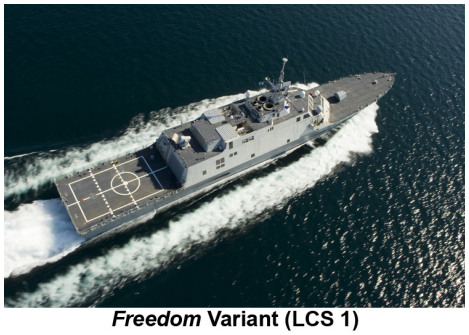
Littoral Combat Ship (LCS)

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.



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

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

  - 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.