Remote Minehunting System (RMS)

Executive Summary

- In FY15, developmental and integrated testing of Remote Minehunting System (RMS) upgrades (consisting of a version 6.0 (v6.0) Remote Multi-Mission Vehicle (RMMV) and AN/AQS-20A/B sonar) did not demonstrate sufficient performance or successful integration with interfacing Littoral Combat Ship (LCS) systems to achieve the Navy's minimum Increment 1 warfighting capability. In particular, testing of the v6.0 RMMV provides no statistical evidence of reliability improvement, and the Navy continues to experience frequent problems with LCS-based launch, handling, and recovery equipment and communications systems essential for conducting timely and sustained Mine Countermeasures (MCM) operations. In addition, following problems encountered during testing in December 2014 and January 2015, the Navy abandoned its earlier plan to develop and field an improved sonar (designated AN/AQS-20B) by the end of FY15.
- In an August 2015 memorandum, DOT&E advised the USD(AT&L) that the reliability of the RMS and its RMMV poses a significant risk to the planned operational test of the *Independence* variant LCS and the Increment 1 MCM mission package, and to the Navy's plan to field and sustain a viable LCS-based minehunting and mine clearance capability prior to FY20. DOT&E recommended that the acquisition strategy for these systems be reexamined to ensure that sufficient testing is performed to inform the procurement of additional vehicles and cautioned that continued development of this program without a fundamental change would be unlikely to result in a system that is effective and suitable. Test data collected throughout FY15 continue to refute the Navy's assertion that vehicle reliability has improved. Moreover, the current estimates of RMMV and RMS reliabilities are 22.7 and 18.3 hours Mean Time Between Operational Mission Failure (MTBOMF), which are well-short of what is needed to complete MCM missions in a timely fashion and meet the Navy's desired mission timelines.
- The Navy chartered an independent program review of the RMS including an evaluation of potential alternative MCM systems in September 2015. The independent review team's report is due in late 1QFY16. Meanwhile, USD(AT&L) delayed its review to consider approval to restart RMS low-rate initial production until at least 3QFY16.
- DOT&E concluded in a November 2015 memorandum to USD(AT&L) and the Navy, based on the testing conducted to date, that an LCS employing the current MCM mission package would not be operationally effective or operationally

suitable if the Navy called upon it to conduct MCM missions in combat. Five of seven primary shortcomings supporting this conclusion were attributed, at least in part, to the RMS:
  - Critical MCM systems, including the RMMV, are 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 LCS crew is not equipped to maintain the ship or the MCM systems.
- Developmental and integrated testing conducted in FY15 continued to show that the AN/AQS-20A sonar does not meet all Navy requirements. The RMS has not demonstrated the detection/classification and localization capabilities needed for an LCS equipped with an Increment 1 MCM mission package to complete timely mine reconnaissance and mine clearance operations in expected operational environments. In addition, testing has revealed several shortcomings that, unless corrected, will delay completion of LCS-based mine reconnaissance and mine clearance operations. The Navy expected to correct these deficiencies prior to operational testing by implementing pre-planned product improvements (the AN/AQS-20B version of the sonar) and integrating the improved sensor into the MCM mission package. However, system prototypes did not perform well in initial testing in FY14/15 and the Navy elected to proceed to LCS MCM mission package Technical Evaluation (TECHEVAL) with the

AN/AQS-20A sonar with known limitations outside the most benign conditions.
- Communications ranges afforded by current RMS radios will require operational commanders to clear a series of LCS operating boxes to support minehunting and clearance operations, particularly for bottom-focused mine-hunting operations. These operating boxes will be necessary to keep an LCS and its crew out of the minefield while operating the RMS in searches for mine-like objects or identifying bottom objects located within shipping lanes that are longer than demonstrated communications ranges. Additional effort to clear operating boxes will increase the demand for mine clearance and delay attainment of strategic objectives. During FY15 testing, LCS 2 also had frequent problems establishing initial communications between the ship and an RMMV using existing over-the-horizon (OTH) and line-of-sight (LOS) channels and maintenance of those communications links once established. These problems frequently delayed the start of RMS missions and periodically terminated missions prematurely.
- Although the Navy implemented materiel, training, and procedural improvements, incidents of equipment damage and launch and recovery failures continue to delay or prevent sustained operations. The Navy completed 16 RMMV launches and 14 RMMV recoveries during 23 days at sea in developmental testing completed in 1QFY15. During 58 days at sea during TECHEVAL, both the pace and success rate of RMMV launch and recovery regressed as LCS 2 completed 24 RMMV launches and only 18 RMMV recoveries. The increased frequency of unrecovered RMMVs is attributed to a larger number of off-board vehicle failures that precluded recovery aboard LCS 2 rather than new launch and recovery problems. Damage to shipboard launch and recovery equipment, LCS-RMMV communications problems, multiple RMMV hydraulics system failures, a suspected RMMV electrical system failure, and RMMV mast latch and fuel system failures contributed to the ship's inability to launch or recover the unmanned vehicle.
- The combination of acoustic radiated noise, frequent RMMV failures that prevent recovery aboard LCS, and the probability the vehicle and its sensor will get entangled with mine or other hazards all pose a risk to losing the RMS. Given the limited existing inventory of RMMVs (four v6.0 vehicles, four vehicles awaiting upgrades to v6.0, and two vehicles designated for training use only), any RMMV attrition would severely degrade the Navy's ability to conduct LCS-based MCM operations.

System
- The RMS is designed to provide off-board mine reconnaissance capability to detect, classify, and localize non-buried bottom and moored mines, and to identify shallow-water bottom mines only.
- The Navy plans to launch, operate, and recover RMS from both LCS Flight 0/0+ variants as part of the MCM mission package (when embarked).
- RMS includes an unmanned, diesel-powered, semi submersible vehicle called the RMMV. The RMMV tows an AN/AQS-20 variable depth sonar mine sensing subsystem. The AN/AQS-20 is a multi-mode, modular towed body that can house as many as five sonars. The sensor can also be fitted with an electro-optical identification device to identify mine-like objects. The Navy is developing an improved forward-looking sonar and new synthetic aperture side-looking sonars that it expects to field in the AN/AQS-20B/C by FY18/19. Following suspension of MH-60S tow missions in 2011, the RMMV is currently the only vehicle that tows the AN/AQS-20.
- A datalink subsystem provides real-time communications between the host ship and the RMMV for command and control and transmission of some sensor data. The RMS datalink subsystem, which includes ultra-high frequency LOS and low-band very high frequency OTH radios, interfaces with the multi-vehicle communications system that resides on both LCS variants.
- Shipboard operators control the RMMV using a remote minehunting functional segment integrated into the LCS mission package computing environment.
- RMS sensor data are recorded to a removable hard drive during minehunting operations. Following vehicle recovery, operators transfer data to an organic post mission analysis station and review sonar data to mark contacts as suspected mine-like objects.

Mission

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

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

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Activity
- During 1QFY15, the Navy completed the last scheduled phase of the Increment 1 MCM mission package developmental test DT-B2 aboard USS *Independence* (LCS 2). This phase of testing marked the first time the Navy employed v6.0 RMMVs in the MCM mission package. The test also provided the first opportunity to assess ship-based RMS operations that were unable to be completed in earlier events, described by the RMS Test and Evaluation Master Plan (TEMP), because of

LCS unavailability and deferred integration of RMMV and LCS.

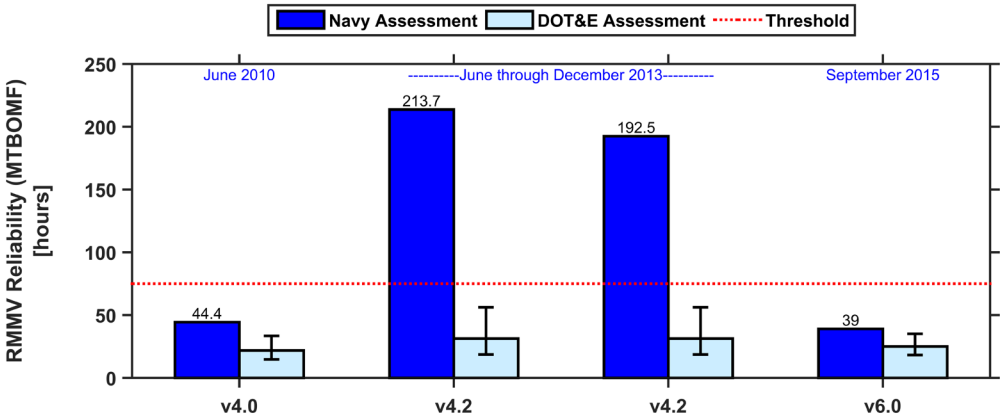
- The Navy conducted shore-based developmental testing (DT-B1) of the RMS, consisting of the v6.0 RMMV and AN/AQS-20A/B from the contractor's facility at West Palm Beach, Florida. The Navy commenced testing in December 2014 with an upgraded version of the sensor, designated AN/AQS-20B, but in January 2015 determined the new sensor was not yet sufficiently mature and elected to complete testing with the AN/AQS-20A sonar. The Navy subsequently suspended testing in January 2015 to investigate RMMV reliability problems and complete corrective maintenance. The Navy resumed and completed testing in March 2015.
- Although the Navy elected to proceed to LCS and Increment 1 MCM mission package TECHEVAL with the AN/AQS-20A, it continued to develop pre-planned product improvements for the sonar. This effort is intended to mitigate deficiencies observed during previous operational assessments and developmental testing of the RMS and AN/AQS-20A. Although the Navy no longer plans to field the AN/AQS-20B, it will continue to perform risk reduction testing of the v6.0 RMMV and the improved AN/AQS-20B sensor in FY16.
- From April through August 2015, the Navy employed four v6.0 RMMVs in TECHEVAL of the *Independence* variant LCS and Increment 1 MCM mission package aboard LCS 2. Although the Navy planned to complete the test by June 2015, problems with failures of seaframe and MCM systems, including RMMVs, caused the testing to be extended. The Navy delayed operational testing of the Increment 1 MCM mission package, which it expected to complete in FY15, until the spring of 2016, at the earliest.
- In June 2015, the Navy commenced RMS cybersecurity operational testing concurrently with LCS 2 cybersecurity testing. The initial phase of the cybersecurity operational test, a Cooperative Vulnerability and Penetration Assessment was completed in July 2015, but the final phase of the test, an Adversarial Assessment, is on hold pending a Navy decision on the readiness of the Increment 1 MCM mission package and *Independence* variant seaframe for operational testing.
- In an August 2015 memorandum, DOT&E advised the USD(AT&L) that the reliability of the RMS and its RMMV is so poor that it poses a significant risk to the planned operational test of the *Independence* variant LCS and the Increment 1 MCM mission package, and to the Navy's plan to field and sustain a viable LCS-based minehunting and mine clearance capability prior to FY20. DOT&E recommended that the acquisition strategy for these systems be reexamined to ensure that sufficient testing is performed to inform the procurement of additional vehicles and cautioned that continued development of this program without a fundamental change would be unlikely to result in a system that is effective and suitable.
- The Navy chartered an independent program review of the RMS, including an evaluation of potential alternative MCM systems in September 2015. Their report is due in late 1QFY16. Additionally, USD(AT&L) delayed its review to consider approval to restart RMS low-rate initial production was delayed until at least 3QFY16.
- In November 2015, DOT&E provided the USD(AT&L), the Assistant Secretary of the Navy for Research Development and Acquisition, and the Program Executive Officer for Littoral Combat Ships a classified assessment of the performance of the *Independence* variant seaframe and Increment 1 MCM mission package, including the RMS. DOT&E based the assessment on the data collected during the TECHEVAL and earlier periods of development and operational testing.
- In FY15, the Navy continued an effort, initiated in 2QFY14, to update the RMS and AN/AQS-20A TEMPs. DOT&E advised the Navy that both TEMPs should be further combined in the LCS TEMP, which is also being updated. It remains unclear when the Navy will complete updates to either the RMS or LCS TEMPs.

Assessment

- DOT&E's assessment is based on information from developmental and integrated testing, results provided by the Navy Program Offices, operational assessments of the RMS and AN/AQS-20A, and operational cybersecurity testing aboard LCS 2. A summary of the RMS portion of DOT&E's recent memorandum on LCS 2 and Increment 1 MCM mission package TECHEVAL is also provided below.

Reliability Growth

- The RMS program, which the Navy initiated in 1993, has a history of reliability problems. The Navy instituted reliability improvement initiatives when the v4.0 system did not meet its reliability or availability requirements during an aborted IOT&E in 2007. Following an operational assessment in 2008 and a Nunn-McCurdy review of the program in 2010, the Navy assessed v4.0 system reliability as 44.4 hours MTBOMF when it embarked on a three-phased reliability growth program (v4.1, v4.2, and v4.3) designed to retire RMMV failure modes and improve reliability. DOT&E assessed v4.0 RMMV reliability as 21.8 hours MTBOMF based on developmental and operational testing completed prior to June 2010. The figure below provides a comparison of Navy and DOT&E reliability assessments of v4.0 RMMV and subsequent vehicle configurations employed in developmental and integrated testing. The Navy assessed v4.2 RMMV reliability twice obtaining two different results.



- By June 2013, the Navy indicated it had grown reliability of the v4.2 RMMV configuration to 213.7 hours, and declared that the third phase of its reliability growth program (v4.3) was no longer necessary. Following developmental and integrated testing that fall, the Navy reported v4.2 RMMV reliability was 192.5 hours MTBOMF. Based on the same testing, DOT&E assessed that RMMV-only reliability was 31.3 hours MTBOMF when counting only failures that would have required intermediate- or depot-level intervention to fully correct. In addition, DOT&E's assessment noted that the Navy had inflated operating time estimates in its reliability calculation by assuming post-mission analysis time (when the vehicle is not in the water and not operating) could be counted. DOT&E also assessed that the Navy's calculation missed several critical failures that precluded continuation of operational missions. DOT&E's assessment of v4.2 RMMV reliability also identified specific deficiencies the Navy had not yet corrected in two phases of its reliability growth program but hoped to mitigate in conjunction with vehicle upgrades (v6.0) required to make it more compatible with LCS communications and launch, handling, and recovery systems. Although the Navy acknowledged these deficiencies, they determined that v4.2 RMMV testing had demonstrated that it met its Nunn-McCurdy exit criterion for reliability in preparation for a potential Milestone C decision and restart of low-rate initial production.
- In an August 2015 memorandum to USD(AT&L), DOT&E assessed that the v6.0 system the Navy is relying upon to underpin the first increment of the LCS MCM mission package continued to exhibit reliability problems in both shore- and LCS-based testing. In the same memorandum, DOT&E assessed that recent developmental testing provided no statistical evidence that the system was demonstrating improved reliability, and instead indicated that reliability plateaued nearly a decade ago. The figure above shows DOT&E and the Navy reporting comparable quantitative results for v6.0 RMMV reliability based on partial TECHEVAL data available at that time. Moreover, the Navy assessment of v6.0 RMMV reliability, 39 hours MTBOMF, provides evidence supporting DOT&E's conclusion that reliability has not improved despite multiple upgrade phases since the program exited its Nunn-McCurdy review in 2010. The figure also shows that the Navy's estimate for v6.0 RMMV reliability is still less than the Navy's estimate of v4.0 RMMV reliability at the outset of its reliability growth program.
- In total, RMS operated for 265.7 hours between April 7, 2015, when LCS 2 began scenario-based MCM workups, and August 30, 2015, when TECHEVAL concluded. During this test period, the RMS experienced 17 operational mission failures with 15 of those failures attributable to the RMMV. Thus, as shown in the table below, the reliabilities of RMS and v6.0 RMMV were 15.6 hours and 17.7 hours MTBOMF, respectively, during TECHEVAL. When TECHEVAL data are combined with previous data, reliabilities RMS and v6.0 RMMV are 18.3 hours and 22.7 hours MTBOMF.

RMS and v6.0 RMMV Reliability in 2014-2015 Testing

Test Event	Test Period	System Operating Time (Hours)	RMMV OMFs	RMMV MTBOMF (Hours)	RMS OMFs	RMS MTBOMF (Hours)
LCS MCM MP DT-B2 Ph4 Pd2	Sept 11 – Oct 20, 2014	139.0	3	46.3 *(20.8-126.1)*	6	23.2 *(13.2-44.1)*
DT-B1	Jan 13 –Mar 25, 2015	163.4	7	23.3 *(13.9-42.0)*	8	20.4 *(12.6-35.1)*
LCS MCM MP TECHEVAL	Apr 7 – Aug 30, 2015	265.7	15	17.7 *(12.5-25.8)*	17	15.6 *(11.3-22.2)*
All	***Sep 11, 2014 – Aug 30, 2015***	***568.1***	***25***	***22.7 (17.4-30.1)***	***31***	***18.3 (14.4-23.6)***

Note: Values in parentheses represent 80 percent confidence intervals.
MCM – Mine Countermeasures; MP – mission package; TECHEVAL – Technical Evaluation; RMMV – Remote Muti-Mission Vehicle; OMF – Operational Mission Failure; MTBOMF – Mean Time Between Operational Mission Failure

- As DOT&E assessed in August 2015, the reliability of existing systems poses a significant risk to the Navy's plan to field and sustain a viable LCS-based minehunting and mine clearance capability prior to FY20. In particular, recurrent failures preventing vehicle recovery aboard LCS, problems establishing and maintaining RMMV-LCS communications, the accelerated failure of control surface actuators, and the need for frequent intermediate- and depot-level assistance to initiate and continue sorties continue to handicap the crew's ability to sustain system operations. Unless corrected, these problems will continue to prevent the Navy from fielding an LCS and MCM mission package capable of replacing legacy systems or decreasing significantly the time required to conduct MCM operations.
- While the Navy agrees that existing RMMVs fail at a high rate and are demonstrating reliability that is less than required, it believes, the system and the MCM mission package can still accomplish their intended missions. This is incorrect. TECHEVAL provided numerous examples of system shortcomings that prevented the Navy from demonstrating RMS operating tempo over an extended period of time that was close to the expectations of the Navy's Design Reference Mission Profile for the LCS equipped with the MCM mission package.
  - During TECHEVAL, four RMMVs and six AN/AQS-20As operated off-board LCS for 226 hours and conducted 94 hours of minehunting (employing the sonar to actively search for mines, revisit contacts, and identify bottom objects). On six occasions, an RMMV could not be recovered aboard LCS 2 and had to be towed to port by test support craft, and then shipped to the remote operating site (simulating an in-theater intermediate- and depot-level maintenance activity) or prime contractor site (original equipment manufacturer depot-level repair facility) for repairs. On average, the LCS 2 completed a total of 5 hours of RMS minehunting per week (1.25 hours per week per RMMV), and an RMMV had to be towed to port for every 16 hours of RMS minehunting.
  - The pace of RMS operations demonstrated by one LCS with four RMMVs is less than 10 percent of the operating tempo for a single ship shown in the Navy's Design Reference Mission Profile for Increment 1 bottom-focused minehunting operations. Based on the demonstrated pace of operations during TECHEVAL, all of the RMMVs the Navy plans to acquire to outfit 24 MCM mission packages would be required to search the area that the Navy originally projected a single LCS and MCM mission package could search.
  - Although the Navy considers one of the two RMMVs in the Increment 1 mission package an embarked spare that permits continued RMS operations even after one unit fails, LCS 2 averaged just 3.5 days underway before losing all RMS capability, that required a call for outside RMS repair assistance, or necessitated a return to port.
  - LCS 2 was underway for more than one week with at least one mission-capable RMS embarked only once during TECHEVAL.
  - On five occasions, LCS 2 operated for less than two days before encountering an RMS problem that required assistance from shore-based intermediate-level maintenance personnel to continue operations.
  - In three cases, an RMMV was recovered without collecting minehunting data. These problems resulted in the RMMV returning to LCS 2 with at least some fraction of the expected mission data in only 15 of 24 launches (63 percent).
  - Mishaps severely damaged two RMMVs, causing them to be returned to the prime contractor's site for extensive repairs.
  - Despite underway periods that were short relative to the expectations of the LCS Design Reference Mission Profile, both RMMVs embarked at the beginning of an underway period were unavailable to conduct minehunting missions six times during TECHEVAL.
  - On three occasions, totaling 19 days, all four v6.0 RMMVs in the Navy's inventory were unavailable to execute minehunting missions.
  - The Navy completed TECHEVAL with one of four RMMVs operational. However, post-test inspections revealed that the sonar tow cable installed in that unit was no longer functional.

Minehunting Performance

- The RMS program has not yet demonstrated that the AN/AQS-20A can meet its detection and classification requirements over the prescribed depth regimes and simultaneously provide adequate coverage against all threats. Specifically, the RMS program has not yet demonstrated that the system, operating in its tactical single pass search modes, can meet its detection and classification requirements against deep water targets moored near the ocean bottom, near-surface moored mines that can only be detected by the Airborne Laser Mine Detection System in very clear waters, or stealthy bottom mines. Unless corrected, these problems will likely affect the quality LCS-based minehunting and mine clearance operations adversely in some threat scenarios. As an alternative, additional RMS search passes that will negatively affect the efficiency of minehunting and mine clearance operations might be required in some cases.
- The results of developmental and integrated testing to date continue to show that the RMS's AN/AQS-20A sensor does not meet Navy requirements for contact depth localization accuracy or false classification density (number of contacts erroneously classified as mine-like objects per unit area searched). Contact depth localization problems complicate efforts to complete identification and neutralization of mines. False classifications, unless eliminated from the contact list, require identification and neutralization effort,

result in the expenditure of limited neutralizer assets, and negatively affect the LCS sustained area coverage rate. To mitigate the problem of false classifications, the Navy has implemented tactics and software designed to compare the results of multiple search passes over the same area to "prune out" most false classifications and minimize the number conveyed for identification/neutralization. Under some conditions, the Navy has demonstrated that these pruning tactics reduce false classification densities to the Navy's acceptable limits. However, as observed during developmental testing in 1QFY15, these new procedures do not reduce false classification densities appreciably in all operationally relevant conditions. The continued need for additional passes to "prune out" excessive classifications will prevent the LCS MCM mission package from achieving the Navy's predictions for Sustained Area Coverage Rates that were based on the expectation that RMS would be a "single-pass" system.

- The Navy is developing AN/AQS-20 pre-planned product improvements (P3I) as a longer-term solution to improve probability of correct classification, reduce false classifications, and resolve contact localization accuracy problems. In early FY15, the Navy was optimistic that it could produce a mature P3I system prior to the first phase of LCS MCM operational testing originally planned in late FY15. The Program Office now expects the improved AN/AQS-20C system to enter operational testing in FY18.
- Developmental testing of the RMS in 2008 revealed that the system had problems reacquiring bottom objects for identification in deeper waters. Although the Navy implemented fixes in the v6.0 RMMV designed to correct this deficiency, the Navy has not yet conducted sufficient testing to evaluate the efficacy of its fix.
- During an AN/AQS-20A Operational Assessment in 2012, operators had difficulty identifying bottom objects in areas with degraded, but operationally relevant, water clarity. Unless system performance in this environment improves, degraded water clarity will delay MCM operations.
- Current tactics indicate the RMS will survey its tasking area multiple times before sailors are able to determine the absence or presence of mines or complete mine clearance operations. Following an initial search by the RMS, tactics advise sailors to plan additional RMS sorties to assess persistence of in-volume contacts marked as mine-like and to identify bottom contacts marked as mine-like as either mines or non-mines. When operators conclude that RMS in-volume contacts are persistent, those contacts are passed to a follow-on system for identification/neutralization.
- Although DOT&E's analysis of RMS data collected during LCS 2 and Increment 1 MCM mission package TECHEVAL is still in progress, preliminary results indicate that the RMS and its operators made multiple mine-like calls on some mines. This is an expected result when the sonar has multiple opportunities to detect the same mine in favorable conditions. The Navy's contact management tool is designed to post-process and compare the positions of the mine-like calls generated by multiple opportunities to produce a list of unique contact positions for follow-on action. During TECHEVAL, however, the Navy noted multiple cases where more than one RMS contact was generated for a single mine, passed through the contact management tool, and assigned to the Airborne Mine Neutralization System (AMNS) on multiple identification and neutralization attempts. In most of these cases, LCS 2 conducted additional, and unnecessary, AMNS attack runs even after the mine was successfully identified and neutralized. If large numbers of duplicate classifications are passed to the AMNS for follow-on action, LCS will expend needless resources and mine clearance rates will be reduced.

Communications

- Two significant communications shortcomings limit the effectiveness of the current LCS MCM mission package system-of-systems. One is the limited range of high data rate communications between an off-board RMMV and the host LCS and the other is related to the persistent difficulty with establishing and maintaining the existing LOS and OTH communications channels. The former limits the reach and productivity of LCS MCM operations, and the latter results in frequent mission delays and the potential loss of an RMMV with which the LCS is unable to communicate. Unless these problems are solved, the LCS and its MCM mission package will never be able to fulfill its wartime MCM missions within the timelines required.
- Although the RMMV can search autonomously while operating OTH from the LCS, it can only conduct electro-optical identification operations to reacquire and identify bottom mines when operating within LOS communications range of the LCS. This limitation will complicate MCM operations in long shipping channels, and will make it necessary to clear a series of LCS operating areas to allow the ship to follow MCM operations as they progress along the channel. The cleared operating areas must be close enough to the intended search area to maintain LOS communications and large enough to enable LCS operations, including ship maneuvering to facilitate launch and recovery of the RMMV and MH-60S helicopter. The additional time required to clear these areas will increase the demand for mine clearance. Although a May 2012 Navy briefing proposed development of an airborne relay and a high frequency ground wave radio capability, along with other upgrades, to make the Increment 1 MCM mission package "good enough" for IOT&E, the Navy has not yet fielded either of those capabilities. Had LCS 2 been required to clear its operating areas during the 2015 TECHEVAL and the Area Coverage Rate Sustained remained unchanged, the time required to complete MCM operations in the test field would have increased nearly

three-fold. In the May 2012 briefing cited above, the Navy reached a similar conclusion regarding the operational consequences of limited RMMV communications ranges.

- During TECHEVAL, LCS 2 had frequent problems establishing initial communications between the ship and an RMMV using existing OTH and LOS channels and maintaining those communications links once established. These problems frequently delayed the start of RMS missions and periodically terminated missions prematurely. On one occasion, loss of communications during an attempt to launch an RMMV caused the ship to return to port with the RMMV suspended from the Twin-Boom Extensible Crane because the crew was unable to complete the launch or bring the vehicle back into the mission bay. On another occasion, loss of LOS communications resulted in extensive damage to an RMMV that required months of depot-level repair at the contractor's facility when the ship attempted to recover it using OTH communications. On a third occasion, an abrupt loss of power led to loss of communications with an RMMV, making it necessary for a test support craft to take the RMMV under tow. In addition to these incidents, the LCS crew routinely found it necessary to seek help from shore-based technicians to resolve communications problems. During the latter portion of TECHEVAL, the program manager embarked a team of subject matter experts to monitor LCS-RMMV communications, assist with troubleshooting, and collect diagnostics. Shortly after the TECHEVAL, the Program Office established a task force to analyze the communications problems and propose solutions. The task force has since recommended a multi-faceted approach that includes improving operating and troubleshooting documentation for the communications systems, enhanced crew training for initializing of communications links and fault troubleshooting, and, longer term, a reexamination of the communications architecture.

Launch and Recovery

- The *Independence* variant LCS has had difficulty launching and recovering the RMMV because of the vehicle's erratic motion in the ship's wake. In past developmental testing, violent RMMV yaw and roll motions have overstressed and damaged the launch and recovery hardware and resulted in damage to the RMMV. Although the Navy implemented materiel, training, and procedural improvements, incidents of equipment damage and launch and recovery failures continue to delay or prevent sustained operations. The Navy completed 16 RMMV launches and 14 RMMV recoveries during 23 days at sea in developmental testing conducted in 1QFY15. During 58 days at sea during TECHEVAL, both the pace and success rate of RMMV launch and recovery regressed as LCS 2 completed 24 RMMV launches and only 18 RMMV recoveries. The increased frequency of unrecovered RMMVs is attributed to a larger number of off-board vehicle failures that precluded recovery aboard LCS 2 rather than new launch and recovery problems. Damage to shipboard launch and recovery equipment, LCS-RMMV communications problems, multiple RMMV hydraulics system failures, a suspected RMMV electrical system failure, and RMMV mast latch and fuel system failures contributed to the ship's inability launch or recover the unmanned vehicle.
- No RMMV launch and recovery operations have been conducted aboard a *Freedom* variant LCS at sea.

RMS Vulnerabilities

- The combination of acoustic radiated noise, frequent RMMV failures that prevent recovery aboard LCS, and the probability the vehicle and its sensor will get entangled with mines or other hazards all pose a risk to losing the RMS. Given the limited existing inventory of RMMVs (four v6.0 vehicles, four vehicles awaiting upgrades to v6.0, and two vehicles designated for training use only), any additional RMMV attrition would severely degrade the Navy's ability to conduct LCS-based MCM operations.
- RMMV acoustic radiated noise measurements, last collected during developmental testing in 2007/2008, indicated that existing RMMVs might be vulnerable to some mines. The RMS Program Office has not assessed radiated noise following recent vehicle configuration changes and has requested a waiver to deploy the system even through it did not previously meet its acoustic radiated noise specification. If RMMV radiated noise continues to exceed acceptable limits, systems could be lost during LCS-based minehunting and mine clearance operations depleting the Navy's limited inventory of assets. The magnetic signature of the v6.0 RMMV has not been measured.
- As noted earlier, only 18 of 24 RMMVs launches from LCS 2 ended with an RMMV recovery aboard LCS 2 during TECHEVAL. Frequent RMMV failures that preclude vehicle recovery aboard LCS might result in lost RMMVs and expose personnel who attempt to recover RMMVs in open waters to air, surface, and mine threats. Because of the number of incidents in which an RMMV could not be recovered, the Navy is now considering options that would provide LCS with additional support to recover RMMVs that it cannot recover otherwise. On four occasions during TECHEVAL, RMMV failures precluded LCS 2 from controlling the movements of an off-board RMMV. If similar failures occur during operations, the RMMV could become disabled in the minefield or drift into a minefield before salvage or support craft arrive to recover it.
- Even though test minefields are deliberately planned to reduce the risk of RMS striking a mine target or becoming entangled in its mooring cable, the RMS has snagged several tethered mines, and other surface and underwater objects during testing. These incidents often cause damage to the vehicle or deployed sonar that leaves the system inoperable. In some cases, divers embarked on test support craft have entered the water to assist in recovery of assets following a snag. Although the Navy is still developing concept of operations to handle these situations during operations in a threat minefield, it is clear that if these incidents occur during wartime operations they will

pose a risk to vehicles and potential recovery personnel. Furthermore, the repeated occurrence of these incidents presents both a tactical and a system design challenge for the Navy as it tries to minimize attrition when the system is employed operationally.

- In FY15, the Navy also disclosed that the AN/AQS-20A does not trail directly behind the RMMV when deployed to tactical minehunting depths. Instead, the sensor tows to starboard of the RMMV path. This offset causes the RMS to behave like a mine sweeping system as the sonar and its tow cable passes through the water, thereby increasing the risk of snagging a tethered mine.
- The RMS Program has not completed the final Adversarial Assessment phase of cybersecurity operational testing of the RMS hardware and software configurations intended for Initial Operational Capability in the LCS MCM mission package in FY16.

Maintainability

- Consistent with the concept of operations, the LCS is reliant on shore-based support for assistance with diagnosis and repair of seaframe equipment and MCM system problems. Although the ship could be more self-reliant if the sailors were provided with better maintenance training, technical documentation, test equipment, and tools and a more extensive stock of spares, the mission package detachment lacks the wherewithal to handle anything beyond relatively uncomplicated RMS preventive maintenance and minor repairs. As a result, the Navy's records show that shore-based RMMV maintenance personnel completed more than 4,000 hours of RMMV maintenance over six months of TECHEVAL work-ups and testing to support approximately 108 hours of RMS minehunting. Not only is this level of support, 38 hours of maintenance per hour of minehunting, far beyond the capability of the embarked crew, it is also not sustainable for wide-area LCS MCM operations that must be quickly completed.

Recommendations

- Status of Previous Recommendations.
  - The Navy made progress on all four FY13 recommendations. Shore-based testing completed in 1QFY14 and shipboard testing completed in 1QFY15 provided additional information regarding RMS, RMMV, and AN/AQS-20A reliability; RMS operational availability; and RMMV launch, handling, and recovery system performance. Although the Navy continues to develop and test AN/AQS-20A upgrades, it has not demonstrated in developmental or operational testing that it has corrected problems with false classifications and contact localization errors that will otherwise limit performance in operational testing. The Navy expects to complete its update to the RMS TEMP, which now includes the AN/AQS-20A sonar, in FY16.
  - The Navy has made progress on two of the nine FY14 recommendations. The Navy initiated RMS cybersecurity and conducted additional ship-based RMS testing to assess readiness for operational testing that it expected to complete in FY15. The Navy did not address the following FY14 recommendations:
    1. Identify the RMS configuration for operational testing of LCS equipped with the first increment of MCM capability and complete the required operationally realistic testing of that system prior to LCS MCM mission package TECHEVAL.
    2. When system maturity is able to support, conduct testing of the RMS consisting of the v6.0 RMMV and AN/AQS-20C in operationally realistic end-to-end minehunting missions to characterize AN/AQS-20B minehunting performance and accurately assess availability of the RMS and reliability of the RMMV and AN/AQS-20B.
    3. Investigate the use of communications relays and other solutions that might improve the standoff distance between an RMMV and its host ship to improve the efficiency of LCS MCM operations.
    4. Document a robust reliability monitoring and growth strategy for any new low-rate initial production vehicles procured following a planned FY15 Milestone C decision.
    5. Reassess v6.0 RMMV radiated noise following vehicle upgrades.
    6. Reexamine minimum vehicle and sensor reliability and LCS organizational-level maintenance support needed to complete timely and realistic operational scenarios without excessive reliance on intermediate- and depot-level support.
    7. Reconsider RMS minehunting requirements in the context of expected LCS tactics and operations.
- FY15 Recommendations. In addition to addressing outstanding FY14 recommendations, the Navy should:
  1. Review RMMV design alternatives as a solution for system reliability problems.
  2. Complete a comprehensive review of RMMV and mission package communications interfaces and, if necessary, re-engineer the Multi-Vehicle Communication System, RMMV, and/or other essential system-of-systems components to improve interoperability and enable reliable LOS and OTH communications between LCS and RMMVs.
  3. Develop tactics to mitigate system vulnerabilities to mines, mine collision, and entanglement hazards, and other surface and underwater hazards.
  4. Assess improvements to post mission analysis and contact management software and training to resolve problems observed during TECHEVAL when multiple RMS contacts on the same mine were passed to AMNS for identification and neutralization.
  5. Continue to develop and implement improvements for launch, handling, RMMV and recovery equipment and procedures.
  6. Provide LCS sailors better training, technical documentation, test equipment, and tools, along with additional spares to improve the crews' self-sufficiency and enhance RMS maintainability.