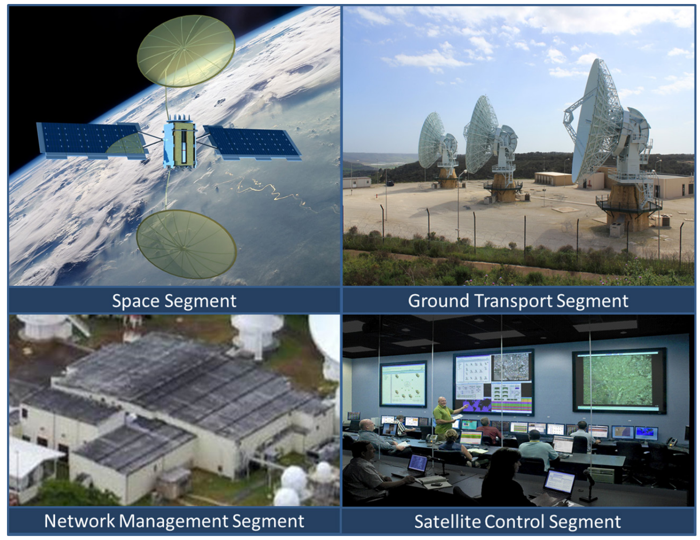
Mobile User Objective System (MUOS)

Executive Summary

- The Navy's Commander, Operational Test and Evaluation Force (COTF) conducted the Mobile User Objective System (MUOS) Multi-Service Operational Test and Evaluation 2 (MOT&E 2) from October 19 through November 20, 2015. DOT&E approved the Test and Evaluation Master Plan (TEMP) on November 29, 2010, and the MOT&E 2 test plan on October 13, 2015.
- MUOS is not operationally effective in providing reliable worldwide Wideband Code Division Multiple Access (WCDMA) communications to tactical users. MUOS was able to provide WCDMA communications on a limited scale during MOT&E 2, but MUOS cannot achieve this performance worldwide given the significant problems with planning and provisioning, situational awareness, network management, and capacity.
- MUOS is not operationally suitable. The ground system lacks the stability and maturity to enter into and sustain global operations. MUOS does not provide communications that deployed users can rely on when the system is in widespread use or at full capacity. MUOS performed poorly in almost every area of operational suitability.
- The system is not survivable against cyber-attacks. The COTF Red Team and U.S. Strategic Command (USSTRATCOM) conducted independent cyber assessments and obtained similar results. They discovered over 1,000 cybersecurity vulnerabilities in the MUOS ground system.
- MUOS is not ready to support military operations. Until the problems are fixed and verified in the FOT&E, the system use should be limited to small non-combat missions, testing, training, and exercises in the United States and protectorates in order to develop, exercise, and mature operational concepts and processes with a particular focus on addressing known issues and MOT&E-2 findings.
- The Navy launched the MUOS-5 on-orbit spare satellite on June 24, 2016. On June 29, the Navy discovered an anomaly during orbit-raising. The satellite is safe and remains in a stable interim orbit while the Navy evaluates options.
- On July 18, 2016, the Commander, USSTRATCOM accepted for Early Combatant Command Use the MUOS capability, consistent with the DOT&E recommendation.

System

- MUOS is a satellite-based communications network designed to provide worldwide, narrowband, beyond line of-sight, point-to-point, and netted communication services to multi Service organizations of fixed and mobile terminal users. The Navy designed MUOS to provide 10 times the throughput capacity of the current narrowband satellite communications.



  The Navy intends for MUOS to provide increased levels of system availability over the current constellation of Ultra High Frequency (UHF) Follow-On satellites and to improve availability for small, disadvantaged terminals.
- MUOS consists of six segments:
  - The Space Segment consists of four operational satellites and one on-orbit spare. Each satellite hosts two payloads: a legacy communications payload that mimics the capabilities of a single UHF Follow-On satellite and a MUOS communications payload.
  - The Ground Transport Segment is designed to manage MUOS communication services and allocation of radio resources.
  - The Network Management Segment (NMS) is designed to manage MUOS ground resources and allow for government-controlled, precedence-based communication planning.
  - The Ground Infrastructure Segment is designed to provide transport of both communications and command and control traffic between MUOS facilities and other communication facilities.
  - The Satellite Control Segment consists of MUOS telemetry, tracking, and commanding facilities at the Naval Satellite Operations Center Headquarters and Detachment Delta.
  - The User Entry Segment provides a MUOS waveform hosted on MUOS-compatible terminals. The Army's Project Manager for Tactical Radios is responsible for developing and fielding MUOS-compatible terminals. The Air Force, Navy, and Marine Corps are upgrading legacy UHF radios to be MUOS-compatible.

Mission

Combatant Commanders and U.S. military forces deployed worldwide will use the MUOS satellite communications system to accomplish globally assigned operational and joint force component missions, especially those involving highly mobile users. Such missions include major conventional war; regional conflicts; search and rescue; humanitarian or disaster relief (including severe weather events); homeland security; homeland defense; counterterrorism; non-combatant; evacuation operations; very important person travel; strategic airlift; global mobility; global strike; intelligence, surveillance, and reconnaissance; training; logistics support; and exercise support.

Major Contractors

- Lockheed Martin Space Systems – Sunnyvale, California
- General Dynamics C4 Systems – Scottsdale, Arizona

Activity

- The Navy conducted a government Developmental Test Technical Evaluation from June 1 – 30, 2015, in preparation for operational testing.
- COTF conducted MOT&E 2 from October 19 through November 20, 2015, in accordance with the approved TEMP and test plan. DOT&E approved the TEMP on November 29, 2010, and the MOT&E 2 test plan on October 13, 2015.
- COTF conducted a two-phase cybersecurity assessment of the MUOS system in conjunction with MOT&E 2. COTF conducted the phase one Cooperative Vulnerability and Penetration Assessment in November 2015 and a phase two Adversarial Assessment in April 2016.
- DOT&E submitted a report in June 2016, evaluating the system based on MOT&E-2.
- The program manager requested a deferral of the geolocation capability from MOT&E 2. Geolocation is the ability to locate a legacy UHF electromagnetic interferer on the ground.
- The Navy launched the MUOS-5 on-orbit spare satellite on June 24, 2016. On June 29, the Navy discovered an anomaly during orbit-raising. The satellite is safe and remains in a stable interim orbit while the Navy evaluates options.
- On July 18, 2016, the Commander, USSTRATCOM accepted for Early Combatant Command Use the MUOS capability, consistent with the DOT&E recommendation.
- The MUOS program manager and COTF have begun updating the previous TEMP to encompass the scope of the next operational test, planned for FY18 or FY19.

Assessment

- When MUOS works, it provides message accuracy and quality of service better than legacy UHF communications. However, MUOS cannot communicate on all types of group network services. COTF did not test fixed assigned networks because of known problems with them.
- MUOS does not meet the threshold capacity Key Performance Parameter criteria, based on the two satellite configurations in MOT&E-2. The 2 satellites under test operated at 72 percent of capacity during MOT&E-2. DOT&E determined that 92 of the possible 128 satellite beam carriers were active on the Pacific and Continental United States region satellites, for an availability of 71.9 percent. The Navy either locked or turned off 28.1 percent of the capacity to prevent problems with interference from ambient radio frequency signals. A locked satellite beam carrier means users cannot access it, effectively losing 5 megahertz of potential spectrum in that beam. A majority (56 percent) of 32 satellite beams across the two satellites were in a degraded mode.
- During MOT&E 2, resource planners were able to obtain information from the system in 61 percent (52 of 85) of attempts. USSTRATCOM cannot monitor MUOS and evaluate actual system performance against planned performance. MUOS does not provide USSTRATCOM with an accurate, real-time status of the system state. The system was unable to maintain call records for the 60 terminals that participated in MOT&E-2.
- The ability of MUOS to create, analyze, and implement communications plans has problems. The system occasionally freezes when analyzing what network resources are available and the network data are sometimes inaccurate. Without a valid and accurate plan, MUOS cannot create configurations for all of the radios and users cannot establish communications with one another.
- The MUOS fault management system is ineffective because it provides the network managers fault alarm events that are cryptic, inconsistently prioritized, and often excessive. The filtering effort was incomplete and arbitrary.
- During developmental and operational test periods, hardware failures at the MUOS Radio Access Facilities have led to the loss of as much as half of the communications resources on a single satellite. MUOS does not provide a proactive means to monitor WCDMA communication failures, resulting in potentially extended outages for deployed users. The MUOS network managers cannot assess and report on WCDMA satellite beam carrier availability. Key systems associated with WCDMA call services, such as the radio base stations in the Radio Access Facilities, do not provide fault information to the fault management system. The program manager is working on a solution to provide improved situational awareness.
- MUOS was able to conduct routine Over-the-Air Rekeys but cannot reliably conduct compromised terminal operations. The reliability problems could result in global communications outages for an entire military Service or all Special Operations units. An outage would persist until its root cause is resolved

and the MUOS ground system broadcasts an updated cryptographic key.

- The NMS was often not operationally available. The NMS was available 6.3 percent of the time during MOT&E-2 against a 95 percent threshold criterion. The NMS had long repair times, numerous high-priority problem reports, poor usability, poor documentation, and high reliance on depot maintainers. Additionally, NMS is undermanned and operators do not consider themselves adequately trained to perform their mission. Multiple failures in the NMS and the Ground Transport Segment during MOT&E-2 created long communications outages.
- During MOT&E-2, there were over 200 high-priority hardware and software problems remaining on the system.
- The geolocation capability is still in development and was deferred from MOT&E 2. The program manager is developing a geolocation capability which will need to be operationally tested in the planned FOT&E.
- MUOS is not operationally effective in providing reliable worldwide WCDMA communications to tactical users. MUOS was able to provide WCDMA communications on a limited scale during MOT&E 2, but MUOS cannot achieve this performance worldwide given the significant problems with planning and provisioning, situational awareness, network management, and capacity.
- MUOS is not operationally suitable. The ground system lacks the stability and maturity to enter into and sustain global operations. MUOS does not provide communications that deployed users can rely on when the system is in widespread use or at full capacity. MUOS performed poorly in almost every area of operational suitability.
- The system is not survivable from cyber-attacks. The COTF Red Team and USSTRATCOM conducted independent cybersecurity assessments and obtained similar results. They discovered over 1,000 cybersecurity vulnerabilities in the MUOS ground system. Approximately half of these vulnerabilities are Category-II and above. Category-II vulnerabilities have a high potential of giving system access to an intruder.
- MUOS is not ready to support military operations. Until the problems are fixed and verified in the FOT&E, the system's use should be limited to small non-combat missions, testing, training, and exercises in the United States and protectorates in order to develop, exercise, and mature operational concepts and processes with a particular focus on addressing known issues and MOT&E-2 findings.
- The Commander, USSTRATCOM decision for Early Combatant Command Use of the MUOS capability will benefit Service members and assist the MUOS program manager in resolving system problems while providing the operational manager, provisioners, and network managers with valuable experience through limited operations.
- The program manager, in coordination with USSTRATCOM, is evaluating courses of action to resolve the anomaly with the MUOS-5 on-orbit spare satellite. They continue to analyze the situation, consider alternate orbit adjustment options, and assess mission impacts.

Recommendations

- Status of Previous Recommendations. The Navy is in the process of updating the TEMP for the planned FOT&E.
- FY16 Recommendation.
  1. The Navy should provide resources to address the recommendations in the DOT&E MOT&E-2 report prior to the FOT&E. COTF should verify the corrections in the FOT&E.

MQ-4C Triton Unmanned Aircraft System

Executive Summary

- The Navy conducted an Operational Assessment (OA) from November 2015 through January 2016. Testing was completed in accordance with the DOT&E-approved test plan. In general, the system demonstrated positive trends for sensor performance and reliability during the OA. The maximum detection and classification ranges for maritime targets exceeded Capability Development Document requirements and the Triton crews were able to transmit Electro-optical/Infrared (EO/IR) video to the Surface/Aviation Interoperability Lab via Common Data Link. The system reliability is currently tracking the Reliability Growth Curve annotated in the System Engineering Plan and the Test and Evaluation Master Plan (TEMP). However, the OA revealed deficiencies in the following areas: lack of Due Regard capability (capability to independently maintain prescribed minimum separation distances); poor EO/IR sensor control; poor Electronic Support Measures operator interface; and difficulty managing the temperature of the radar.
- DOT&E published the classified OA report in May 2016, and approved the MQ-4C TEMP in April 2016, to support the Milestone C decision which occurred in August 2016.

System

- The MQ-4C Triton UAS is an intelligence, surveillance, and reconnaissance system-of-systems consisting of the high-altitude, long-endurance MQ-4C air vehicle, sensor payloads, and supporting ground control stations. The MQ-4C system is a part of the Navy Maritime Patrol and Reconnaissance family-of-systems and will provide multiple types of surveillance data over vast tracks of ocean and littoral areas; overland intelligence, surveillance, and reconnaissance; signals intelligence and target acquisition capabilities designed to complement the P-8A Poseidon Multi-mission Maritime Patrol aircraft.
- The MQ-4C air vehicle design is based on the Air Force RQ-4B Global Hawk air vehicle with significant modifications that include strengthened wing structures and an anti-ice and de-icing system.
- Mission systems include a maritime surveillance radar to detect, identify, and track surface targets and produce high-resolution imagery.
  - An EO/IR sensor provides full motion video and still imagery of surface targets and the Electronic Support Measures system detects, identifies, and geolocates threat radar signals.
  - An Automatic Identification System (AIS) receiver permits the detection, identification, geolocation, and tracking of cooperative maritime vessels equipped with AIS transponders.
- Planned future system upgrades include an air traffic collision avoidance radar system and a signals intelligence collection system. Onboard line-of-sight and beyond line-of-sight datalink and transfer systems provide air vehicle command and control and transmit sensor data from the air vehicle to ground control stations for dissemination to fleet tactical operation centers and intelligence exploitation sites.

Mission

- Commanders employ units equipped with MQ-4C to conduct long-endurance maritime surveillance operations and provide high- and medium-altitude intelligence collection.
  - MQ-4C operators will detect, identify, track, and assess maritime and littoral targets of interest and collect imagery and signals intelligence information.
  - Operators disseminate sensor data to fleet units to support a wide range of maritime missions to include surface warfare, intelligence operations, strike warfare, maritime interdiction, amphibious warfare, homeland defense, and search and rescue.

Major Contractor

Northrop Grumman Aerospace Systems, Battle Management and Engagement Systems Division – Rancho Bernardo, California

Activity

- The Navy conducted an OA from November 2015 through January 2016. Testing was completed in accordance with the DOT&E-approved test plan. However, since the MQ-4C is not yet authorized to operate on Navy operational networks, the Navy did not accomplish a cybersecurity Cooperative Vulnerability and Penetration Assessment (CVPA) of the MQ-4C during the OA. DOT&E published the classified OA report in May 2016.
- DOT&E approved the MQ-4C TEMP in April 2016 to support of the Milestone C decision which occurred in August 2016.
- The program has changed its Acquisition Strategy and moved IOT&E from 4QFY17 to 4QFY20 to align with development and fielding of the Multiple Intelligence (Multi-INT) configuration. The Multi-INT configuration provides a signals intelligence capability, and includes sensors, supporting software and hardware, and changes to permit processing of Top Secret and Sensitive Compartmented Information. The Navy intends for the MQ-4C Multi-INT configuration to replace the EP-3 Aries II aircraft for most missions. The Navy plans to field two MQ-4C aircraft in the baseline configuration (non-Muti-INT) in FY18, prior to Initial Operational Capability (IOC), to provide an Early Operational Capability.
- The program continues to pursue a solution providing traffic de-confliction and collision avoidance capability since development of the Air-to-Air Radar Subsystem was stopped. The program intends to select a technical solution after IOC. The Navy is investigating alternative means of Due Regard compliance including procedures and other cooperative avoidance systems already integrated in the MQ-4C in order to support MQ-4C operations at IOC.

Assessment

- In general, the system demonstrated positive trends for sensor performance and reliability during the OA. The maximum detection and classification ranges for Maritime targets exceeded Capability Development Document requirements and the Triton crews were able to transmit EO/IR video to the Surface/Aviation Interoperability Lab via Common Data Link. The system reliability is currently tracking the Reliability Growth Curve annotated in the System Engineering Plan and the TEMP. However, the OA revealed deficiencies in the following areas: lack of Due Regard capability (capability to independently maintain prescribed minimum separation distances); poor EO/IR sensor control; poor Electronic Support Measures Interface; and difficulty managing the temperature of the radar. DOT&E's classified report provides specific information on these and other aspects of the assessment.
- Traffic de-confliction and collision avoidance (Due Regard capability) provides critical mission capability for operation of the MQ-4C in civil and international airspace in support of global naval operations. Any limitation to this capability at IOT&E will reduce the effectiveness of the MQ-4C.

Recommendations

- Status of Previous Recommendations. The Navy still needs to addressed the following DOT&E recommendations:
  1. Demonstrate any alternative means of compliance with the Due Regard requirement prior to IOT&E and conduct a CVPA sufficiently in advance of the Adversarial Assessment (AA) to allow the program to correct any discovered cybersecurity vulnerabilities;
  2. Conduct both the CVPA and AA prior to any early fielding of the MQ-4C.
- FY16 Recommendations. In addition to addressing the recommendations above, the Navy should:
  1. Resolve deficiencies documented in the DOT&E OA report prior to IOT&E, especially in the following areas: Due Regard capability; EO/IR sensor control; Electronic Support Measures Interface; temperature management of the radar.

MQ-8 Fire Scout

Executive Summary

- The Commander, Operational Test and Evaluation Force (COTF) and Air Test and Evaluation Squadron ONE (VX-1) conducted the land-based Quick Reaction Assessment (QRA) from May through June 2015 in response to a request by the Director, Battlespace Awareness, Operational Navy N2/N6F2, for an assessment of the operational capabilities and limitations of the radar-equipped MQ-8B Fire Scout to support maritime and littoral operations.
  - DOT&E assessed MQ-8B performance in a March 2016 memorandum to the Navy.
  - While this QRA demonstrated the potential of the radar-capable MQ-8B, this land-based-only QRA may have presented an overly optimistic assessment of this capability. The Navy intends for the radar-equipped MQ-8B to launch from a host vessel capable of supporting helicopter flight operations (such as the Littoral Combat Ship (LCS)) in support of intelligence and surface warfare (SUW) operations. This concept of operations was not demonstrated during the QRA.
- VX-1 conducted the MQ-8C operational assessment (OA) at Naval Air Station Point Mugu, California, in November 2015 to support the upcoming Milestone C decision. This testing focused on air vehicle endurance, mission coverage, performance of the MQ-8C electro-optical/infrared (EO/IR) sensor in a littoral environment, reliability of the system, and operator workloads.
  - DOT&E assessed MQ-8C performance in a June 2016 memorandum to the Navy.
  - The MQ-8C OA presents a partial assessment of MQ-8C performance. This land-based MQ-8C OA presents an overly optimistic assessment of the capability since the Navy did not complete shipboard testing under operational conditions.
- The Navy awarded a contract for 10 additional MQ-8C helicopters in September 2015 bringing the total number to 29. The Navy plans to complete their buy of the remaining 11 aircraft in FY17 prior to IOT&E.
- The Navy is planning to conduct the Milestone C decision for the restructured program in 2QFY17.

System

- The MQ-8B and follow-on MQ-8C are helicopter-based tactical unmanned aerial systems that support intelligence, surveillance, and reconnaissance (ISR), SUW, and mine countermeasures (MCM) payloads.
- The Navy plans to replace the MQ-8B airframe (Schweizer 333) with the MQ-8C airframe (Bell 407), which has better endurance and payload capacity. MQ-8B vehicles are deployed on ships in the fleet and will be phased out via attrition. The MQ-8C concept of operations is primarily in support of LCS missions but it can also be employed off other suitably equipped aviation capable ships.

MQ-8B

MQ-8C

- The MQ-8C airframe is equipped with the AN/AAQ-22D Bright Star II, a multi-sensor imaging system with EO/IR cameras and laser designation/range finding.
- The Navy plans to incrementally integrate different mission payloads into the MQ-8C airframe:
  - The Endurance Baseline Increment integrates the AN/AAQ-22D Bright Star II, Automated Identification System (AIS), Tactical ISR (TAC-ISR) Remote Broadcast omni-directional datalink, and an ultra-high frequency/very high frequency (clear or secure) voice communications package.
  - The SUW Increment integrates maritime search radar as well as Inverse Synthetic Aperture Radar and Synthetic

Aperture Radar imagery capability and the Advanced Precision Kill Weapons System (APKWS).
  - The MCM Increment is the final increment that integrates the Coastal Battlefield Reconnaissance and Analysis system and a Data Mission Payload.
- LCS components supporting the MQ-8 airframes are permanently installed on the host platform and consist of one Mission Control System (MCS), one Data Link Suite, and two Unmanned Air Vehicle Common Automatic Recovery Systems. System interoperability is achieved using the Tactical Control System (TCS) software embedded in the MCS and the host platform's command, control, communications, computers, collaboration, and intelligence architecture.

Mission

Commanders employ naval units equipped with MQ-8 airframes to provide ISR, target acquisition capability, communications relay capability, and/or APKWS in support of LCS SUW and MCM operations.

Major Contractor

Northrop Grumman – San Diego, California

Activity

- The Navy requested that USD(AT&L) certify the restructure of the Vertical Take-off and Landing Unmanned Aerial Vehicle (VTUAV) program on June 16, 2014, due to a Nunn-McCurdy breach. The Acquisition Decision Memorandum (ADM) for the restructured VTUAV program rescinded Milestone C approval for the VTUAV program granted in 2007, renamed the program as MQ-8 Fire Scout System, and designated the restructured program as an Acquisition Category (ACAT) ID Program of Record.
- Further Acquisition Category delegation to ACAT IC via the ADM occurred in June 2015. The Navy awarded a contract for 10 additional MQ-8C helicopters in September 2015 bringing the total number to 29. The Navy plans to complete their buy of the remaining 11 aircraft in FY17 prior to IOT&E. The Navy is planning to conduct the Milestone C decision for the restructured program in 2QFY17.
- COTF and VX-1 conducted the land-based QRA in response to a request by the Director, Battlespace Awareness, Operational Navy N2/N6F2, for an assessment of the operational capabilities and limitations of the radar-equipped MQ-8B to support maritime and littoral operations. The operational test events were conducted near the Naval Air Station Patuxent River over a 34-day period from May through June 2015.
- VX-1 conducted an MQ-8C OA at Naval Air Station Point Mugu, California, in November 2015 to support the upcoming Milestone C decision. This testing focused on air vehicle endurance, mission coverage, performance of the MQ-8C EO/IR sensor in a littoral environment, reliability of the system, and operator workloads.
- COTF and VX-1 conducted all operational testing in accordance with the DOT&E-approved test plans.

Assessment

- The MQ-8B QRA presented a partial assessment of radar-capable MQ-8B performance. While this QRA demonstrated the potential of the radar-capable MQ-8B, DOT&E is concerned that the land-based-only QRA presented an overly optimistic assessment of this capability. The Navy intends for the radar-equipped MQ-8B Fire Scout to launch from a host vessel capable of supporting helicopter flight operations (such as the LCS) in support of intelligence and SUW operations. This concept of operations was not demonstrated during the QRA.
- DOT&E assessed the MQ-8B performance based on QRA testing in a March 23, 2016, memorandum to the Navy, which highlighted the following results from the QRA:
  - Target location error (TLE) for radar tracks generated by MQ-8B varied from flight-to-flight. The distance to target, air vehicle speed, and whether or not the target was in the center or off-center of the radar's 180-degree search area had significant effects on TLE.
  - High flight-to-flight variability in TLE suggests that radar performance may change substantially depending on flight-specific factors that were uncontrolled in the test design, such as sea state and weather.
  - The radar-equipped MQ-8B complements the EO/IR payload capability by providing a long-range search and an all-weather target classification capability.
  - The MQ-8B radar demonstrated low detection rates for intended targets. Once potential targets were located with the radar, the MQ-8B crew demonstrated the ability to slew its EO/IR camera to the targets; determine whether these potential targets were threatening or benign; and pass information on these targets to a friendly MH-60R helicopter crew.
  - The MQ-8B demonstrated an inconsistent capability to detect target boats.
  - The MQ-8B demonstrated that the capability to employ its communications relay payload to communicate with other platforms was not consistent. During the coordinated straits transit scenario, the MH-60R and the range boats crews participating in the exercise were not able to communicate with the white cell using MQ-8B communications relay on a consistent basis.
  - During 26.3 hours of testing, testers did not observe any operational mission failures (OMFs) attributable to the AN/ZPY-4(V)1 radar.
  - MQ-8B accrued 32.3 flight hours during this QRA, experiencing two OMFs. MQ-8B suffered one OMF due to an inability to maintain a consistent Tactical Common Data Link connection, a condition known as lost link.

- Aviation vehicle operators (AVOs) and mission payload operators (MPOs) indicated that workload was generally low to moderate.
- The Radar Command and Control Station (RCCS) is a standalone laptop computer capable of displaying information from the radar including tracks generated by the Radar Subsystem (RSS), association of these tracks with AIS tracks, and information linking these tracks to known nautical features such as buoys. The MPO controls the radar via the RCCS from within the ground control station. There is no interface between the RSS and the standard MQ-8B mission payload controls.
- Operator performance demonstrated over the course of the QRA revealed gaps in training. For example, half way through the test, one MPO found that he could move the search arc of the radar when operating in short-range mode much more efficiently than the approach he had been using previously. This reduced his workload when operating the air vehicle in short-range mode.
- The Navy did not conduct cybersecurity testing during this QRA.

• The MQ-8C OA presented a partial assessment of MQ-8C performance. DOT&E is concerned that the land-based-only MQ-8C OA presented an overly optimistic assessment of this capability.
• DOT&E assessed the MQ-8C performance based on OA testing in a June 21, 2016, memorandum to the Navy, which highlighted the following results from the OA:
  - Crews employing the BRITE Star II EO/IR sensor demonstrated the ability to detect and classify targets given accurate cueing conditions. Under ideal conditions, classification ranges varied widely and did not always support sufficient stand-off distance to ensure air vehicle survivability. While these results suggest the technical performance of the sensor is meeting Navy requirements in some conditions, it is not clear whether this performance is adequate to support an LCS defense scenario.
  - Since the system's design does not tie the MQ-8C MCS directly to the ship's combat information center, there is no common operating picture between MQ-8C operators and the combat information center. MQ-8C operators must pass accurate target course and speed information to the combat information center to increase situational awareness.
  - The MQ-8C demonstrated the capability to broadcast full-motion video to ground observers equipped with a remote video terminal. The lack of trained and proficient remote video terminal operators during this OA prevents a full characterization of TAC-ISR performance.
  - The AIS is a passive receiver of commercial ship AIS broadcasts, which integrates a very high frequency transceiver with a GPS and provides identification, position, course, and speed data to the MCS over the secondary datalink. The MQ-8C system integrates the AIS into the MCS, which is a marked improvement over the MQ-8B.
  - MQ-8C operators were successful at establishing, and demonstrated the ability to relay, communications between the MCS and airspace control authorities and other land-based agencies. The sparsity of communications relay data points preludes a full characterization of communications relay capability performance. Operators did not attempt to replicate use of the communications relay capability to extend the host ship's over-the-horizon communications capability in the tactical environment.
  - The MQ-8C performance demonstrated during this OA suggests that it is on track for meeting suitability requirements at IOT&E. The data collected during the OA are not sufficient to determine if the system meets its requirements while operating as part of the LCS SUW mission package. Testing collected suitability data for MQ-8C operating from land locations.
  - The air vehicle encountered three OMFs during 82.8 flight hours for a demonstrated mean flight hours between operational mission failure rate of 27.6 hours (threshold greater than or equal to 30 hours).
  - The demonstrated operational availability exceeds the threshold requirement of 60 percent. The MQ-8C achieved the demonstrated operational availability during land-based operations.
  - The excessive presentation of nuisance Warning, Caution, and Advisory (WCAs) indications contributed to operator workload. During operator training, crews received a list of 16 nuisance WCA indications. These 16 nuisance-warning indications should alert operators to the presence of any hazardous conditions that exist. Over time, an excessive number of nuisance WCAs desensitizes operators to all WCAs. As an example, during 1 flight operators received 1,400 nuisance WCAs. During another flight, operators failed to recognize an actual WCA related to their radios. Desensitized by nuisance WCAs, operators delayed execution of the appropriate emergency procedure, and, in the event of a cascading failure, could have resulted in the air vehicle being in an unsafe situation.
  - The normal operating procedures and emergency procedures sections of the Naval Air Training and Operating Procedures Standardization (NATOPS) manual require refinement.
    ▪ During one flight, operators following the communications relay checklist induced the loss of the command and control datalink. Once operators reestablished the datalink, developmental testers provided them with a different checklist for future use that did not induce a lost link condition.
    ▪ During a different flight, operators encountered a failed workstation. The NATOPS procedures for this emergency induced another loss of the air vehicle command and control datalink. The loss of the command and control datalink did not become apparent until the air vehicle failed to respond to operator commands. In this case, operators called upon a developmental test engineer to reestablish the command and control datalink.

- None of the operator manuals addresses user interface menus internal to the BRITE Star II payload. Operators did not understand BRITE Star II built-in-test indications of system degradation because of this lack of documentation. In each case, mission payload operators relied upon developmental test engineers to correct the deficiency.

Recommendations

- Status of Previous Recommendations. The Navy is addressing the previous recommendations.
- FY16 Recommendations. The following recommendations are from the FY16 QRA and OA reports.
  1. Prior to fielding the radar-equipped MQ-8B in the fleet, the Navy should:
     - Consider whether an MQ-8B equipped with a 180-degree radar is capable of providing area surveillance in all operational scenarios.
     - Conduct additional testing investigating MQ-8B ability to identify intended targets during operationally realistic scenarios.
     - Identify tactics, techniques, and procedures for aircrews to maximize MQ-8B coverage of a protected entity given the inherent limitations of the radar.
     - Improve the AN/ZPY-4(V)1 radar's ability to detect targets in high clutter environments.
     - Provide an interface between the RSS and the standard MQ-8B mission payload controls so that the MPO can more easily operate the RSS and standard payload simultaneously. For example, the MPO should be able to provide the location of a track on the RSS to the AVO.
     - Characterize the performance of the AN/ZPY-4(V)1 radar in different conditions (such as high and low sea state) and in different environments so that commanders can better understand the level of accuracy and probability of detection to expect from MQ-8B system performance.
     - Provide guidelines for when crews should operate the RSS in short-range mode vice long-range mode.
     - Improve operator training by including all of the features of the RCCS, including how to cue the radar's search area efficiently while operating in short-range mode.
     - Conduct cybersecurity testing on the radar-equipped MQ-8B system.
     - Conduct additional testing to determine the maximum detection range for the AN/ZPY-4(V)1 radar-equipped MQ-8B.
  2. Prior to IOT&E and fleet introduction, the Navy should improve MQ-8C capability to assist LCS in defeating SUW attacks as an integral part of the LCS SUW mission package. Specific recommendations include:
     - Improve the center-field-of-view target course and speed algorithm to improve MQ-8C contributions to the ships common operating picture.
     - Improve BRITE Star II auto-track performance to reduce operator workload and increase tactical utility.
     - Clarify the target detection and classification ranges needed for the MQ-8C concept of operations to support LCS missions.
     - During IOT&E, conduct end-to-end HELLFIRE missile engagements to characterize the BRITE Star II auto-track capability.
     - Continue to mature the procedures checklist and emergency procedures in the NATOPS manual to allow for safe operations.
     - Eliminate nuisance WCA indications to reduce operator workload and prevent desensitization to indications.
     - Increase focus on MQ-8C emergency procedures training during operator training to allow for safe and proper operator reactions to pre-flight and in-flight anomalies.
     - Expand the MQ-8C operating theory within the training syllabus to allow operators to fully understand and react to anomalous system behavior.
     - Increase the fidelity of the MQ-8C simulator (especially BRITE Star II operations) and eliminate MQ-8B defaults to increase the value of simulator training.
     - Include instruction on the AIS and TAC-ISR payloads to operator training to allow them to properly employ and troubleshoot the systems.
     - Expand the NATOPS manual to include BRITE Star II user menus and built-in-test indications to allow operators to recognize and troubleshoot system degradations.
     - Review items required in the shipboard spare part kits to ensure inclusion of single point failure items (such as the datalink control processor) to increase system availability aboard ship.

MV-22 Osprey

Executive Summary

- The Navy conducted the first phase of Operational Test IIIK (OT-IIIK) FOT&E from March to August 2015 and a second phase of OT-IIIK from February to May 2016.
- The second phase evaluated modifications to the Defensive Weapon System (DWS) and Ramp Mounted Weapon System (RMWS) that were made after the first phase of testing.
- Modifications implemented between the first and second phase did not improve the reliability of the DWS and RMWS.
- The DWS is now compatible with the Mission Computer Obsolescence Initiative (MCOI) aircraft.

System

- The MV-22 is the Marine Corps variant of the V-22 Osprey. It is a tiltrotor aircraft capable of conventional wing-borne flight and vertical take-off and landing. The Marine Corps is replacing the now-retired CH-46 and CH-53D helicopters with the MV-22.
- The MV-22 can carry 24 combat-equipped Marines and operate from ship or shore. It can carry an external load up to 10,000 pounds over 50 nautical miles and can self-deploy 2,363 nautical miles with a single aerial refueling.
- Recent system upgrades include the following:
  - MCOI. The MCOI computer hardware initiative is designed to improve the performance of the existing Advanced Mission Computer architecture by adding greater processing speed and more data storage while maintaining the same functionality as the original computer.
  - Blue Force Tracker 2 (BFT-2). The updated BFT-2 GPS-enabled system receives information on friendly, neutral, and hostile forces, as well as sends and receives text and image messages via a federated cockpit display.
  - DWS. GAU-17 DWS improvements add a sensor-only mode that allows the gunner to use the electro-optical sensor when the gun turret is not being used. The turreted, remotely operated, all-quadrant, 7.62 mm DWS is designed for fire suppression against ground troops and soft targets.
  - RMWS. The GAU-21 .50 caliber RMWS replaced the GAU-18 RMWS.

Mission

- Squadrons equipped with MV-22s provide medium-lift assault support in the following operations:
  - Ship-to-Objective Maneuver
  - Sustained operations ashore
  - Tactical recovery of aircraft and personnel
  - Self-deployment
  - Amphibious evacuation

Major Contractors

Bell-Boeing Joint Venture:
- Bell Helicopter – Amarillo, Texas
- The Boeing Company – Ridley Township, Pennsylvania

Activity

- Testing activity focused on the four recent upgrades to the MV-22. The first phase of OT-IIIK was conducted from March to August 2015. The Navy conducted a second phase of OT-IIIK FOT&E from February to May 2016, which evaluated modifications designed to address deficiencies in the DWS and to the RMWS that were discovered in the first phrase of testing. Testing was done in accordance with the DOT&E-approved test plan.
- Marine Corps pilots conducted testing at locations with conditions representative of those encountered in fleet operations. These locations included Marine Corps Base Camp Lejeune, North Carolina; at or near Kirtland AFB, New Mexico; and at or near Marine Corps Air Station Yuma, Arizona. They used three production-representative Advanced Mission Computer aircraft and a production-representative MCOI aircraft. The Advanced Mission Computer configuration is the original, pre-MCOI configuration.
- The Navy's Commander, Operational Test and Evaluation Force, with assistance from Marine Operational Test and Evaluation Squadron 22, conducted cybersecurity testing of

the MV-22 aircraft, mission planning system, and maintenance systems from May 4 – 8, 2015, at Marine Corps Air Station New River, North Carolina. The cybersecurity evaluation was based upon an Adversarial Assessment that included a test of the ability of the unit to protect against cyber-attacks, detect and respond to a cyber-attack, and restore to normal operations in the event of a successful cyber-attack. At the current time, the Navy does not have the capability to do cybersecurity testing on Military Standard (MIL-STD)-1552 data buses, so those were not evaluated.

Assessment

- The upgrades did not enhance the operational effectiveness, suitability, or survivability of the MV-22-equipped unit and MV-22 units remain effective, suitable, and survivable.
- Crews employing MV-22 aircraft equipped with updated mission computers (commonly referred to as "MCOI-equipped") discovered two deficiencies that would hinder the ability of a MCOI-equipped unit to perform its mission:
  1. Pilots reported that numbers and text on the cockpit displays in the MCOI aircraft were not as sharp as those in legacy aircraft despite the new displays' higher resolution.
  2. The MCOI hover display mode did not transition into and out of hover mode without extra pilot actions.
- MCOI aircraft demonstrated compatibility with the DWS in Phase 2, which was not the case in Phase 1.
- The BFT-2 delivery of digital messages is improved over BFT-1. BFT-2 pilot workload remains high for use in a busy cockpit. The BFT 2 transfer of digital images did not work.
- Inherent deficiencies in the design of the DWS continue to limit the unit's ability to provide suppressive fire against threat targets. The Phase 2 modifications to the DWS design had no measureable effect on the aircrew's capability to provide suppressive fire with the DWS.
- The field of fire of the RMWS has expanded and the gun provides suppressive fire to the rear when it fires, but the RMWS cannot be counted on to fire when needed.
- Modifications to the DWS and RMWS did not improve the effectiveness or reliability of the weapon systems.
- After conclusion of the 2016 test period, fuselage damage to several test aircraft was discovered in an area not usually inspected during normal postflight procedures. This damage was discovered in the vicinity of where the DWS ejects shell casings.
- During testing, the OT-IIIK MV-22 aircraft met reliability requirements but did not meet maintainability and availability thresholds. Demonstrated reliability, maintainability, and availability performance is consistent with that of the MV-22 fleet.
- Cybersecurity vulnerabilities were discovered during testing; the details of which are classified.
- The Air Force Special Operations Command observed repeated problems with the CV-22 Icing Protection System (IPS) during testing of the Tactical Software Suite this year, as stated in the CV-22 Annual Report. As the MV-22 has the same system, there could be similar problems on its system.

Recommendations

- Status of Previous Recommendations. The Navy has not completed actions to address the following FY15 recommendations:
  - Address failure modes and supply issues that limit aircraft availability.
  - Use Marine Air-Ground Task Forces to employ tactics, techniques, and procedures to compensate for limitations in the DWS.
  - Improve BFT-2 message latency.
  - Investigate and improve RMWS reliability.
  - Address cyber vulnerabilities of the MV-22 and its supporting systems.
- FY16 Recommendations. The Navy should:
  1. Continue to execute a viable reliability growth program for the MV-22 fleet, and address failure modes that degrade aircraft availability.
  2. Address the MCOI shortcomings and focus on improving the clarity of cockpit displays and modifying the hover page function so that it always returns to the previously selected page.
  3. Investigate and remedy the cause of BFT-2 image messaging failures.
  4. Continue to investigate and remedy the causes of reliability failures in the DWS and RMWS.
  5. Inspect the MV-22 fleet for possible fuselage damage caused by the DWS. If damage is discovered, the cause should be investigated and prevention/remediation actions should be taken.
  6. Address cybersecurity vulnerabilities of the MV-22 and supporting systems.
     a. Develop the capability to conduct cybersecurity testing of MIL-STD-1553 data buses.
     b. Investigate whether modifications to aircraft restore procedures are needed after a cyber-attack.
  7. Investigate MV-22 IPS performance fleet-wide. If MV-22 IPS problems are discovered, the Navy should initiate improvement actions to correct repeated IPS failures.

Next Generation Jammer (NGJ) Increment 1

Executive Summary

- The USD(AT&L) signed an Acquisition Decision Memorandum (ADM) on April 5, 2016, approving Milestone B and entry into the Engineering and Manufacturing Development (EMD) phase for the Next Generation Jammer (NGJ) Increment (Inc) 1 program.
- The Navy's Commander, Operational Test and Evaluation Force (COTF) conducted an Early Operational Assessment (EOA) between June, and October 2015, to assess the current status of the NGJ Inc 1 technical design, examine the NGJ Inc 1 potential capabilities to satisfy future EA-18G Airborne Electronic Attack (AEA) mission requirements, and identify any risks to successful completion of the IOT&E in FY21.
- DOT&E submitted an EOA report on February 10, 2016, in support of the Milestone B decision. The EOA was a preliminary assessment and thus did not present conclusions on NGJ Inc 1 operational effectiveness, suitability, or survivability. The EOA did assess the potential strengths and weaknesses of the NGJ Inc 1 design, effects on the EA-18G aircraft while carrying the NGJ Inc 1, and potential limitations to the successful completion of IOT&E.
- Given the current state of the test ranges, the NGJ Inc 1 testing was adequate, albeit with substantial limitations. However, with the DOT&E-recommended DOD Enterprise-wide range improvements, which will serve numerous acquisition systems for testing, the upgraded ranges will enable both adequate open air testing and validation of modeling and simulation against operationally relevant threats during the NGJ Inc 1 IOT&E.
  - The improved ranges will require numerous programs, to include NGJ Inc 1, to revisit their respective evaluation frameworks.
  - The electronic warfare range upgrades that DOT&E has identified and recommended for funding to the Department's Leadership are needed to conduct adequate testing of NGJ and other key systems without the substantial degradations in operational realism limitations that current test capabilities impose.

System

- The NGJ system is a replacement for the ALQ-99 Tactical Jamming System pods that were initially developed and fielded in 1971 on the EA-6B aircraft to perform AEA against radars associated with threat integrated air defense systems. The ALQ-99 pods have been flown more recently on the EA-18G aircraft that entered full-rate production in FY09.
- The NGJ system is an evolutionary acquisition program designed to provide capability in three increments: Inc 1 (Mid-Band), Inc 2 (Low-Band), and Inc 3 (High-Band).

  The order of development was determined by the assessed capabilities of the developing threat and shortfalls of the legacy system to counter those capabilities, with Inc 1 covering the most critical threats. Inc 1 was the only increment in development during FY16.
- NGJ Inc 1 will be deployed as an AEA system on the EA-18G aircraft, working with the organic ALQ-218 receiver system and off-board assets as a component of future carrier air wings and expeditionary forces, providing capabilities against a wide variety of radio frequency targets. NGJ Inc 1 is intended to expand the current ALQ-99 mission set to include non-kinetic attack against a full spectrum of agile and adaptive communications, datalinks, and non-traditional radio frequency targets.

Mission

- Commanders will use the NGJ Inc 1 to deny, degrade, or deceive the enemy's use of the electromagnetic spectrum employing both reactive and pre-emptive jamming techniques, while enhancing the friendly force's use of the electromagnetic spectrum.
- AEA increases the survivability of joint forces tasked to enter denied battlespace and engage anti-access threats/high-value targets and provides additional means via Information Operations to thwart enemy offensive actions.

Major Contractors

- Raytheon Space and Airborne Systems – El Segundo, California
- The Boeing Company, Defense, Space & Security – St. Louis, Missouri

Activity

- The USD(AT&L) signed an ADM on April 5, 2016, approving Milestone B and entry into the EMD phase. The ADM also:
  - Designated the NGJ Inc 1 program as an Acquisition Category ID Major Defense Acquisition Program
  - Authorized the Navy to proceed with the award of the EMD contract, which includes a future modification for four System Demonstration Test Article ship-sets (two pods per ship-set) and support to operational testing
  - Authorized a low-rate initial production quantity of up to 30 ship-sets
- An EOA was conducted by COTF between June and October 2015, in accordance with the DOT&E-approved Test and Evaluation Master Plan and test plan. The EOA was conducted to assess the current status of the technical design, to examine potential capabilities to satisfy future EA-18G AEA mission requirements, and to identify any risks to successful completion of the IOT&E in FY21. DOT&E submitted an EOA report on February 10, 2016, in support of the Milestone B decision.
- An operational assessment is scheduled for 3QFY19.

Assessment

- The EOA was a preliminary assessment and thus did not present conclusions on NGJ Inc 1 operational effectiveness, suitability, or survivability.
- Potential strengths of the NGJ Inc 1 design demonstrated during the EOA were:
  - High Effective Isotropic Radiated Power (EIRP) for larger stand-off ranges
  - Wide frequency range to counter more frequency diverse threats
  - Large field of regard for operations in a dense threat environment
  - Sufficient Ram-air Turbine Generator power generation to provide the pod system with the power required without drawing from the host platform
- Potential weaknesses of the NGJ Inc 1 design demonstrated during the EOA were:
  - Degraded ALQ-218 host platform receiver capability due to radio frequency interoperability problems caused by higher EIRP requirements
  - Hazards of Electromagnetic Radiation to Ordnance effects on the AGM-88 High-speed Anti-Radiation Missile/Advanced Anti-Radiation Guided Missile affecting reliability
- Based on early small-scale wind tunnel testing and current computational fluid dynamics (CFD) modeling, there is decreased margin to meeting the EA-18G mission radius.
- COTF identified potential limitations to the successful completion of IOT&E through visits to modeling and simulation (M&S) facilities and focus groups with test resource staff, test engineers, test aircrew, and operational stakeholders. The currently-approved M&S plan sufficiently covers M&S for EMD. This plan will need to be updated prior to Milestone C to incorporate specific IOT&E requirements. Additionally, scheduling of the test ranges, test aircraft, test aircrew, and maintenance personnel needs to be planned for well in advance of the beginning of IOT&E due to limitations in availability and conflicting EA-18G test programs.
- Given the current state of the test ranges, the NGJ Inc 1 testing was adequate, albeit with substantial limitations. However, with the DOT&E-recommended DOD Enterprise-wide range improvements, which will serve numerous acquisition systems for testing, the upgraded ranges will enable both adequate open air testing and validation of modeling and simulation against operationally relevant threats during the NGJ Inc 1 IOT&E.
  - The improved ranges will require numerous programs, to include NGJ Inc 1, to revisit their respective evaluation frameworks.
  - The electronic warfare range upgrades that DOT&E has identified and recommended for funding to the Department's Leadership are needed to conduct adequate testing of NGJ and other key systems without the substantial degradations in operational realism limitations that current test capabilities impose.

Recommendations

- Status of Previous Recommendations. This is the first annual report for this program.
- FY16 Recommendations. The Navy should:
  1. Perform planned wind tunnel and CFD modeling of the NGJ Inc 1 configuration as it matures during EMD to predict installed aircraft performance.
  2. Perform planned testing and analysis to determine the extent of Hazards of Electromagnetic Radiation to Ordnance effects on operational use of the AGM-88 High-speed Anti-Radiation Missile/Advanced Anti-Radiation Guided Missile.
  3. Update the M&S plan prior to Milestone C to incorporate specific IOT&E requirements.
  4. Prioritize resources to ensure the test ranges, test aircraft, test aircrew, and maintenance personnel needed to execute IOT&E are available when required.
  5. Fund range upgrades and have all programs, to include NGJ Inc 1, test against the improved ranges.

P-8A Poseidon Multi-Mission Maritime Aircraft (MMA)

Executive Summary

- In FY16, the Navy completed the P-8A Data Storage Architecture Upgrade (DSAU)/Verification of Correction of Deficiencies (VCD) FOT&E. DOT&E's May 2016 P-8A DSAU/VCD operational test report concluded that the DSAU modification provided an effective data transfer and storage architecture to replace legacy system components. The modification effectively reduced the number of data transfer and media recording devices without introducing new system deficiencies. The associated Fleet Release 35 operational flight software successfully corrected seven previously identified system deficiencies. These corrections provided marginal improvements to system performance and user interfaces that affect the mission areas of anti-submarine warfare (ASW); intelligence, surveillance, and reconnaissance (ISR); and aircraft mobility.
- The Navy delayed the P-8A Engineering Change Proposal (ECP) 2 OT&E, originally planned for early FY16, until 1QFY17 due to developmental ASW software deficiencies. This operational test period includes: re-evaluation of the P-8A wide-area ASW search capability with the Multi-static Active Coherent (MAC) Phase I sensor system; complete re-evaluation of the P 8A ISR mission, including both imagery and signals intelligence capabilities; evaluation of air-to-air refueling; cybersecurity assessment; and evaluation of additional AGM-84 Harpoon employment modes. Operational testers will also collect reliability, maintainability, and availability data during this test period to re evaluate P-8A fleet operational availability with a fully mature logistics support system in place. The ECP 2 OT&E will be the most extensive P-8A operational test conducted since the 2012 P-8A IOT&E.
- The Navy continues to delay the development of the MAC system and MAC tactics for deep water and convergence zone acoustic environments. Thus, even after fielding ECP-2, the P-8A will not have an effective wide area acoustic ASW search capability in many threat ocean areas.
- In April 2016, USD(AT&L) approved a revised Navy P-8A acquisition strategy which incorporated all P-8A Increment 3 capability requirements into the baseline P-8A program. These capabilities will now be developed and delivered as a series of ECPs designated as ECPs 4 through 7. They include implementation of significant open system architecture changes, ASW capability enhancements, communication system upgrades, radar and electronic signal sensor upgrades, and AGM-84 Harpoon 2+ anti-ship missile integration. Navy development of a comprehensive Test and Evaluation Master Plan (TEMP) and test schedule for the new P-8A ECP capability releases has been delayed due to evolving capability requirements, potential budget reductions, and schedule uncertainties. TEMP development activities are currently behind schedule to support the start of ECP 4 testing in 2QFY17.

System

- The P-8A Poseidon Multi-mission Maritime Aircraft (MMA) design is based on the Boeing 737-800 aircraft with significant modifications to support Navy maritime patrol mission requirements. It is replacing the P-3C Orion.
- The P-8A incorporates an integrated sensor suite that includes radar, electro-optical, and electronic signal detection sensors to detect, identify, locate, and track surface targets. An integrated acoustic sonobuoy launch and monitoring system detects, identifies, locates, and tracks submarine targets. Sensor systems also provide tactical situational awareness information for dissemination to fleet forces and ISR information for exploitation by the joint intelligence community.
- The P-8A carries MK 54 torpedoes and the AGM-84D Block 1C Harpoon anti-ship missile system to engage submarine and maritime surface targets.
- The P-8A aircraft incorporates aircraft survivability enhancement and vulnerability reduction systems. An integrated infrared missile detection system, flare dispenser, and directed infrared countermeasure system is designed to improve survivability against infrared missile threats. On and off-board sensors and datalink systems are used to improve tactical situational awareness of expected threat systems. Fuel tank inerting and fire protection systems reduce aircraft vulnerability.
- The Navy is integrating the MAC sensor system into the P-8A to provide a wide-area, active ASW search capability.
- Planned future upgrades include the addition of the High Altitude ASW Weapon Capability (HAAWC), AGM 84 Harpoon II+, MAC wide-area ASW search enhancements,

signals intelligence sensors, and advanced mission system architectures and processing upgrades.

Mission

- Theater Commanders primarily use units equipped with the P-8A MMA to conduct ASW operations including the detection, identification, tracking, and destruction of submarine targets.
- Additional P-8A maritime patrol missions include:
  - ASW operations to detect, identify, track, and destroy enemy surface combatants or other maritime targets
  - ISR operations to collect and disseminate imagery and signals information for exploitation by the joint intelligence community
  - Command, control, and communication operations to collect and disseminate tactical situation information to fleet forces
  - Identification and precise geolocation of targets ashore to support fleet strike warfare missions

Major Contractor

Boeing Defense, Space, and Security – St. Louis, Missouri

Activity

- In FY16, the Navy completed the P-8A DSAU/VCD FOT&E. This test evaluated improvements in ASW and ISR mission data loading and storage following the DSAU modification. This test event also included testing to verify corrections for nine previously identified weapons bay, electronic signal collection, Information Assurance, and avionics integration deficiencies, as well as a system-level cybersecurity assessment. DOT&E released the P-8A DSAU Operational Test Report in May 2016.
- The Navy developed improvements to the P-8A acoustic system, the Active System Performance Estimate Computer Tool, and the MAC program that were designed to improve ASW capability. The Navy updated MAC search tactics in shallow water environmental areas and continues to develop the tactics and MAC system upgrades for deeper ocean areas.
- The Navy delayed the P-8A ECP 2 OT&E, originally planned for early FY16, until 1QFY17 due to developmental ASW software deficiencies. This test will evaluate P-8A wide-area ASW search capability with the MAC Phase I sensor system; P-8A ISR capabilities, including both imagery and signals intelligence collection; air-to-air refueling; cybersecurity; and additional AGM-84D Block 1 Harpoon missile employment modes. Operational testers will also collect reliability, maintainability, and availability data during this test period to re-evaluate P-8A fleet operational availability with a fully mature logistics support system in place.
- Contractor and government developmental testing of HAAWC system capability to employ sonobuoys and the MK 54 torpedo from the P-8A at medium to high altitudes is in progress. As a result of increased program cost estimates and reduced funding, the Navy transferred resource sponsor organizational responsibilities within the Navy staff and is currently revising performance thresholds in the HAAWC draft Capabilities Development Document. The HAAWC program has not yet developed a comprehensive test strategy and does not have an approved TEMP.
- In April 2016, USD(AT&L) approved a revised Navy P-8A acquisition strategy which incorporated all P-8A Increment 3 capability requirements into the baseline P-8A program. These capabilities will now be developed and delivered as a series of ECPs designated as ECPs 4 through 7. They include implementation of significant open system architecture changes, ASW capability enhancements, communication system upgrades, radar and electronic signal sensor upgrades, and AGM-84 Harpoon 2+ anti-ship missile integration. The Navy is currently working to develop a revised P-8A TEMP to define the developmental and operational test strategy for this new series of ECPs. Per the approved P-8A acquisition strategy, the Navy should submit a revised P 8A TEMP for DOT&E approval prior to the start of ECP 4 testing in 2QFY17. Tentative test schedules include a series of ECP operational test events in FY18, FY19, FY21, and FY22 to support the incremental release of new P-8A capabilities.
- The Navy completed the second lifetime of fatigue and durability testing on P-8A full-scale test aircraft in FY15 and conducted extended lifetime testing in FY16. Teardown and final analysis of the full-scale fatigue test aircraft will occur when the extended life testing is completed in FY17. Residual strength testing on both the full-scale test article and horizontal stabilizer was also completed in FY16. Main and nose landing gear subassemblies completed the equivalent of three lifetimes of fatigue testing in FY15, followed by landing gear post-test teardown and analysis in FY16.

Assessment

- DOT&E's May 2016 P-8A DSAU/VCD operational test report concluded that the DSAU modification provided an effective data transfer and storage architecture to replace legacy system components. The modification effectively reduced the number of data transfer and media recording devices without introducing new system deficiencies. The associated Fleet Release 35 operational flight software successfully corrected seven previously identified system deficiencies and partially corrected one additional deficiency. These corrections provide marginal improvements to system performance and user interfaces that affect ASW, ISR, and aircraft mobility mission areas. These improvements do not significantly alter previous assessments of overall P-8A mission capabilities.
- The P-8A DSAU/VCD FOT&E cybersecurity test events identified a collection of exploitable P-8A cybersecurity

vulnerabilities. Based on the results of this test, DOT&E recommended that the Navy conduct a more comprehensive P-8A cybersecurity test to include end-to-end cyber-attack and response threads for the complete P-8A system-of-systems, including maintenance support systems, Tactical Mobile mission planning and support systems, and physical access points to P-8A integrated workstations. The Navy is planning to include an expanded cybersecurity test event as part of the FY17 P-8A ECP 2 OT&E.

- The Navy's FY17 P-8A ECP 2 OT&E evaluates significant new P-8A capabilities, including wide-area ASW search with the MAC Phase I sensor system, air-to-air refueling, and additional AGM-84 Harpoon employment modes. It also includes a complete re-evaluation of P-8A imagery and signals intelligence collection capabilities. This will be the most extensive P 8A operational test conducted since the 2012 P-8A IOT&E.
  - The Navy did not complete the development of MAC capability or MAC tactics for wide-area active ASW search in deep or Convergence Zone acoustic environments; therefore, the P-8A ECP-2 OT&E will only evaluate improvements to the MAC Phase I system in shallow and littoral environments. Thus, the P-8A does not have the full wide-area acoustic ASW capability required by the baseline Capability Development Document.
  - The Navy continues to develop and test corrective actions for 106 open system deficiencies identified as operationally significant during previous test periods. The ECP 2 OT&E test plan includes events to verify corrective actions for 37 of these deficiencies. During this test, operational testers will also collect reliability, maintainability, and availability data during this test period to re-evaluate P 8A fleet operational availability with a fully mature logistics support system in place.
- The Navy continued ECP-2 testing to evaluate improvements to the P-8A's acoustic and MAC software and employment tactics in representative littoral shallow water environments. The Navy continues to develop tactics and system improvements to use the MAC system in deeper water ASW environments. A higher source level active buoy is undergoing developmental testing; when combined with new tactics and MAC software improvements, it could improve and expand the current ECP-2 ASW capability. Once the new MAC source buoy is completed and fielded, a re-evaluation of the MAC capability will be required. This testing will be included in the updated P-8A TEMP.
- The Navy's contractor testing of the HAAWC MK 54 weapon delivery capability is progressing. The contractor completed two successful test flights in FY16. The P-8A program conducted initial testing to verify the HAAWC captive carriage, buffet load margins, and safe separation.
- The Navy delayed development of a comprehensive test strategy and schedule for the new P-8A ECPs 4 through 7 (formerly the P-8A Increment 3 program) due to evolving capability requirements, potential budget reductions, and schedule uncertainties. Development of a revised P-8A TEMP is necessary to ensure that test resources are defined and available to support development of P-8A open system architecture changes, enhanced ASW capabilities, communication system upgrades, radar and electronic signal sensor upgrades, and AGM-84 Harpoon 2+ anti-ship missile integration. Navy TEMP development activities are currently behind schedule to support the start of ECP 4 testing in 2QFY17.
- The Navy completed landing gear fatigue test assembly data analysis with no significant findings. Teardown of the full-scale aircraft fatigue test article will occur when all extended life test events are complete. The program continues to review the full-scale test article data to refine fleet airframe inspection requirements and depot repair procedures to ensure the airframe meets the intended 25-year design life. To date, no significant long term structural problems have been identified.

Recommendations

- Status of Previous Recommendations. The Navy made progress on all three FY15 recommendations. The Navy completed P-8A ECP 1 OT&E to evaluate initial P-8A MAC wide-area search capabilities. The program also initiated TEMP development for the new P-8A ECPs 4 through 7 capability enhancements (formerly P-8A Increment 3). The Navy also verified correction of 7 previously identified system deficiencies in FY16 and planned verification of an additional 37 (of 106 remaining) system deficiencies in FY17.
- FY16 Recommendations. The Navy should:
  1. Submit a comprehensive P-8A TEMP for DOT&E approval covering new P-8A ECPs 4 through 7 and MAC system improvements prior to the start of ECP 4 testing in FY17.
  2. Continue to implement corrective actions for the significant number of operationally significant system deficiencies identified in previous P-8A operational test reports and conduct additional follow-on operational tests to verify improved mission capabilities.
  3. Conduct a comprehensive P-8A cybersecurity evaluation to include complete end-to-end cyber-attack and response threads for the P-8A aircraft and key mission support systems.

Remote Minehunting System (RMS)

Executive Summary

- In the wake of the Navy's 2015 Technical Evaluation (TECHEVAL) of the Increment 1 mine countermeasures (MCM) mission package, and following the Navy's independent review of the program, the Navy cancelled the Remote Minehunting System (RMS) program and announced its intention to evaluate alternatives to the RMS. Those alternatives included use of an unmanned surface vessel (USV) to tow improved minehunting sensors and the Knifefish unmanned undersea vehicle (UUV). The Navy's decision came after approximately two decades of RMS development and repeated claims by Navy officials that the system had achieved remarkable reliability growth in recent years. As illustrated clearly in the FY15 edition of this report, the Navy's claims regarding reliability improvement were demonstrably incorrect.
- The Navy has reportedly funded refurbishment of a small number of the existing Remote Multi-Mission Vehicles (RMMVs) and may still employ these vehicles in some capacity. However, planning for developmental and operational testing of the mission package is proceeding under the assumption that the future minehunting capability will be provided by one or two USVs towing an AN/AQS-20C or AN/AQS-24C minehunting sensor and a pair of Knifefish UUVs.
- The Navy continued to develop pre-planned product improvements for the AN/AQS-20 sonar in FY16. It's plans to commence realistic AN/AQS-20C developmental and operational testing are uncertain because of limited availability of two potential tow platforms; existing RMMVs are not reliable but the Navy does not expect to begin upgrades necessary to make the initial, limited-quantity USVs compatible with the improved sonar until at least FY18.

System

- The RMS is designed to provide off-board mine reconnaissance capability to detect, classify, and localize non-buried bottom and moored mines, and to identify bottom mines in shallow water.
- RMS uses the RMMV, which is an unmanned, diesel-powered, semi-submersible vehicle, to tow the AN/AQS-20 variable depth sensor.
  - The AN/AQS-20 is a multi-mode sensor in a modular towed body that can house as many as five sonars. The AN/AQS-20 can also be fitted with an electro-optical identification device to identify mine-like objects. The Navy is developing a new variant of the sensor, designated AN/AQS-20C, which includes an improved forward-looking sonar and new synthetic aperture side-looking sonars. The Navy expects to field the AN/AQS-20C by FY18 or FY19, pending availability of a tow vehicle.

  - Although the Navy cancelled the RMS program and suspended further RMMV procurement, it plans to overhaul some of the existing RMMVs for possible deployment with early variants of the Littoral Combat Ship (LCS) MCM mission package. The Navy is also developing the capability to tow a minehunting sensor (AN/AQS-20C or AN/AQS-24) with an USV (based on the vessel used in the Unmanned Influence Sweep System being developed for LCS) to replace the RMS.
- A datalink subsystem provides real-time communications between the host ship and the RMMV for command and control and transmission of some sensor data. The RMS datalink subsystem, which includes ultra-high frequency line-of-sight (LOS) and low-band very-high frequency over-the-horizon (OTH) radios, interfaces with the multi-vehicle communications system installed in the LCS seaframes.
- Shipboard operators control the RMMV using a remote minehunting functional segment integrated into the LCS mission package computing environment.
- The RMS records sensor data to a removable hard drive during minehunting operations. Following vehicle recovery, operators transfer data to an organic post mission analysis station and review sonar data to mark contacts as suspected mine-like objects. The RMS does not determine the absence or presence of mines or complete mine clearance operations in a single pass. Following an initial search by the RMS, sailors plan additional RMS sorties in the same area to assess persistence of in-volume contacts marked as mine-like and to identify bottom contacts marked as mine-like as either mines or non-mines. When operators conclude that RMS in-volume contacts are persistent, those contacts are passed to another system for identification and neutralization.

Mission

If the system is fielded, MCM Commanders would likely employ the RMS from an MCM mission package-equipped LCS, to detect, classify, and localize non-buried bottom and moored mines, and to identify shallow-water bottom mines in support of theater minehunting operations.

Major Contractors

- RMMV: Lockheed Martin – West Palm Beach, Florida
- AN/AQS-20 (all variants): Raytheon Corporation – Portsmouth, Rhode Island

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Activity

- The Navy initiated RMS cybersecurity testing and conducted additional ship-based RMS testing to assess readiness for operational testing that it expected to complete in FY15
- In October 2015, the Navy delayed IOT&E of the *Independence*-variant LCS equipped with the first increment of the MCM mission package pending the outcome of an independent program review, including an evaluation of potential alternatives to the RMS. The Navy chartered the review in response to an August 21, 2015, letter from Senators John McCain and Jack Reed, Chairman and Ranking Member of the Senate Committee on Armed Forces expressing concerns about the readiness to enter operational testing given the significant reliability problems observed during a TECHEVAL in 2015.
- In early 2016, following the completion of the independent review, the Navy:
  - Concluded that reliance on shore-based test metrics provided a false sense of RMMV maturity and contributed to the RMS progressing to sea-based test events prematurely.
  - Cancelled the RMS program and halted further RMMV procurement.
  - Announced its intention to field existing RMMVs following overhauls to mitigate high impact failure modes.
  - Revealed initial plans (subsequently dashed by lack of funding for Knifefish improvements) to evaluate alternatives to the RMS, including an USV towing either the AN/AQS-20C or AN/AQS-24C minehunting sensor and an improved version of the Knifefish UUV already in development.
  - Abandoned plans to conduct operational testing of individual MCM mission package increments and delayed the start of LCS MCM mission package IOT&E until at least FY20.
- In June 2016, DOT&E submitted an early fielding report to the Congress in response to the Navy's plan to deploy the *Independence*-variant LCS equipped with the MCM mission package, including the existing v6.0 RMMVs and AN/AQS-20As, prior to the conduct of operational testing. The classified report, which does not support the Full-Rate Production decision, provided DOT&E's interim assessments of operational effectiveness and operational suitability of the *Independence*-variant LCS employing the MCM mission package and its components, including the RMS.
- The Navy continued to develop pre-planned product improvements for the AN/AQS-20 sonar in FY16. It's plans to commence realistic AN/AQS-20C developmental and operational testing are unsettled because of limited availability of two potential tow platforms; existing RMMVs are not reliable but the Navy does not expect to make the initial, limited-quantity USVs compatible with the AN/AQS-20C until late FY18. In testimony to the Senate Armed Services Committee in December, the Navy announced that two RMMVs will be groomed and one will be overhauled. These RMMVs will then be used to continue AN/AQS-20 sonar testing, conduct data collection, and support user evaluation until the first USV is available.

Assessment

- The RMS would not be operationally effective or operationally suitable if called upon to conduct MCM missions in combat. The primary reasons for these conclusions are:
  - The system is not reliable.
  - The system's minehunting capabilities are limited in other-than-benign environmental conditions.
  - The fleet is not equipped to maintain the system.
- Since the Navy has not implemented corrective actions to mitigate the problems observed in earlier testing, the substantive unclassified details of DOT&E's assessment are unchanged from the FY15 edition of this report. DOT&E's classified June 2016 early fielding report provides additional detail.

Recommendations

- Status of Previous Recommendations.
  - The Navy made progress on all four FY13 recommendations. Shore-based testing completed in 1QFY14 and shipboard testing completed in 1QFY15 provided additional information regarding RMS, RMMV, and AN/AQS-20A reliability; RMS operational availability; and RMMV launch, handling, and recovery system performance. Although the Navy continues to develop and test AN/AQS-20 upgrades, it has not demonstrated in developmental or operational testing that it has corrected problems with false classifications and contact localization errors that will otherwise limit performance in operational testing. The Navy has not determined the test program for the AN/AQS-20 sonar yet, but will include that as an annex to the LCS TEMP rather than having a separate document.
  - The Navy has made progress on two of the nine FY14 recommendations. The Navy did not act on the following FY14 recommendations:

  - Conduct testing of the RMS consisting of the v6.0 RMMV and AN/AQS-20B/C in operationally realistic end-to-end minehunting missions to characterize minehunting performance and accurately assess availability of the RMS and reliability of the RMMV and sonar.
  - Investigate the use of communications relays and other solutions that might improve the standoff distance between an RMMV and its host ship to improve the efficiency of LCS MCM operations.
  - Reassess RMMV v6.0 radiated noise following vehicle upgrades.
  - Reexamine minimum vehicle and sensor reliability and LCS organizational-level maintenance support needed to complete timely and realistic operational scenarios without excessive reliance on intermediate- and depot-level support.
  - Reconsider RMS minehunting requirements in the context of expected LCS tactics and operations.
- By reviewing alternatives to the RMMV, the Navy has made progress on one of the six FY15 recommendations. The Navy did not act on the following FY15 recommendations, which are applicable to RMS and potential replacement systems:
  - Complete a comprehensive review of RMMV and mission package communications interfaces and, if necessary, re-engineer the Multi-Vehicle Communication System (MVCS), RMMV, and/or other essential system-of-systems components to improve interoperability and enable reliable line-of-sight and over-the-horizon communications between LCS and RMMVs.
  - Develop tactics to mitigate system vulnerabilities to mines and other hazards.
  - Assess improvements to post mission analysis and contact management software and training to resolve problems observed during TECHEVAL when multiple RMS contacts on the same mine were passed to AMNS for identification and neutralization.
  - Continue to develop and implement improvements for launch, handling, and recovery equipment and procedures.
  - Provide LCS sailors better training, technical documentation, test equipment, and tools, along with additional spares to improve the crews' self-sufficiency and enhance RMS maintainability.

- FY16 Recommendations. The Navy should address the prior applicable recommendations and consider the following actions:
  1. Suspend further use of RMMV v6.0 until completing a comprehensive reliability-centered analysis, correcting high impact failure modes, and testing repairs in an operationally realistic environment.
  2. Complete a comprehensive LCS-based cybersecurity assessment of the RMMV before deploying any existing units for operational use.
  3. Limit procurement of AN/AQS-20 sonars and upgrade kits, which are not yet meeting the Navy's original requirements and negatively affect LCS MCM capability, until much needed performance improvements are developed, tested, and proven effective in testing representative of realistic LCS mine-clearance operations.
  4. Given the cancellation of the RMS program, fully fund and accelerate the development of the most promising minehunting alternatives, including the USV with a towed AN/AQS-20C or AN/AQS-24C sensor and the Knifefish UUV with pre-planned product improvements.

Rolling Airframe Missile (RAM) Block 2

Executive Summary

- DOT&E issued a classified Early Fielding Report to Congress on March 23, 2016, because a ship deployed with the Rolling Airframe Missile (RAM) Block 2 system prior to completion of IOT&E. Based on all the results of the completed IOT&E tests, DOT&E stated that:
  - Insufficient data exist to characterize RAM Block 2's performance against all the anti-ship cruise missile (ASCM) threats the missile is intended to defeat. This condition will continue until the Navy completes RAM Block 2 IOT&E, which is expected in late 2017.
  - Completed testing has demonstrated that RAM Block 2 incorporates several improvements over its RAM Block 1 and 1A predecessors.
  - Deficiencies in RAM Block 2 integration with the Ship Self-Defense System (SSDS)-based combat system caused several RAM Block 2 missiles to miss their target during one of the IOT&E missile firing scenarios.
  - Due to the Navy's inability to develop a Multi-Stage Supersonic Target (MSST), no assessment of RAM Block 2's capability against MSST-like ASCM threats is possible.
  - RAM Block 2 met its in-flight reliability requirement.
- The Navy's Commander, Operational Test and Evaluation Force (COTF) continued the IOT&E with one RAM Block 2 missile firing scenario at the Naval Air Warfare Center, Point Mugu, California, in April 2016 from the Self-Defense Test Ship in accordance with a DOTE-approved test plan.

System

- The RAM, jointly developed by the United States and the Federal Republic of Germany, provides a short-range, lightweight self-defense system to defeat ASCMs. There are three RAM variants:
  - RAM Block 0 uses dual mode, passive radio frequency/infrared guidance to home in on ASCMs.
  - RAM Block 1A adds infrared guidance improvements to extend defenses against ASCMs that do not radiate radio frequencies.

  - RAM Block 2 incorporates changes to improve its kinematic capability and capability to guide on certain types of ASCM radio frequency threat emitters in order to defeat newer classes of ASCM threats.
- RAM Block 2 can be launched from the 21 round RAM Guided Missile Launch System resident on LPD 17, LHA 6, LSD 41/49, LCS *Freedom*, and CVN 68 ship classes or from the SeaRAM standalone self-defense system composed of the Close-In Weapon System radar/electronic warfare sensor suite and command/decision capability combined with an 11-round missile launcher which is resident on selected Aegis DDG 51 Destroyers and the LCS *Independence* ship class.

Mission

Commanders employ naval surface forces equipped with RAM to provide a defensive short-range, hard-kill engagement capability against ASCM threats.

Major Contractors

- Raytheon Missiles Systems – Tucson, Arizona
- RAMSys – Ottobrunn, Germany

Activity

- DOT&E issued a classified Early Fielding Report to Congress on March 23, 2016, because a ship deployed with the RAM Block 2 system prior to completion of IOT&E.
- COTF continued the IOT&E with one RAM Block 2 missile firing scenario at the Naval Air Warfare Center, Point Mugu, California, in April 2016 from the Self-Defense Test Ship in accordance with a DOTE-approved test plan.

Assessment

- The classified March 2016 DOT&E Early Fielding Report, based on results of all completed IOT&E tests, stated that:
  - Insufficient data exist to characterize RAM Block 2's performance against all the ASCM threats the missile is intended to defeat. This condition will continue until the Navy completes the RAM Block 2 Probability of Raid

Annihilation modeling and simulation IOT&E phase, which is expected in late 2017.
- Completed testing has demonstrated that RAM Block 2 has demonstrated several improvements over its RAM Block 1 and 1A predecessors.
- Deficiencies in RAM Block 2 integration with the SSDS-based combat system caused several RAM Block 2 missiles to miss their target during one of the IOT&E missile firing scenarios.
- Due to the Navy's inability to develop an MSST, no assessment of RAM Block 2's capability against MSST-like ASCM threats is possible.
- The current steerable antenna system used on Navy aerial targets does not allow for an adequate emulation of specific ASCM threats.
- The Navy has not tested RAM Block 2's ability to home-on and destroy helicopter, slow aircraft, and surface threats thus no assessment of RAM Block 2's capability in this secondary mission area is possible.
- RAM Block 2 met its in-flight reliability requirement.

Recommendations

- Status of Previous Recommendations. The Navy has not completed the following previous recommendations:
  1. Correct the identified integration deficiencies with the SSDS-based combat system and RAM Block 2. Demonstrate these corrections in a phase of operational testing.
  2. Correct the SSDS scheduling function to preclude interference from prior intercepts and warhead detonations with RAM's infrared guidance. Demonstrate corrections in a phase of operational testing.
- FY16 Recommendations. The Navy should:
  1. Develop an MSST adequate for use in FOT&E. See the Test Resources section in this Annual Report for further details.
  2. Conduct FOT&E to determine RAM Block 2's capability to home-on and destroy helicopter, slow aircraft, and surface threats.
  3. Develop an improved steerable antenna system for its ASCM surrogates.

Ship Self-Defense for LHA(6)

Executive Summary

- The Navy's Commander, Operational Test and Evaluation Force (COTF) conducted a missile firing exercise on the Self-Defense Test Ship (SDTS) in April 2016. The SDTS was configured with the USS *America* (LHA 6) Ship Self-Defense System (SSDS)-based combat system. COTF conducted the test in accordance with a DOT&E-approved test plan. Results of testing completed to date continue to indicate that LHA 6 has some ship self-defense capability against older anti-ship cruise missile (ASCM) threats. LHA 6 ship self-defense performance against newer ASCM threats remains undetermined pending completion of the LHA 6 Probability of Raid Annihilation (PRA) modeling and simulation (M&S) test bed tests for IOT&E in late-2017.
- COTF conducted cybersecurity testing for the LHA 6 IOT&E and SSDS FOT&E on the LHA 6 in August 2016. Testing was conducted in accordance with a DOT&E-approved test plan. The test began with many known problems discovered during developmental testing in 2014 uncorrected. Data from the operational test are still being analyzed.

System

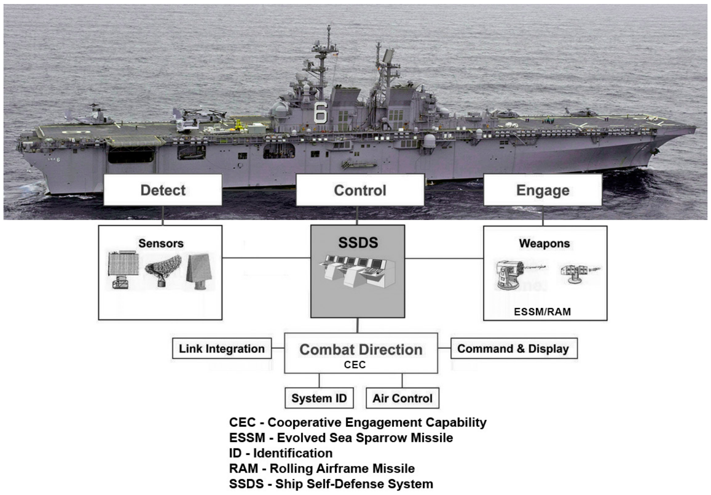
- Surface ship self-defense for the LHA 6 is addressed by several legacy combat system elements (including the AN-SPS-49A(V)1, AN/SPS-48E(V)10, and AN/SPQ-9B radars that are the primary self-defense radars) and five acquisition programs:
  - Ship Self-Defense System (SSDS)
  - Rolling Airframe Missile (RAM)
  - Evolved Seasparrow Missile (ESSM)
  - Cooperative Engagement Capability (CEC)
  - Surface Electronic Warfare Improvement Program (SEWIP)

SSDS

- SSDS is a local area network that uses open computer architecture and standard Navy displays to integrate a surface ship's sensors and weapons systems to provide an automated detect-track-engage sequence for ship self-defense.
- SSDS MK 1 is the legacy command and control system for LSD 41/49 class ships.
- SSDS MK 2 has six variants:
  - Mod 1, used in CVN 68 class aircraft carriers
  - Mod 2, used in LPD 17 class amphibious ships
  - Mod 3, used in LHD 7/8 class amphibious ships
  - Mod 4, used in LHA 6 class amphibious ships
  - Mod 5, used in LSD 41/49 class amphibious ships
  - Mod 6, in development for CVN 78 class aircraft carriers

RAM

- The RAM, jointly developed by the United States and the Federal Republic of Germany, provides a short-range, lightweight self-defense system to defeat ASCMs.



- There are three RAM variants:
  - RAM Block 0 uses dual-mode, passive radio frequency/infrared guidance to home in on ASCMs.
  - RAM Block 1A adds infrared guidance improvements to extend defense against ASCMs that do not emit radar signals.
  - RAM Block 2 adds kinematic and guidance improvements to extend the capability of RAM Block 1A against newer classes of ASCM threats.

ESSM

- The ESSM, cooperatively developed among 13 nations, is a medium-range, ship-launched, self-defense guided missile intended to defeat ASCM, surface, and low-velocity air threats.
- The ESSM is currently installed on LHA 6 and LHD 8 amphibious ships, DDG 51 Flight IIA destroyers, and CVN 68 class aircraft carriers equipped with the SSDS MK 2 Mod 1 Combat System.
- There are two variants of ESSM:
  - ESSM Block 1 is a semi-active radar-guided missile that is currently in service.
  - ESSM Block 2 is in development and will have semi active radar guidance and active radar guidance.

CEC

- CEC is a sensor network with an integrated fire control capability that is intended to significantly improve battle force air and missile defense capabilities by combining data from multiple battle force air search sensors on CEC-equipped units into a single, real-time, composite track picture.
- The two major hardware pieces are the Cooperative Engagement Processor, which collects and fuses radar data, and the Data Distribution System, which distributes CEC data to other CEC-equipped ships and aircraft.

- CEC is an integrated component of, and serves as the primary air tracker for, non-LSD class SSDS MK 2 equipped ships.
- There are two major surface ship variants of CEC:
  - The CEC AN/USG-2/2A is used in selected Aegis cruisers and destroyers, LPD 17/LHD/LHA 6 amphibious ships, and CVN 68 class aircraft carriers.
  - The CEC AN/USG-2B, an improved version of the AN/USG-2/2A, is used in selected Aegis cruisers/ destroyers as well as selected amphibious assault ships, including the LHA 6 ship class and CVN 68 class aircraft carriers.

SEWIP

- The SEWIP is an evolutionary development program providing block upgrades to the AN/SLQ-32 electronic warfare system to address critical capability, integration, logistics, and performance deficiencies.
- There are three major SEWIP block upgrades:
  - SEWIP Block 1, which is used on LHA 6 class ships, replaced obsolete parts in the AN/SLQ-32 and incorporated a new, user-friendly operator console, an improved electronic emitter identification capability, and an embedded trainer.
  - SEWIP Block 2 is in development and will incorporate a new receiver antenna system intended to improve the AN/SLQ-32's passive electronic warfare capability.
  - SEWIP Block 3 is in development and will incorporate a new transmitter antenna system intended to improve the AN/SLQ-32's active electronic warfare capability.

Mission

- Naval Component Commanders use SSDS, RAM, ESSM, SEWIP, and CEC, as well as many legacy systems, to accomplish ship self-defense missions.
- Naval surface forces use the:
  - SSDS to provide automated and integrated detect to engage ship self-defense capabilities against ASCM, air, and surface threats.
  - RAM to provide a short-range, hard-kill engagement capability against ASCM threats.
  - ESSM to provide a medium-range, hard-kill engagement capability against ASCM, surface, and low velocity air threats.
  - CEC to provide accurate air and surface threat tracking data to SSDS.
  - SEWIP-improved AN/SLQ 32 as the primary electronic warfare sensor and soft-kill weapons system for air defense (to include self defense) missions.

Major Contractors

- SSDS (all variants): Raytheon – San Diego, California
- RAM and ESSM (all variants): Raytheon – Tucson, Arizona
- CEC (all variants): Raytheon – St. Petersburg, Florida
- SEWIP
  - Block 1: General Dynamics Advanced Information Systems – Fair Lakes, Virginia
  - Block 2: Lockheed Martin – Syracuse, New York
  - Block 3: Northrop Grumman – Baltimore, Maryland

Activity

- COTF conducted a missile firing exercise on the SDTS in April 2016. The SDTS was configured with the USS *America* (LHA 6) SSDS-based combat system. This test, originally scheduled for early FY15, was postponed due to concerns over possible poor system performance.
- COTF conducted the test in accordance with a DOT&E-approved test plan
- COTF commenced cybersecurity testing for the LHA 6 IOT&E and the SSDS FOT&E on LHA 6 in August 2016 in accordance with a DOT&E-approved test plan; it is expected to complete in March 2017.
- COTF continued planning for the LHA 6 IOT&E PRA M&S test bed phase scheduled to commence in early-2017.

Assessment

- The April 2016 missile firing exercise on the SDTS resulted in the ESSM missile failing to destroy any of the threat surrogate targets. This failure was compounded by a combat system time synchronization problem that prevented the launch of a full salvo of ESSMs.
- Results of the April 2016 missile firing exercise on the SDTS identified deficiencies in SSDS processing of threat surrogate emitters and sensor detections; both of which could affect mission success.
- Results of testing completed to date continue to indicate that the LHA 6 has some ship self-defense capability against older ASCM threats. The LHA 6 ship self-defense performance against newer ASCM threats remains undetermined pending completion of the LHA 6 PRA M&S test bed runs for IOT&E in late-2017.
- Due to the Navy's inability to develop a Multi-Stage Supersonic Target (MSST), no assessment of the LHA 6 ship self-defense capability against MSST-like ASCM threats is possible.
- Final plans for operational testing and introduction of the Fire Control Loop Improvement Program (FCLIP) improvements in the LHA 6 ship class is unknown.
- Cybersecurity operational testing began with many known problems discovered during developmental testing in 2014

that were uncorrected. Data from the completed cybersecurity operational tests are still being analyzed.

- The Navy's reluctance to proceed with operational testing when it believes the outcome will unfavorably highlight poor performance is troubling because the ability of these ships' to defend themselves in a conflict is unknown and the root causes of any performance problems and the potential for correcting those problems also remains unknown.

Recommendations

- Status of Previous Recommendations. The Navy has satisfactorily completed some of the previous recommendations. However, the Navy has not resolved the following previous recommendations related to LHA 6 ship self-defense:
  1. Optimize SSDS MK 2 weapon employment timelines to maximize weapon Probability of Kill.
  2. Develop an adequate open-loop seeker subsonic ASCM surrogate target for ship self-defense combat system operational tests.
  3. Correct the identified SSDS MK 2 software reliability deficiencies.
  4. Correct the identified SSDS MK 2 training deficiencies.
  5. Develop and field deferred SSDS MK 2 interfaces to the Global Command and Control System – Maritime and the TPX-42A(V) command and control systems.
  6. Improve the ability of legacy ship self-defense combat system sensor elements to detect threat surrogates used in specific ASCM raid types.
  7. Improve the SSDS MK 2 integration with the MK 9 Track Illuminators to better support ESSM engagements.
  8. Develop combat system improvements to increase the likelihood that ESSM and RAM will home on their intended targets.
  9. Correct the cause of the ESSM missile failures and demonstrate the correction in a future phase of operational testing.
  10. Investigate means to mitigate the chances of an ESSM pre-detonating on debris before approaching its intended target.
  11. Investigate why target emitters continue to be reported as valid by the AN/SLQ-32 EWS with the SEWIP Block 1 upgrade after the target is destroyed. Test any corrections in a future operational test phase.
  12. Correct the SSDS scheduling function to preclude interference from prior intercepts and warhead detonations with RAM's infrared guidance. Demonstrate corrections in a phase of operational testing.
  13. Correct the integration problems with the SSDS-based combat system and the AN/SPQ-9B radar to ensure that all valid AN/SPQ-9B detections are used by the combat system when tracking targets. Demonstrate the corrections in a phase of operational testing.
- FY16 Recommendations. The Navy should:
  1. Complete the LHA 6 IOT&E at-sea test phase, cybersecurity testing, and the planning for the LHA 6 PRA M&S test bed IOT&E test phase.
  2. Update the LHA 6 and SSDS Test and Evaluation Master Plans to include at-sea and PRA test bed operational test phases to enable evaluation of the ship self-defense capabilities of the LHA 8 equipped with the new Enterprise Air Surveillance Radar.
  3. Continue to take action on the classified recommendations contained in the March 2011 and November 2012 DOT&E reports to Congress on the ship self-defense mission area.
  4. Provide a plan of action and milestones for introduction and operational testing of FCLIP improvements.
  5. Investigate and correct the cause of the ESSM missile failure to destroy any of the threat surrogate targets.
  6. Investigate and correct the combat system time synchronization problem that prevented the launch of a full salvo of ESSMs.
  7. Investigate and correct the SSDS processing of threat surrogate emitters and sensor detection deficiency.
  8. Develop an adequate MSST target as well as adequate electronic warfare target surrogates for use during operational testing. See the Test Resources section in this Annual Report for further details.

Ship Self-Defense for LSD 41/49

Executive Summary

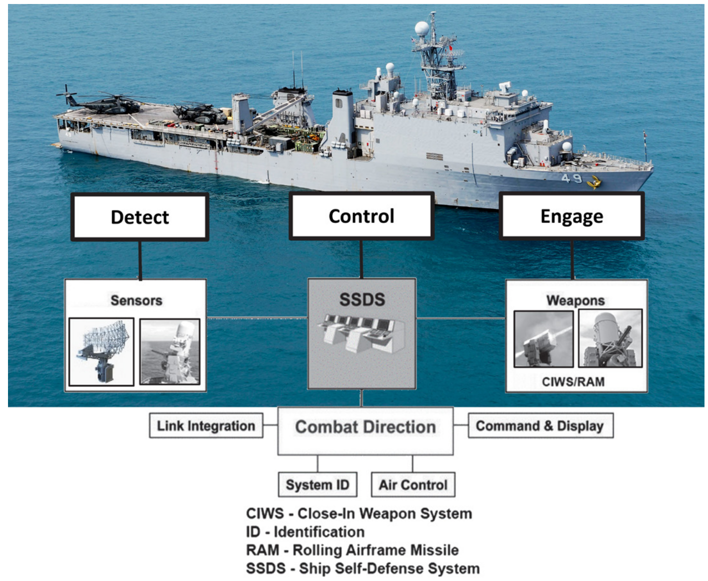
- The Navy postponed gun and missile firing operational tests planned for June 2016 from the Self-Defense Test Ship (SDTS) equipped with the Ship Self-Defense System (SSDS) MK 2 Mod 5 Combat System due to initial concerns about possible poor performance and the desire to conduct detailed predictive analysis before proceeding with testing.
- The Navy's detailed predictive analysis is scheduled for completion in October 2016. A total of four missile firing and two gun firing operational test scenarios from the SDTS are planned. One missile firing scenario from the SDTS is scheduled for December 2016. The remaining three missile firing and two gun firing operational test scenarios from the SDTS are scheduled for no earlier than FY19.
- DOT&E intends to issue an SSDS MK 2 Mod 5 Early Fielding Report to Congress once the first SSDS MK 2 Mod 5-equipped LSD 41/49 ship deploys in late 2016. An additional two SSDS MK 2 Mod 5-equipped LSD 41/49 ships are planned to deploy in FY17 with at least one more planned to deploy in FY18. The report will state that there is a paucity of operational test results to support any assessment of the self- defense capabilities of the LSD 41/49 class ships equipped with the SSDS MK 2 Mod 5 Combat System and that the Navy is deploying those ships with unknown self-defense capabilities.

System

- Surface ship self-defense for the LSD 41/49 class ship is addressed by several legacy combat system elements (including the AN/SPS-49A(V)1 and Close-in Weapon System Radars that are the primary self-defense radars) and three acquisition programs:
  - Ship Self-Defense System (SSDS)
  - Rolling Airframe Missile (RAM)
  - Surface Electronic Warfare Improvement Program (SEWIP)

SSDS

- SSDS is a local area network that uses open computer architecture and standard Navy displays to integrate a surface ship's sensors and weapons systems to provide an automated detect-track-engage sequence for ship self defense.
- SSDS MK 1 is the legacy command and control system for LSD 41/49 class ships.
- SSDS MK 2 has six variants:
  - Mod 1, used in CVN 68 class aircraft carriers
  - Mod 2, used in LPD 17 class amphibious ships
  - Mod 3, used in LHD 7/8 class amphibious ships
  - Mod 4, used in LHA(R) class amphibious ships
  - Mod 5, used in LSD 41/49 class amphibious ships
  - Mod 6, in development for CVN 78 class aircraft carriers



RAM

- The RAM, jointly developed by the United States and the Federal Republic of Germany, provides a short-range, lightweight self-defense system to defeat anti-ship cruise missiles (ASCMs).
- There are three RAM variants:
  - RAM Block 0 uses dual-mode, passive radio frequency/infrared guidance to home in on ASCMs.
  - RAM Block 1A adds infrared guidance improvements to extend defense against ASCMs that do not emit radar signals.
  - RAM Block 2 adds kinematic and guidance improvements to extend the capability of RAM Block 1A against newer classes of ASCM threats.

SEWIP

- The SEWIP is an evolutionary development program providing block upgrades to the AN/SLQ-32 electronic warfare system to address critical capability, integration, logistics, and performance deficiencies.
- There are three major SEWIP block upgrades:
  - SEWIP Block 1, which is used on LSD 41/49 class ships, replaced obsolete parts in the AN/SLQ-32 and incorporated a new, user-friendly operator console, an improved electronic emitter identification capability, and an embedded trainer.
  - SEWIP Block 2 incorporates a new receiver antenna system intended to improve the AN/ SLQ-32's passive electronic warfare capability.

- SEWIP Block 3 is in development and will incorporate a new transmitter antenna system intended to improve the AN/SLQ-32's active electronic warfare capability.
- SEWIP-improved AN/SLQ 32 as the primary electronic warfare sensor and soft-kill weapons system for air defense (to include self defense) missions.

Mission

- Naval Component Commanders use SSDS, RAM, and SEWIP, as well as many legacy systems, to accomplish ship self-defense missions.
- Naval surface forces use the:
  - SSDS to provide automated and integrated detect to engage ship self-defense capabilities against ASCM, air, and surface threats.
  - RAM to provide a short-range hard-kill engagement capability against ASCM threats.

Major Contractors

- SSDS (all variants): Raytheon – San Diego, California
- RAM (all variants): Raytheon Missile Systems – Tucson, Arizona; RAMSys – Ottobrunn, Germany
- SEWIP
  - Block 1: General Dynamics Advanced Information Systems – Fair Lakes, Virginia
  - Block 2: Lockheed Martin – Syracuse, New York
  - Block 3: Northrop Grumman – Baltimore, Maryland

Activity

- The Navy postponed gun firing and missile firing operational tests planned for June 2016 from the SDTS equipped with the SSDS MK 2 Mod 5 Combat System due to initial concerns about possible poor performance and the desire to conduct detailed predictive analysis before proceeding with testing.
- The Navy's detailed predictive analysis is scheduled for completion in October 2016. A total of four missile firing and two gun firing operational test scenarios from the SDTS are planned. One missile firing scenario from the SDTS is scheduled for December 2016. The remaining three missile firing and two gun firing operational test scenarios from the SDTS are scheduled for no earlier than FY19.
- The first SSDS MK 2 Mod 5-equipped LSD 41/49 ship deploys in late 2016. An additional two SSDS MK 2 Mod 5-equipped LSD 41/49 ships are planned to deploy in FY17 with at least one more planned to deploy in FY18.

Assessment

- The Navy's reluctance to proceed with any operational testing as scheduled in June 2016 over concerns of highlighting poor system performance is troubling because the ability of these deploying ships' to defend themselves in a conflict is unknown and the root causes of any performance problems and the potential for correcting those problems also remains unknown. The resulting delay now allows for conduct of only one of the six required missile/gun firing operational tests (December 2016) to support deployments of the first four LSD 41/49 ships equipped with the SSDS MK 2 Mod 5 Combat System. There is, therefore, a paucity of operational test results to support any assessment of the self-defense capabilities of the LSD 41/49 class ships equipped with the SSDS MK 2 Mod 5 Combat System and the Navy is deploying these ships with unknown self-defense capabilities. The assessment of the self-defense capabilities of the LSD 41/49 class ship equipped with the SSDS MK 2 Mod 5 Combat System cannot be completed until all planned operational tests are conducted. SDTS scheduling constraints will delay completion of the remaining five required missile/gun firing operational tests until FY19 at the earliest when most, if not all, LSD 41/49 ships equipped with the SSDS MK 2 Mod 5 Combat System will have been deployed.

Recommendations

- Status of Previous Recommendations. This is the first annual report for this program.
- FY16 Recommendation.
  1. The Navy should complete all planned operational tests of the LSD 41/49 ship class equipped with the SSDS MK 2 Mod 5 Combat System as soon as possible and prior to further ship deployments.

Ship-to-Shore Connector (SSC)

Executive Summary

- Ship-to-Shore Connector (SSC) delays have resulted in a delivery of the first craft, designated as the test and training craft, at the end of FY17. IOT&E is scheduled for mid-FY19, with Initial Operational Capability planned for FY20. LFT&E events to assess susceptibility of the craft to naval mines, controlled damage test to determine the ability to maintain mission capability following damage from a threat weapon, and seaworthiness testing to verify the modeling results from scale model testing conducted in FY13 are also delayed until FY18. The data and analysis necessary to inform a Full-Rate Production decision will not be available until the end of FY19. The Navy intends to go into full-rate production in FY19.
- In FY16, the Navy completed the data analysis of the live fire full-hull tests conducted in 2015 on the legacy Landing Craft Air Cushion (LCAC), the approved surrogate for this test. This full-scale test data informs the continuing refinement of the models needed to assess the vulnerability of the SSC and personnel to surf-zone mines, fragmenting artillery rounds, and land mines.
- An initial analysis of the live fire full-hull test data confirmed the need for follow-on component tests to aid in determining the survivability of the platform and crew. Additional live fire events are planned for FY17.

System

- The SSC is a fully amphibious air cushion vehicle intended to replace the existing LCACs.
- Compared to the existing LCAC, the Navy intends the SSC to have increased payload, reliability, and availability.
- The Navy intends to operate the SSC from the well decks of current and planned Navy amphibious ships and onboard the planned Mobile Landing Platform.
- The SSC has ballistic/fragmentation protection for manned crew and embarked troop spaces, various installed and portable damage control and firefighting systems intended to support recoverability from peacetime fire and flooding casualties
- The SSC is designed to carry a crew of 5 and up to 26 passengers with their combat equipment.

Mission

Commanders will employ amphibious forces equipped with the SSC to transport equipment, personnel, and weapons systems from ships through the surf zone and across the beach to landing points in support of amphibious operations worldwide.

Major Contractor

Textron Systems – New Orleans, Louisiana

Activity

- In FY16, the Navy completed the analysis of the full-hull test data collected using an operational LCAC (as a surrogate for the SSC) against a surf-zone mine emplaced under the skirt, an under-hull land mine, and a blast and fragmentation threat. The Navy is using the data to refine the kill criteria used for the SSC vulnerability modeling and simulations. The Navy is preparing a Vulnerability Assessment Report (VAR) with the revised kill criteria from the surrogate testing. This VAR was due in FY16, but the Navy has adjusted the delivery date to the end of CY16. Delays in completing this report and production delays may jeopardize the planning for the controlled damage test planned in FY17 and FY18.
- The 2015 full-hull test data review confirmed the need to conduct additional testing on the propulsion power plant components. The Navy is in the process of planning this test for execution in FY17.
- The 2015 full-hull test data review confirmed the need to evaluate the potential for personnel injury in some of the installed SSC seats for a loading condition similar to those experienced during the test. While the SSC energy-attenuating seats were not available for installation in the Command Module for the full-hull test, the Navy collected data using the LCAC seats to facilitate future analysis on the performance of

new seats when these become available. The Navy is in the process of planning this test for execution in FY17.
- Armor characterization testing, originally scheduled for early FY16, was delayed in order to allow for the procurement of armor that meets the SSC specifications. The testing began in late FY16 with a partial delivery of armor test coupons and is expected to be completed in FY17.

Assessment
- The SSC's ballistic/fragmentation protection for manned crew and embarked troop spaces, installed and portable damage control and firefighting systems provide limited capability for recoverability from battle damage incurred during combat.
- The preliminary analysis of the full-hull testing data collected in FY15 identified data that can be used to refine craft damage predictions and crew and troop casualty predictions. DOT&E will assess the validity of this approach to support the final determination of the survivability of the SSC and the crew in FY19.
- The SSC propulsion plant is different from the legacy LCAC, which was used in the full-hull tests. It shares the MV-22 power plant; however, the SSC shafts are larger and have different composite material composition. Based on the full-hull test data review, DOT&E concurs with the Navy's proposal to execute a test to further assess the response of the propulsion plant composite shafts to weapon effects because such data are not available from historical tests (conducted for helicopters and the MV-22). DOT&E will review the proposed test plan for adequacy in FY17.
- While the SSC has energy-absorbing seats for the pilot and co-pilot, these are designed to mitigate the loading condition to the body during normal operation of the craft. The full-hull test confirmed the need to assess the significance of loading conditions to the occupants of these seats following an under hull blast event. DOT&E will review the proposed test plan for adequacy in FY17.
- The Navy is conducting armor characterization testing in accordance with the DOT&E-approved test plan.

Recommendations
- Status of Previous Recommendations. The Navy has addressed some of the FY15 recommendations. It evaluated the results of the full-hull tests and determined that additional component tests were warranted. The Navy is currently planning two additional test series to include the propulsion plant composite shaft tests and energy-absorbing seat tests. However, it still needs to address the outstanding FY15 recommendation to evaluate the classified findings from the full-hull test to determine if the risk for personnel casualties can be reduced.
- FY16 Recommendation.
  1. The Navy should complete and deliver the VAR to DOT&E in FY17 to enable adequate planning of remaining live fire test series and determination of platform survivability.

SSN 774 *Virginia* Class Submarine

Executive Summary

- The Navy deployed the first *Virginia* class Block III submarine, USS *North Dakota* (SSN 784), in May 2015, with only limited developmental testing of the platform's major subsystem upgrades. Major testing phases included developmental testing of the new Large Aperture Bow (LAB) sonar array, testing of the system to support weapon system accuracy (this included sonar performance assessments), testing of the weapon system interfaces, and a limited operational assessment phase to support deployment certification.
- DOT&E submitted a classified Early Fielding Report in September 2015 detailing the results of the testing to date. DOT&E concluded that:
  - The *Virginia* class Block III submarine with the LAB array has the potential to perform as an adequate replacement for the spherical array used on previous *Virginia* class variants.
  - System reliability meets the Navy's thresholds.
  - The new LAB array and the Light Weight Wide Aperture Array (LWWAA) sonar processing systems suffer from some deficiencies. Although the Navy has implemented corrective action in each case, a full operational evaluation has not yet been conducted.
- The Navy commenced a cybersecurity assessment of the *Virginia* class Block III submarine in September 2016. The Navy intends to complete a comprehensive operational test of the *Virginia* class Block III submarine in FY17 that covers anti-submarine warfare, anti-surface ship warfare, strike warfare, and intelligence collection mission areas.

System

- The *Virginia* class submarine is the Navy's latest fast attack submarine and is capable of targeting, controlling, and launching MK 48 Advanced Capability torpedoes and Tomahawk cruise missiles.
- The Navy is procuring *Virginia*-class submarines incrementally in a series of blocks; the block strategy is for contracting purposes, not necessarily to support upgrading capabilities.
  - Block I (hulls 1-4) and Block II (hulls 5-10) ships were built to the initial design of the *Virginia* class.
  - Block III (hulls 11-18) and Block IV (hulls 19-28) ships include the following affordability enhancements starting with SSN 784, USS *North Dakota*:
    - A LAB array in place of the spherical array in the front of the ship.
    - Two *Virginia* payload tubes replace the 12 vertical launch tubes; each payload tube is capable of storing and launching six Tomahawk land attack missiles used in strike warfare missions.
  - Block V and beyond will increase strike payload capacity from 12 to 40 Tomahawk land attack missiles by adding a set of four additional payload tubes in an amidships payload module, capable of storing and launching seven Tomahawk missiles each, as well as providing the potential to host future weapons and unmanned systems.

Mission

The Operational Commander will employ the *Virginia* class Block III submarine to conduct open-ocean and littoral covert operations that support the following submarine mission areas:

- Strike warfare
- Anti-submarine warfare
- Intelligence, surveillance, and reconnaissance
- Mine warfare
- Anti-surface ship warfare
- Naval special warfare
- Battle group operations

Major Contractors

- General Dynamics Electric Boat – Groton, Connecticut
- Huntington Ingalls Industries, Newport News Shipbuilding – Newport News, Virginia

Activity

- The Navy completed the shock qualification testing for the *Virginia* Common Weapons Launcher and the *Virginia* Payload Tube hatch in late 2014, but has since redesigned a subcomponent of the hatch. Electric Boat has requested hatch shock qualification with a noted exception of the modified component and is investigating methods to resolve this exception. The Navy is evaluating, but has not yet approved, the request.
- In September 2015, DOT&E submitted a classified Early Fielding Report on the first *Virginia* class Block III submarine due to submarine deployment prior to the completion of operational testing.
- The Navy continued its analysis, but delayed validation of the Transient Shock Analysis modeling method used for the design of *Virginia* class Block III items until FY17.
- The Navy delayed the update of the *Virginia* class Vulnerability Assessment report that addresses Block III modifications until FY17.
- In September 2016, the Navy commenced a cybersecurity assessment of the *Virginia* class Block III submarine in accordance with a DOT&E-approved test plan. The assessment will complete in FY17.
- The Navy intends to complete a comprehensive operational test of the *Virginia* class Block III submarine in FY17 that covers anti-submarine warfare, anti-surface ship warfare, strike warfare, and covert intelligence collection mission areas.

Assessment

- The September 2015 DOT&E classified Early Fielding Report details the impact of the new major components of the system with respect to the intended mission during the early deployment. The report concluded the following:
  - The changes to the *Virginia* class Block III submarine do not appear to improve or degrade the system's ability to conduct submarine missions.
  - The LAB array demonstrates the potential to perform as an adequate replacement for the legacy spherical array.
  - Although the technical parameters are similar, the system presented a series of display artifacts, which could affect performance. The Navy issued software fixes to mitigate the effects; however, the software remains to be operationally tested.
  - The sonar LWWAA experienced a hardware fault which limited the ability to assess effectiveness of the system.
  - Developmental testing of the system indicates that system software reliability meets the Navy's thresholds. Hardware reliability was not able to be evaluated because of the limited time available to testers for the evaluation. The LAB array outboard signal processing equipment has exhibited some early failures. The Navy issued fleet guidance for monitoring system performance and continues to investigate potential causes.
- The cybersecurity assessment of the *Virginia* class Block III submarine remains ongoing and will be reported in FY17.

Recommendations

- Status of Previous Recommendations. The following are recommendations that remain from FY15. The Navy should:
  1. Test against a diesel submarine threat surrogate in order to evaluate *Virginia's* capability, detectability, and survivability against modern diesel-electric submarines.
  2. Conduct an FOT&E to examine *Virginia's* susceptibility to airborne anti-submarine warfare threats such as Maritime Patrol Aircraft and helicopters.
  3. Coordinate the *Virginia*, Acoustic Rapid Commercial Off-the-Shelf Insertion (A-RCI), and AN/BYG-1 Test and Evaluation Master Plans to facilitate testing efficiencies.
  4. Complete the verification, validation, and accreditation of the Transient Shock Analysis method used for *Virginia* class Block III items.
  5. Repeat the FOT&E event to determine *Virginia's* susceptibility to low-frequency active sonar and the submarine's ability to conduct anti-surface ship warfare in a low-frequency active environment. This testing should include a *Los Angeles* class submarine operating in the same environment to enable comparison with the *Virginia* class submarine.
  6. Investigate and implement methods to aid the Special Operation Forces in identifying the submarine during operations in conditions of low visibility.
  7. Address the three classified recommendations listed in the September 2015 Block III *Virginia* class Early Fielding Report.
- FY16 Recommendations. None.

Standard Missile-6 (SM-6)

Executive Summary

- The performance deficiency discovered during IOT&E and outlined in the May 2013 classified Standard Missile-6 (SM-6) IOT&E report remains unresolved and continues to affect DOT&E's final assessment of effectiveness.
  - The Navy is assessing several options for a solution, each with varying degrees of complexity. A primary concern is to ensure the solution causes no degradation to the existing SM-6 performance envelope.
  - The Navy plans to incorporate these changes in Block I (BLK I) and Block IA (BLK IA) production variants and conduct operational testing in FY17.
- In FY16, the Navy completed FOT&E live fire testing. These tests provided validation data for the modeling and simulation runs for the record phase of the FOT&E. The Navy intends to conduct the modeling and simulation tests in FY17, which will complete the SM-6 BLK I FOT&E.
- In FY16, the Navy successfully demonstrated the maximum range Key Performance Parameter (KPP) and the launch availability Key System Attribute during SM-6 BLK I FOT&E and Aegis Baseline 9 operational testing.
- The Navy commenced developmental testing of pre-planned product improvements to the SM-6 BLK I missile in FY14; these improvements are the SM-6 BLK IA configuration. The Navy conducted a successful developmental test of the SM-6 BLK IA Guidance Test Vehicle (GTV) mission (GTV-3) in FY16. The Navy plans to conduct operational testing of the SM-6 BLK IA in FY17.
- The Navy conducted six SM-6 BLK I missile tests during FY16. Of the planned launches, four successfully supported FOT&E with Aegis Baseline 9; one test successfully supported Navy Integrated Fire Control – Collateral (NIFC-CC) Demonstration; one Agile Prism developmental test launch was unsuccessful.
- The uplink/downlink antenna shroud reliability problem discovered in IOT&E has been resolved; 34 production missiles with the new design have been fired without failure.
- NIFC – Counter Air (CA) From-the-Sea (FTS) Increment I became a fielded capability in 2015 and fully integrated as a tactical option in fleet air defense. Future testing of the Advanced Capability Build (ACB) 16 and ACB 20 Aegis Modernizations and SM-6 will evaluate the NIFC-CA FTS Increment II capability.

System

- SM-6 is the latest evolution of the Standard Missile family of fleet air defense missiles.
- The Navy employs the SM-6 from cruisers and destroyers equipped with the Aegis combat systems.
- The SM-6 seeker and terminal guidance electronics derive from technology developed in the Advanced Medium-Range Air-to-Air Missile program.
- SM-6 retains the legacy Standard Missile semi-active radar homing capability.
- SM-6 receives midcourse flight control from the Aegis Combat System (ACS) via ship's radar; terminal flight control is autonomous via the missile's active seeker or supported by the ACS via the ship's illuminator.
- The Navy is upgrading SM-6 to the BLK I configuration to address hardware and software improvements and to address advanced threats.
- SM-6 Dual I capability is being added to provide Sea-Based Terminal capability against short-range ballistic missiles.
- The Navy is upgrading the SM-6 to add an anti-surface target capability.

Mission

- The Joint Force Commander/Strike Group Commander will employ naval units equipped with the SM-6 for air defense against fixed-/rotary-winged targets and anti-ship missiles operating at altitudes ranging from very high to sea skimming.
- The Joint Force Commander will use SM-6 as part of the NIFC-CA FTS operational concept to provide extended range over-the-horizon capability against at-sea and overland threats.
- The Joint Force Commander will use SM-6 as part of the NIFC-CC operational concept to provide extended range capability against surface targets.

Major Contractor

Raytheon Missile Systems – Tucson, Arizona

Activity

- The Navy conducted six SM-6 BLK I missile tests during FY16. Of the planned launches, four successfully supported FOT&E with Aegis Baseline 9, one successfully supported the NIFC-CA Tactical Demonstration, but one supporting the Aegis Agile Prism demonstration was unsuccessful.

SM-6 BLK I FOT&E

- In January 2016, at the Pacific Missile Range Facility, Kauai, Hawaii:
  - An SM-6 BLK I FOT&E mission (D1A) successfully engaged a maximum downrange target.
  - An SM-6 BLK I FOT&E mission (D1B) successfully engaged a maximum cross-range target.
  - An SM-6 BLK I FOT&E mission (D1D) successfully engaged two SM-6s against two subsonic targets. An Aegis Weapon Control System integration problem appeared that did not affect the mission.
  - An SM-6 BLK I FOT&E mission (D1Ga) successfully engaged a target that was using electronic attack against the SM-6.
- The Navy conducted the FOT&E in accordance with the DOT&E-approved test plan.

Navy Integrated Fire Control – Collateral (NIFC-CC) Demonstration

- In January 2016, at the Pacific Missile Range Facility, the Navy successfully conducted the SM-6 NIFC-CC Demonstration mission.

Navy Integrated Fire Control – Counter Air From the Sea Increment I (NIFC-CA FTS Increment I)

- In September 2016, at White Sands Missile Range, New Mexico, the Navy and Marine Corps successfully conducted a NIFC-CA FTS Increment I demonstration event using an F-35 Lightning II as a targeting source for the Aegis BL9 Desert Ship test configuration and the SM-6. This demonstration was developmental testing and did not represent a fleet operational configuration of the ACS or all the required communications links. The demonstration used a non-tactical engineering computer software build in the Aegis Desert Ship test site, itself not fully representative of the ACS, interfaced to a datalink gateway that could receive the F-35 Multifunction Advanced Data Link (MADL) and port track data from the aircraft sensor to the AWS. Using this track data, an SM-6 was initialized and launched at an MQM-107 unmanned target drone.
- In September 2016, at the Pacific Missile Test Center, California, the Navy conducted an at-sea flight demonstration of the NIFC-CA FTS Increment I.

AGILE PRISM

- In March 2016, at the Pacific Missile Range Facility, an SM-6 BLK 1 missile did not successfully engage either of the two threat targets at low altitude during a developmental test event.

SM-6 BLK IA

- The Navy commenced developmental testing of pre-planned product improvements to the SM-6 BLK I missile in FY14; these improvements are the SM-6 BLK IA configuration. The Navy conducted a successful developmental test of the SM-6 BLK IA Guidance Test Vehicle (GTV) mission (GTV-3) in FY16. The Navy plans to conduct operational testing of the SM-6 BLK IA in FY17.

Assessment

- In FY16, the Navy completed FOT&E live fire testing. These tests provided validation data for the modeling and simulation runs for the record phase of the FOT&E. The Navy will conduct this phase of test during FY17, which will complete the SM-6 BLK I FOT&E.
- During FY16 flight tests, there were no occurrences of the uplink/downlink antenna shroud reliability deficiency. DOT&E considers the uplink/downlink antenna shroud reliability deficiency to be resolved. To date, the Navy has fired 34 SM-6s with full production antennas with no observations of anomalies. At the 80 percent confidence level, the reliability of the antennas is at least 95.4 percent.
- The March 2015 SM-6 BLK I mission D1G misfire remains under investigation by the Navy with no root cause determination to date.
- In the May 2013 SM-6 IOT&E report, DOT&E assessed SM-6 BLK I as suitable. This assessment considered combined data from the IOT&E and developmental/operational flight tests. During FY16 testing, DOT&E collected additional reliability data and assessed that the SM-6 BLK I continues to remain suitable. DOT&E will continue to collect suitability and effectiveness data throughout SM-6 BLK IA FOT&E testing in FY17, as well as during all SM-6 flight testing in support of NIFC-CA FTS, Missile Defense Agency, and Aegis software baseline development.
- The performance deficiency discovered during IOT&E and outlined in the classified IOT&E report remains unresolved and continues to affect DOT&E's final assessment of effectiveness. The Navy is assessing several options for a solution, each with varying degrees of complexity. A primary concern is to ensure the solution causes no degradation to the existing SM-6 performance envelope. The corrective actions will be incorporated into production of the SM-6 BLK I and BLK IA configurations and tested during FOT&E in FY17.
- In FY16, the Navy successfully demonstrated the maximum range KPP during SM-6 FOT&E and the maximum cross-range Key System Attribute.
- DOT&E assesses the launch availability KPP to be resolved. The Navy stored seven missiles aboard an operational ship for at least 8 months prior to firing during FOT&E with no launch availability problems noted. This yields a launch availability of 1.0 with an 80 percent confidence lower bound of 0.81, against a requirement of 0.98.
- Upon completion of the SM-6 FOT&E in FY17, the Navy will have conducted sufficient testing to allow an assessment of the SM-6 Capability Production Document performance requirement for interoperability.
- The failure during the Aegis Agile Prism test remains under investigation by the Navy.

- The Navy's NIFC-CA FTS Increment I test events conducted to date were sufficient to demonstrate basic capability; however, these demonstrations were not conducted under operationally realistic conditions or against aerial targets representative of modern threats. Additionally, the scenarios conducted were not sufficiently challenging to demonstrate the NIFC-CA FTS requirements defined in the Navy's September 2012 NIFC-CA FTS Testing Capability Definition Letter. Nevertheless, since NIFC-CA FTS Increment I has been fully integrated as a tactical option in fleet air defense, DOT&E removed the NIFC-CA FTS, as a distinct program, from test and evaluation oversight. DOT&E will assess and report NIFC-CA FTS (Increment II) performance as part of the FY18-23 ACB 16 and ACB 20 Aegis Modernization operational testing and SM-6 FOT&E.
- In September 2016, at White Sands Missile Range, the Navy and Marine Corps successfully conducted a NIFC-CA FTS Increment I demonstration event using an F-35 Lightning II as a targeting source to allow the ACS (partial) installed at the Desert Ship test facility to engage an aerial target with the SM-6. The configuration of the F-35 and the Desert Ship was not operationally representative and not all the required communications links were present. This demonstration was part of developmental testing and did not represent a fleet operational configuration of the ACS. The demonstration used a non-tactical engineering computer software build in the Aegis Desert Ship test site – itself not fully representative of the ACS – interfaced to a datalink gateway that could receive the F-35 MADL and port track data from the aircraft sensor to the AWS. Using these track data, an SM-6 successfully engaged an MQM-107 unmanned target drone. This demonstration was conducted as a proof of concept to show that the NIFC-CA FTS Increment I capability could utilize additional airborne sensors to provide fire control quality data to the AWS. In the context of the event, this objective was met; however, this demonstration should not be construed as an operational capability.
- In September 2016, at the Pacific Missile Test Center, the Navy successfully conducted an at-sea flight demonstration of the NIFC-CA FTS Increment I. This test resulted in the longest-range SM-6 interception to-date.

Recommendations

- Status of Previous Recommendations. The Navy is addressing the previous recommendations from FY14 to complete corrective actions of the classified performance deficiency discovered during IOT&E and develop a flight test program to test those corrective actions. The Navy plans to conduct verification flight tests in FY17. The Navy has not addressed the FY15 recommendation; however, this recommendation is rescinded as NIFC-CA FTS Increment I has been fully integrated as a tactical option in fleet air defense, DOT&E removed the NIFC-CA FTS, as a distinct program, from test and evaluation oversight and will be tested as a normal tactic in future Aegis/SM-6 testing.
- FY16 Recommendations. None.

Surface Electronic Warfare Improvement Program (SEWIP) Block 2

Executive Summary

- The Navy's Commander, Operational Test and Evaluation Force (COTF) conducted IOT&E in March and June 2016, on USS *Bainbridge* (DDG 96) in the Virginia Capes operating area in accordance with a DOT&E-approved test plan.
- DOT&E submitted a classified IOT&E report in September 2016 to Congress on the results of the IOT&E for the AN/SLQ-32 Electronic Warfare System (EWS) equipped with the Surface Electronic Warfare Improvement Program (SEWIP) Block 2 upgrade. The analysis showed that the SEWIP Block 2 upgrade was operationally effective but not operationally suitable or survivable.

System

- SEWIP is an incremental development program that is intended to improve the electronic warfare capability on all Navy surface combatants.
- The SEWIP Block 2 upgrade incorporates a new antenna system and enhanced processing capabilities into the AN/SLQ-32 EWS, which are intended to improve the AN/SLQ-32's passive electronic support capabilities.

Mission

Commanders employ Navy surface ships equipped with SEWIP Block 2 to enhance the AN/SLQ-32 EWS anti-ship missile defense, counter-targeting, and counter surveillance capabilities and to improve the system's ability to collect electronic data.

Major Contractor

SEWIP Block 2: Lockheed Martin – Syracuse, New York

Activity

- COTF conducted the IOT&E in March and June 2016, on USS *Bainbridge* (DDG 96) in the Virginia Capes operating area.
- DOT&E submitted a classified IOT&E report in September 2016 to Congress on the results of the IOT&E for the AN/SLQ-32 EWS equipped with the SEWIP Block 2 upgrade.

Assessment

- Analysis of the IOT&E data showed the SEWIP Block 2 to be operationally effective.
- Analysis of the IOT&E data showed the SEWIP Block 2 to be not operationally suitable due to:
  - Poor software reliability.
  - Insufficient data were collected during the IOT&E to fully assess the SEWIP Block 2 hardware reliability.
  - Fleet operators were not being adequately trained to operate and maintain the system.
  - Although the Mean Time to Reboot met the requirement of 18 minutes, it took 8 minutes on average, which is a significant amount of time if a reboot occurs during an anti-ship cruise missile attack.
- Analysis of the IOT&E data showed that the SEWIP Block 2 to be not survivable due to cybersecurity deficiencies.

Recommendations

- Status of Previous Recommendations. The Navy has not resolved the following SEWIP FY06 and FY08 previous recommendations to:
  1. Continue to review and modify the SEWIP software to improve its reliability.
  2. Develop threat representative aerial target/threat seeker combinations and/or procure actual threat anti-ship cruise missiles for more realistic operational testing of future SEWIP block upgrades and other EWSs.
- FY16 Recommendations. The Navy should:

1. Review and modify the SEWIP Block 2 software to improve its reliability and test the modifications in a phase of FOT&E.
2. Improve the SEWIP Block 2 training so fleet operators can effectively operate and maintain the system.
3. Improve the SEWIP Block 2 Mean Time to Reboot times and test those improvements in a phase of FOT&E.
4. Gather hardware reliability data from fleet units equipped with SEWIP Block 2 to enable a full assessment of hardware reliability.
5. Take action on the recommendations contained in the classified September 2016 DOT&E IOT&E report.
6. Correct the cybersecurity deficiencies and test those corrections in an FOT&E phase.

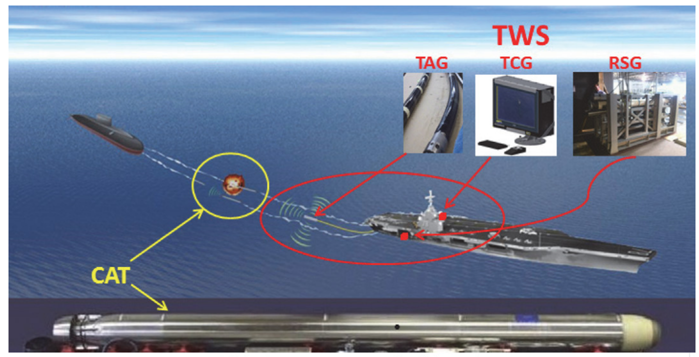
Surface Ship Torpedo Defense (SSTD) System: Torpedo Warning System (TWS) and Countermeasure Anti-Torpedo (CAT)

Executive Summary

- USS *Dwight D. Eisenhower* commenced deployment in 3QFY16 with a temporary roll-on/roll-off version of the Torpedo Warning System (TWS) and Countermeasure Anti-Torpedo (CAT) referred to as the Anti-Torpedo Torpedo (ATT) Defense System (ATTDS). Like previous carrier deployments, the *Dwight D. Eisenhower* deployed with a passive only TWS array.
- USS *Theodore Roosevelt* returned from deployment in 1QFY16 and USS *Harry S. Truman* returned from deployment later in 3QFY16. During these deployments, the crews rarely deployed the TWS arrays; thus, little data were collected to determine the TWS arrays' reliability or to assist the developer with improving its detection, tracking, alerting, and false alert rejection software.
- A combined TWS and CAT contractor test in July 2016 demonstrated the Navy's contractors are making progress toward developing an initial defensive capability to counter a salvo of threat torpedoes and improving the active source reliability. The test demonstrated that the TWS active and passive system, with a highly qualified sensor operator, is capable of detecting, tracking, and alerting on threat torpedoes; that operators can initiate a salvo of CATs to intercept the threat torpedoes; and that a salvo of CATs can intercept a salvo of threat torpedoes.

System

- Surface Ship Torpedo Defense is a system of systems that includes two new sub-programs: the TWS (an Acquisition Category III program) and CAT (will not become an acquisition program until FY17). Combined, TWS and CAT are referred to as the ATTDS.
- TWS is being built as an early warning system to detect, localize, classify, and alert on incoming threat torpedoes and consists of three major subsystems:
  - The Target Acquisition Group consists of a towed acoustic array, tow cable, winch, power supply, and signal processing equipment. Data from the array and the ship's radar system are processed into contact tracks and alerts to be forwarded to the Tactical Control Group. The Navy intends the array to be capable of both passive and active sonar operations.
  - The Tactical Control Group consists of duplicate consoles on the bridge and Combat Direction Center (on CVNs) that displays contacts, issues torpedo alerts to the crew, and automatically develops CAT placement presets using information sent from the Target Acquisition Group.



CAT - Countermeasure Anti-Torpedo
RSG - Ready Stow Group
TAG - Target Acquisition Group
TCG - Tactical Control Group
TWS - Torpedo Warning System

  The operator uses these displays to manage the threat engagement sequence and command CAT launches.
  - The Ready Stow Group will consist of the steel cradles housing the CATs. The permanent system consists of four steel cradles and associated electronics, each housing six ATTs at different locations (port/starboard and fore and aft on the CVN).
- CAT is a hard-kill countermeasure intended to neutralize threat torpedoes and consists of the following:
  - The ATT is a 6.75-inch diameter interceptor designed for high-speed and maneuverability to support rapid engagement of the threat torpedo.
  - The All-Up Round Equipment consists of a nose sabot, ram plate, launch tube, muzzle cover, breech mechanism, and energetics to encapsulate and launch the ATT.
  - The tactical CAT is powered by a Stored Energy Propulsion System (SCEPS). The battery-powered electric motor CAT is for test purposes only. Engineering Development Model (EDM)-2 is the current hardware version of the CAT.
- The Navy developed a temporary version of TWS and CAT (designated a roll-on/roll-off system) in addition to the permanent-installation version. The Navy intends for this version to provide the same functionality as the permanent one.
  - The Ready Stow Group steel cradles are replaced by two lighter-weight and less-robust aluminum Launch Frame Assemblies that each hold four CATs.
  - The processing required for the Target Acquisition Group and the Tactical Control Group resides in two cabinets

contained in a container express box located on the carrier's hangar deck.

- The towed acoustic array, tow cable, and winch are permanently installed on the carrier's fantail. The other components of the system, including the operator displays and fire enable switch, reside in the container express box located on the hangar deck.

Mission

Commanders of nuclear-powered aircraft carriers and Combat Logistic Force ships will use the Surface Ship Torpedo Defense system to defend against incoming threat torpedoes.

Major Contractors

TWS

- Ultra Electronics-3Phoenix – (Prime Contractor) – Chantilly, Virginia, and Wake Forest, North Carolina
- Alion Science and Technology – (Acoustics and testing consultant) – New London, Connecticut
- In-Depth Engineering – (Tactical Control Group software development) – Fairfax, Virginia
- Pacific Engineering Inc. (PEI) – (Ready Stow Group manufacture) – Lincoln, Nebraska
- Rolls-Royce – (Winch manufacture) – Ontario, Canada
- Teledyne – (Towed Array manufacture and assembly) – Houston, Texas

CAT

- Pennsylvania State University Applied Research Laboratory – (ATT Systems) – State College, Pennsylvania
- Pacific Engineering Inc. (PEI) – (Canister fabrication) – Lincoln, Nebraska
- SeaCorp – (All Up Round Equipment fabrication and assembly) – Middletown, Rhode Island

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Activity

- In August 2015, the Naval Surface Warfare Center, Indian Head Explosives Ordnance Disposal Technology Division, conducted ATT warhead and safety and arming device airburst testing at Fort A.P. Hill, Virginia. This testing verified the arming, fuzing, and firing of the ATT warhead.
- During FY16, the Navy and DOT&E continued development of an enterprise Test and Evaluation Master Plan (TEMP) for the TWS and CAT systems. The Navy made their TWS Milestone B decision without a TEMP; they are not planning to make the CAT system an acquisition program until later in FY17.
- USS *Theodore Roosevelt* returned from deployment in 1QFY16. The *Theodore Roosevelt* deployed with a temporary roll-on/roll-off version of the TWS and CAT. During the deployment, the crew rarely deployed the TWS array.
- In February/March 2016, the Navy and Pennsylvania State University Applied Research Laboratory conducted contractor testing of CAT on the Dabob Bay, Washington, acoustic tracking range. The testing consisted of three highly scripted scenarios to obtain data and evaluate the salvo capability of the CATs. During this test, both the threat torpedo target surrogates and the ATTs were fired from a single test platform (torpedo retriever). The target surrogates ran a scripted geometry and the ATTs ran tactical profiles to intercept the threat surrogates.
- USS *Dwight D. Eisenhower* commenced deployment in 3QFY16 with a temporary roll-on/roll-off version of TWS and CAT that includes the TWS Target Acquisition Group and the Tactical Control Group hardware and two of the four planned CAT Ready Stow Group cradles containing eight CAT EDM-2s powered by SCEPS. Like previous carrier deployments, the Towed Active Acoustic Source (TAAS) was not ready and the *Dwight D. Eisenhower* deployed with a passive-only TWS array. Ultra-Electronics-3Phoenix contractor personnel deployed aboard the *Dwight D. Eisenhower* to operate and maintain the TWS system, train Navy operators, and to collect system data. The Navy Program Office intends *Dwight D. Eisenhower* to be the last carrier to receive the temporary installation and is planning the installation of the permanent version of the TWS and CAT early fielded hardware on selected CVNs before their next deployments.
- USS *Harry S. Truman* returned from deployment later in 3QFY16. The *Harry S. Truman* has a permanent installation of TWS and CAT that includes the TWS Target Acquisition Group and the Tactical Control Group hardware and two of the four planned CAT Ready Stow Group steel cradles. During the deployment, the *Harry S. Truman*'s crew rarely deployed the TWS array.
- In July 2016, the Navy, in conjunction with the TWS and CAT system contractors, conducted contractor testing of both the TWS and CAT on the Nanoose Bay, British Columbia, Canada, acoustic tracking range. The Navy installed a roll-on/roll-off version of the TWS and CAT system aboard the USNS *Brittin*, which served as a deep draft test platform. The TWS array consisted of the passive array (similar to the array deployed on carriers) and the latest version of the active source (TAAS). The testing included structured scenarios requiring a TWS system and operator to detect/alert on threat torpedoes, initiate a CAT salvo engagement, and for the CATs to intercept the threat torpedoes. Test scenarios also assessed TWS alert and false alert rates; TWS and CAT interoperability; TAAS and passive array reliability; and TWS array speed, turn rate, depth, and stability tow profiles. The Navy recorded the TWS and CAT data during all events for later analysis and reprocessing in future versions of the system.

Assessment

- The combined TWS and CAT contractor testing in July 2016 demonstrated the Navy's contractors are making progress toward developing an initial defensive capability to counter a salvo of threat torpedoes.
  - The testing demonstrated the TWS active and passive system, with a highly qualified sensor operator, is capable of detecting, tracking, and alerting on threat torpedoes, that operators can initiate a salvo of CATs to intercept the threat torpedoes, and that a salvo of CATs can intercept a salvo of threat torpedoes.
  - However, to achieve the test objectives, the contractor test scenarios were highly structured, were not conducted with realistic threat torpedo profiles, and were not conducted in conjunction with events that could have provided potential false alerts.
  - Safety considerations, implemented to prevent a collision between the threat torpedo surrogates, the CATs, and the deep draft tow ship, also prevented assessing the TWS detection capability for threats that operate near the surface. The same limitations prevent assessing the CAT's ability to detect, track, and intercept threat torpedoes in this challenging region of the water column.
  - Testing and data collection near the surface is necessary for developing the torpedo defense capability and this testing could be accomplished safely in a controlled manner without a deep draft tow ship.
- The July 2016 contractor testing demonstrated the Navy's TWS array contractors are making progress towards implementing solutions for the passive array twisting problem and with fixing the TAAS reliability failure modes. The July test event completed with no TWS or CAT hardware failures. This included 64 hours of TAAS active operations, 14 array deployments and retrievals, and 11 CAT or Electric-drive CAT (ECAT) launches.
- Completed testing also demonstrated the importance of having a trained TWS operator to initiate manual threat alerts when the automated detects and alerts are not initiated or occur late for assessing if threat alerts are valid or false.
- The testing of TWS (passive) and CAT EDM-2, powered by SCEPS, fielded aboard *George H. W. Bush*, *Theodore Roosevelt*, *Harry S Truman*, and *Dwight D. Eisenhower* has yet to demonstrate an effective capability against realistic threat torpedo attack scenarios.
  - The Navy's testing of the fielded TWS system has shown it is capable of detecting and targeting a threat torpedo and CAT demonstrated the limited capability to detect and home on certain types of torpedo threats. However, this capability assessment is based on limited testing conducted in areas with generally benign acoustic conditions when compared to the expected threat operating areas, which may bias the results high.
  - Very few of the threat surrogates used during testing were operated in operationally realistic threat torpedo profiles due to Navy-imposed safety constraints. Additionally, the acoustic properties of the current surrogate torpedoes are suspected to be louder than most threats in certain operating circumstances.
- The program's focus on preparing systems to deploy on carriers has hampered their development of more extensive system detection; tracking and alerting software; operator tactics, techniques, and procedures; and assessments of system availability and reliability because of their limited budget. Although the Pennsylvania State University Applied Research Laboratory was able to conduct independent structured CAT testing, 3Phoenix's TWS testing is limited because the prototype TWS arrays are rapidly fielded to the deploying CVN, leaving the 3Phoenix contractors without a full system to continue development. The Navy hoped to obtain data from the deployed CVNs to support TWS development, but their operations did not permit that. The July 2016 testing, which utilized portions of the systems removed from carriers following their deployments, provided a significant amount of recorded data (subject to the limitations discussed above) to support continued contractor development of the TWS and CAT systems.
- The Navy delayed the Initial Operational Capability of the TWS and CAT from 2018 to 2022. Because the Navy required the Program Office to deliver an early capability for the early fielded TWS and CAT, it has resulted in a 3- to 4-year delay in delivering the Capability Development Document-required torpedo defense capability to the CVNs.
- The Navy's decision to add a highly-trained contractor as the acoustic operator to supplement the automated detection and alerting functions of TWS has improved threat detection performance during all completed test events. DOT&E assesses the majority of the TWS's detection and alerting capability is a result of the contractor acoustic operators monitoring the TWS displays to provide early alerts on threat torpedoes. However, the test areas did not offer the same number of opportunities for false alerts as expected in the threat area; thus, it is not known if the presence of the operator could also reduce the false alarm rate. For safety reasons, testing was highly structured, which allowed the operators to focus on torpedo detections and firing the CAT. Therefore, completed testing was inadequate to resolve the rate of false alarms or their effect on mission accomplishment.
- Additional information concerning the testing of the fielded TWS and CAT performance is included in DOT&E's March 2015 classified Early Fielding Report.

Recommendations

- Status of Previous Recommendations. The Navy has made some progress on previous recommendations. However, the Navy should still:
  1. Complete the TEMP for the TWS and CAT system and an LFT&E strategy for the ATT lethality as soon as possible.
  2. Conduct additional testing in challenging, threat representative environments.
  3. Conduct additional CAT testing using operationally realistic threat target profiles closer to the surface to assess

the CAT's terminal homing, attack, and fuzing within the lethality range of the warhead.

4. Investigate test methods designed to reduce or eliminate the safety limitations that have previously prevented testing against operationally realistic target scenarios. The Navy should consider using geographic separation, range boundaries, and shallow draft ships for future TWS and CAT testing.
5. Continue to investigate, correct, and retest deficiencies identified with the active source before planning to field TAAS.
6. Adequately resource the TWS program to build dedicated test assets and conduct adequate dedicated contractor and developmental testing.
7. Adequately resource the Program Office and its contractors to conduct TWS and CAT system development and testing.
8. Investigate and implement the outstanding recommendations in the classified March 2015 DOT&E Early Fielding Report.

- FY16 Recommendation.
  1. The Navy should measure the signatures of available surrogates at representative threat torpedo depths and speeds. The Navy should also determine the adequacy of available torpedo surrogates to represent threat torpedoes.

Tactical Tomahawk Missile and Weapon System

Executive Summary

- The FOT&E Operational Test Launch program concluded in 2013. That phase of operational testing ran from 2004 to 2013. Upon completion of the Operational Test Launch program, DOT&E removed the Tomahawk Weapon System (TWS) from operational testing oversight. This decision was based upon TWS' history of consistent satisfactory performance over the past 9 years in test planning, test execution, and meeting reliability and performance requirements.
- Flight testing to evaluate All-Up Round changes, emerging deficiencies requiring immediate correction, and hardware obsolescence continued under a program monitored by the Navy's Commander, Operational Test and Evaluation Force.
- In 2016, Tactical Tomahawk Weapon Control System (TTWCS) operational test event OT-D-8 included cybersecurity events, a reliability/maintainability maintenance demonstration, non-firing strike group scenario, and modeling and simulation flight test events. OT-D-8 is planned to conclude in FY17 with a live fire flight test. As the program was not under T&E oversight, DOT&E did not oversee these test events or approve the test plan.
- In 2016, the Navy started development of an acquisition strategy for a series of incremental upgrades that modify the Block IV Tactical Tomahawk (TACTOM) into a Maritime Strike Tomahawk (MST) to develop an anti-ship capability. Consistent with mission changes brought about by plans to develop an anti-ship capability, the TWS was placed back on DOT&E oversight. The Navy intends to field MST as a Rapid Deployment Capability (RDC) with a Quick Reaction Assessment (QRA) test strategy. DOT&E assessed that the QRA would not support an adequate operational test but the Navy continues to not plan for any additional operational testing.
- To collect sufficient data for an adequate assessment of the capability, DOT&E identified the need for 36 test flights (based on the existing validated requirements for the Offensive Anti-Surface Warfare (OASuW) program since there were no identified requirements for MST), which could be accommodated by a combination of developmental and operational tests. This test scope could be reduced if the program undertakes an effort to develop a tactical software-in-the-loop modeling and simulation test bed similar to the current Tomahawk modeling and simulation test bed for the land attack mission area.
- The Navy has yet to provide any plans required to assess the functionality and lethality of the warhead against the new MST target set.

System

- The Tomahawk Land Attack Missile is a long-range, land attack cruise missile designed for launch from submarines and surface ships. Beginning in 2017, the Navy plans to develop the MST anti-ship capability as part of the Block IV modernization program.
- There are three fielded variants: a Block III with a conventional unitary warhead, a Block III with a conventional submunitions warhead, and a Block IV with a conventional unitary warhead. Production of Tomahawk Block II and III missiles is complete. Block IV Tomahawk is in production as the follow-on to the Block III conventional unitary warhead variant. These missiles are produced at lower cost and provide added capability, including the ability to communicate and be redirected to an alternate target during flight.
- The Tomahawk Weapon System (TWS) also includes the Tomahawk Theater Mission Planning Center (TMPC) and the shipboard TTWCS. The TMPC and TTWCS provide for command and control, targeting, mission planning, distribution of Tomahawk tactical and strike data, and post-launch control of Block IV missiles.

Mission

The Joint Force Commander employs naval units equipped with the TWS for long-range, precision strikes against land targets. Planned upgrades will allow the Joint Force Command to employ the TWS in anti-ship missions.

Major Contractors

- Missile element: Raytheon Missile Systems – Tucson, Arizona

- Weapon Control System element: Lockheed Martin – Valley Forge, Pennsylvania
- Mission Planning Element:
  - Vencore, Inc. – San Jose, California (Mission Distribution System)
  - Tapestry Solutions – St. Louis, Missouri (Tomahawk Planning System)
  - BAE Systems – San Diego, California (Targeting Navigation Toolset)

Activity

- In 2013, DOT&E removed the TWS from operational testing oversight. This decision was based upon TWS's history of consistent satisfactory performance over the past 9 years in test planning, test execution, and in meeting reliability and performance requirements. Flight testing to evaluate All-Up Round changes, emerging deficiencies requiring immediate correction, and hardware obsolescence continued under a program monitored by the Navy's Commander, Operational Test and Evaluation Force.
- In 2016, based on direction by the Deputy Secretary of Defense, the Navy started development of an acquisition strategy for a series of incremental upgrades that modify the Block IV TACTOM into an MST. The Navy plans to insert this capability in a subset of the TACTOM population (Block IV) as these missiles are inducted into the recertification line.
- In 2016, operational test event OT-D-8, that commenced while the program was not under DOT&E oversight, continued. Testing included cybersecurity events, a reliability/maintainability maintenance demonstration, non-firing strike group scenarios, and modeling and simulation flight test events. OT-D-8 is planned to conclude in FY17 with a live fire flight test. As the program was not under T&E oversight, DOT&E did not oversee these test events or approve the test plan.

Assessment

- The Navy plans to insert the MST capability into the Block IV TACTOM missiles as they go through their modernization process (potentially up to 4,000 rounds), which is a de-facto full fielding of the new mission enhancement. Currently, the Navy does not intend to develop an MST Capability Development Document/Capability Production Document or any other type of requirements document to guide the developmental or operational test planning. Rather, the Navy will issue a "Capability Memorandum." The form and utility of this document for acquisition and test planning purposes remains undetermined.
- The Navy intends to field MST as an RDC supported by a QRA test. Despite being advised by DOT&E that the QRA would not be an adequate operational and live fire test, the Navy continues to not plan for any additional operational and live fire tests. Traditionally, RDCs conduct QRAs in order to support a decision to expeditiously field an initial capability but then plan a full operational test program to support their full-fielding decision. Plans to conduct operational or live fire testing to support the capability deployment are unclear because there are no scheduled Milestones for the TACTOM program.
- DOT&E provided the Navy with an initial operational test design based on the existing validated requirements for the OASuW program as there were no identified requirements for MST. While the OASuW material solution is different (Long Range Anti-Ship Missile (AGM-158C LRASM)), the basic mission was assumed to be similar enough to develop a test design. To collect sufficient data for an adequate assessment of the capability, the test design identified the need for 36 test flights between developmental and operational testing. This number could be reduced if the program undertakes an effort to develop a tactical software-in-the-loop modeling and simulation test bed similar to the current Tomahawk modeling and simulation test bed for the land attack mission area. Because of the very different environments and target characteristics, the current modeling and simulation test bed, optimized for the land attack mission, is not adequate for the maritime strike mission.
- The Navy has yet to provide any plans needed to rigorously assess the functionality and lethality of the warhead against the new MST target set.

Recommendations

- Status of Previous Recommendations. The Navy has addressed all previous recommendations.
- FY16 Recommendations. The Navy should:
  1. Develop and validate operational requirements for the MST mission.
  2. Plan to conduct, and budget appropriately for, full operational and live fire testing of the MST capability. This should include development of a tactical software-in-the-loop modeling and simulation test bed, and functionality and lethality testing of the warhead for the new target set.

VH-92A Presidential Helicopter Replacement Program

Executive Summary

- The VH-92A program is progressing on or ahead of schedule.
- The VH-92A system-level Critical Design Review was held July 18 – 21, 2016, and resulted in minimal action items, which are all progressing to closure.
- Modifications to two Sikorsky S-92A aircraft to produce two VH-92A aircraft continue on schedule with modification completion projected in FY17. This effort includes the Lockheed Martin integration of the Mission Communications System (MCS) designed by Naval Air Systems Command (NAVAIR) at St. Inigoes, Maryland.
- Contractor flight testing is projected to commence in mid-FY17.
- VH-92A-unique fuel bladders did not pass drop tests and mitigation efforts are ongoing. The program intends to qualify the bladders for flight partially full so flight tests will not be delayed.
- There are some challenges relative to connection to the Crisis Management System and the Executive Airlift Command Network. Work on solving these challenges is ongoing.

System

- The VH-92A aircraft will replace the current Marine Corps fleet of VH-3D and VH-60N helicopters flown by Marine Helicopter Squadron One to perform the presidential airlift mission.
- The VH-92A is a dual-piloted, twin-engine helicopter based on the Sikorsky S-92A. The Navy intends the VH-92A to maintain Federal Aviation Administration (FAA) airworthiness certification throughout its lifecycle.
- The VH-92A is planned to be capable of operating worldwide in day, night, or adverse weather conditions. The VH-92A will be air-transportable to remote locations via Air Force C-17 cargo aircraft.
- The government-designed MCS will provide the ability to conduct simultaneous short- and long-range secure and non-secure voice and data communications. It can exchange situational awareness information with outside agencies, organizations, and supporting aircraft. The MCS will be integrated into the VH-92A by Lockheed Martin in Owego, New York.
- Delivery of the first two Engineering Development Models (EDM-1 and EDM-2) is planned for 2018, followed by four System Development Test Article aircraft in 2019.

Mission

- Marine Helicopter Squadron One equipped with the VH-92A aircraft will provide safe and timely transport of the President of the United States and other parties as directed by the White House Military Office.
- The VH-92A is required to operate from commercial airports, military airfields, Navy ships, and austere sites throughout the world.

Major Contractors

- Sikorsky Aircraft Corporation (owned by Lockheed Martin since November 2015) – Stratford, Connecticut
- Lockheed Martin – Owego, New York

Activity

- The VH-92A program completed co-site risk reduction tests in September 2015 using a Sikorsky S-92A modified with antennas planned for the VH-92A configuration. Tests on this aircraft (designated at the time as EDM-0) provided data that led to refinement of the VH-92A design early in the program.
- Modifications to EDM-0 and a second S-92A aircraft into EDM-1 and EDM-2 (the VH-92A configuration) are on schedule.
- NAVAIR at St. Inigoes is designing the MCS software. NAVAIR has delivered MCS hardware and initial software to Lockheed at Owego for EDM-1 and EDM-2. Lockheed Martin is integrating the MCS into the VH-92A system architecture and is assembling installation kits for each aircraft.
- Systems integration laboratories, which replicate the MCS for development, test, and training, are up and running and MCS software development is on schedule.

- The VH-92A System Critical Design Review was held July 18 – 21, 2016. All requests for action and information are resolvable to bring the Critical Design Review to closure.
- The VH-92A-unique fuel bladders failed during drop testing. Mitigation efforts are progressing with the assistance of NAVAIR experts and Sikorsky engineers. In order to maintain FAA certification and not delay flight testing, the bladders will initially be qualified at a reduced fuel level.
- Live fire testing is proceeding well without major concerns.

Assessment

- The program is progressing on or ahead of schedule. Maintenance of FAA airworthiness certification is a key emphasis area.
- Lockheed Martin is on schedule to deliver MCS kits for EDM-1 and EDM-2 in 1QFY17.
- Sikorsky is on schedule to complete modification/manufacture of EDM-1 and EDM-2 in FY17.
- Contractor testing is projected to commence in mid-FY17.
- Delivery of EDM-1 and EDM-2 is projected for FY18 followed by the commencement of integrated testing.
- An operational assessment is planned for 4QFY18 to support a Milestone C decision in 2QFY19. A two-aircraft operational assessment is planned for 30 flight hours over 30 days using HMX-1 aircrews. The Commander, Operational Test and Evaluation Force (COTF) will function as the Operational Test Agency and testing will be overseen by COTF and DOT&E. Timing of EDM-2 delivery in time for this operational assessment is a watch item.
- Fuel bladder deficiencies are being appropriately addressed and are expected to be resolved in the near future.
- The program is facing some challenges meeting the Net Ready Key Performance Parameter for the MCS relative to connection to the Crisis Management System and connection to the Executive Airlift Command Network. Work is continuing on resolving these integration issues.

Recommendations

- Status of Previous Recommendations. This is the first annual report for this program.
- FY16 Recommendations. The program should:
  1. Complete mitigation efforts for fuel bladders.
  2. Complete plans for the operational assessment planned for 4QFY18.
  3. Continue planning efforts for HMX-1 transition to VH-92A.