Remote Minehunting System (RMS)

Executive Summary

- In June 2014, DOT&E reported the Remote Minehunting System (RMS) (consisting of a version 4.2 (v4.2) Remote Multi-Mission Vehicle (RMMV) and AN/AQS-20A sonar) had not demonstrated sufficient performance or successful integration with interfacing Littoral Combat Ship (LCS) systems to demonstrate the Navy's minimum Increment 1 warfighting capability. Although the Navy is working on upgrades to improve system performance and LCS capability in the v6.0 RMMV and the AN/AQS-20A/B sonar, developmental testing completed in 1QFY15 demonstrated continued performance issues and RMS mission package integration challenges.
- In 4QFY14, USD(AT&L) delayed a review to consider approval of RMS low-rate initial production (LRIP) until 3QFY15.
- Combined developmental and integrated testing completed in FY14 provides a point estimate for v4.2 vehicle reliability of 31.3 hours Mean Time Between Operational Mission Failure (MTBOMF). Developmental testing completed in 1QFY15 provides a point estimate for v6.0 vehicle reliability of 34.6 hours MTBOMF. Statistical analysis of all test data indicates the result is not sufficient to conclude that reliability has actually improved since a Nunn-McCurdy review of the program in 2010. Therefore, test data currently available (including early testing of the v6.0 vehicle) do not support the Navy's assertion that vehicle reliability has improved. Moreover, the current estimate of RMS reliability, once all of the other components of the system are considered, is no more than 20 hours MTBOMF, which is well-short of what is needed to complete MCM missions in a timely fashion and meet the Navy's desired mission timelines.
- Developmental testing conducted in FY14 and 1QFY15 continued to show that the AN/AQS-20A sonar does not meet all Navy requirements. The Navy expected to correct these deficiencies prior to operational testing in FY15 by implementing pre-planned product improvements (the AN/AQS-20B version of the sonar) and integrating the improved sensor into the Mine Countermeasures (MCM) mission package. Delays in the delivery of AN/AQS-20B prototypes and problems discovered in early characterization testing in FY14 leave little time to complete necessary developmental and operational testing of the AN/AQS-20B prior to the planned operational testing of LCS equipped with the MCM mission package in FY15.
- 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. 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. The analysis of communications data collected during the most recent period of LCS developmental testing is still in progress, but test observers reported continued communication problems.

System

- The RMS is designed to provide an organic, off-board mine reconnaissance capability to detect, classify, and localize non-buried bottom and moored mines, as well as to identify shallow-water bottom mines only.
- The RMS will be launched, operated, and recovered from the LCS as part of the MCM mission package (when embarked).
- The RMS is comprised of four major components:
  - RMMV
    - The RMMV is an unmanned, semi-submersible, untethered vehicle designed to conduct autonomous or semi-autonomous mine reconnaissance missions.
    - The RMMV physically transports AN/AQS-20A/B sensors, processors, and datalink equipment to the operations area where mine reconnaissance data are collected, recorded, and transmitted to the host LCS platform.
    - 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.

- The Navy has not yet presented its plans to incorporate reliability growth improvements in a future system increment (LRIP 2).
- AN/AQS-20A sensor
  - The AN/AQS-20A is a variable depth forward-looking and side-scanning sonar that is deployed and retrieved by the RMMV.
  - The sensor tow body automatically controls depth based on specific mission planning parameters, providing a stable platform for integral mine reconnaissance sensors.
  - The AN/AQS-20A provides detection, classification, and localization of non-buried bottom (on the ocean floor) and volume (in the water column) mine-like-contacts. The sensor utilizes port and starboard Side-Looking Sonars and a Gap Filler Sonar for detection of bottom and closely tethered moored mines in shallow waters. A Volume Search Sonar (VSS) and a Forward-Looking Sonar are utilized for all other moored mine detection. An Electro-Optic Identification Device can replace the VSS for missions requiring identification (mine versus non-mine) of shallow-water bottom mine-like contacts via high-resolution imaging.
  - The Navy plans to incorporate an improved forward-looking sonar and new synthetic aperture side-looking sonars (AN/AQS-20B) in FY15.
- Remote Minehunting Functional Segment (RMFS)
  - The RMFS is the control system hosted in the mission package computing environment on the LCS.
  - RMFS is a two-operator system that enables the Remote Vehicle Operator and Remote Sensor Operator to command and monitor RMS operations.
  - Specific RMFS functionality enables the operator to (1) command and monitor the RMMV; (2) receive, process, and display real-time mission data; (3) conduct performance monitoring/fault detection/fault localization; and (4) perform network communication to the Data Link System (DLS).
  - RMFS also exchanges data with the Global Command and Control System – Maritime/Mine Warfare Environmental Decision Aids Library for mission planning and interface to the Department of Defense Information Network.
- DLS
  - The DLS enables the RMMV to communicate with the LCS MCM mission package via one of two radio frequency datalink subsystems.
  - The Multi-Vehicle Communications System (MVCS) consists of two radios – an Ultra High Frequency line-of-sight datalink that is used for vehicle launch and recovery and near-ship operations and a low-band Very High Frequency datalink that is used for over-the-horizon mission operations. Both datalinks provide encrypted communications between the LCS MCM mission package and the RMMV for real-time command and control and transmission of some sensor data.

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, as well as to identify shallow-water bottom mines in support of theater minehunting operations in shallow-water and deep-water minefields.

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

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Activity
- In 1QFY14, the Navy completed two phases of developmental testing (DT-IIG) of the RMS consisting of a v4.2 RMMV and an AN/AQS-20A sensor from a shore base at the contractor's facility in West Palm Beach, Florida. A third phase of testing described by the RMS Test and Evaluation Master Plan (TEMP) as an opportunity to assess risk of the interfaces with the LCS, including cybersecurity, was not conducted. The Navy cited lack of LCS availability as the rationale for cancellation of this phase, but incompatibility of the v4.2 RMMV with LCS was also a factor. The v4.2 vehicles did not have the needed structural improvements or communications upgrades to make them compatible with LCS systems.
- DOT&E disapproved the Navy's plan to conduct an operational assessment (OA) of the RMS in 2QFY14 because the OA would have been a wasted effort for the following reasons:
  - The proposed test article was not representative of the system the Navy plans to employ in the first increment of the LCS MCM mission package and therefore would not provide data necessary to augment the operational testing of an LCS equipped with that mission package.
  - Test limitations would have precluded an operational evaluation of key phases of the end-to-end mission.
  - Conduct of the test would have delayed vehicle upgrades necessary to support testing of the system the Navy expects to field.
- DOT&E advised the Navy that this testing may be conducted as combined developmental and integrated testing if the standards of operational realism are met. The Navy expects to conduct testing from December 2014 to January 2015 to satisfy objectives of the planned OA.
- The Navy initiated updates to the RMS and AN/AQS-20A TEMPs that merged the TEMPs into a single document in 2QFY14. To avoid confusion and promote efficiency, DOT&E advised the Navy that both TEMPs should be further

combined in the LCS TEMP, which is also being updated. It is unclear when updates to either the RMS or LCS TEMPs will be completed.

- The Navy continued to develop pre-planned product improvements for the AN/AQS-20A and is investigating improved tactics, techniques, and procedures for its employment. Both efforts are intended to mitigate deficiencies observed during previous OAs and developmental testing of the RMS and AN/AQS-20A. The Navy plans to conduct developmental testing of the RMS configured with the newly integrated v6.0 RMMV and the improved AN/AQS-20B sensor in late 1Q/early 2QFY15.

- The Navy imposed a weight limit on LCS 2 and LCS 4 launch and recovery systems as a result of finding cracks in the welds at the base of support stanchions located in the mission bay that the Navy attributes to LCS 2's heavy weather testing. As a result, subsequent testing of the launch and recovery operations could be conducted only when wave-induced loading on the recovery system (a function of wave height and period) did not exceed 32,000 pounds-force. (For example, a significant wave height of 2 feet coupled with a wave period of 2 seconds, which could be encountered in a Sea State 2, would preclude RMMV recovery until calmer sea conditions developed.) The Navy reported they are making design changes to LCS 6 and later seaframes to correct the stress cracking problem and remove the launch and recovery system weight limit. LCS 2 and LCS 4 will be corrected during their next shipyard availabilities. Prior to discovering the damaged support stanchions, the Navy had already imposed a sea state limit of less than Sea State 3 because of the erratic motion of the RMMV in the ship's wake, which had caused damage to capture spines and RMMVs.

- In 3QFY14, the Navy conducted dockside and at-sea developmental testing to verify correction of RMMV launch, handling, and recovery system and communications deficiencies observed in FY13 developmental testing.

- DOT&E provided an assessment of RMS performance in testing to members of the Defense Acquisition Board in June 2014 after the program was recertified following an FY10 Nunn-McCurdy breach. In 4QFY14, USD(AT&L) delayed a review to consider approval of RMS LRIP until FY15.

- The Navy commenced additional dockside and at-sea developmental testing of the RMMV launch, handling, and recovery system and the multi-vehicle communications system in 4QFY14. In 1QFY15, the Navy conducted the last scheduled phase of the Increment 1 MCM mission package developmental test DT-B2 aboard USS *Independence* (LCS 2). This phase was the first time that RMS (configured with a v6.0 RMMV) and the airborne MCM mission package components had operated together off an LCS. However, because the Navy now expects to make additional RMMV software changes and deferred a decision on which variant of the AN/AQS-20 to field until December 2014, LCS Technical Evaluation is expected to be the first time the fielded system will be tested in realistic end-to-end missions.

- The Joint Requirements Oversight Council (JROC) and the Navy approved the RMS Capability Production Document in March 2014.

Assessment

- As DOT&E reported to members of the Defense Acquisition Board in June 2014, the combined results of shore-based and LCS-based testing conducted since the program was recertified following a Nunn-McCurdy in 2010 have not demonstrated that an LCS equipped with an MCM mission package that includes two RMMVs and three AN/AQS-20A sonars will be able to support the sustained area coverage rate that the Navy has established for the Increment 1 MCM mission package. Few test data are available to indicate whether planned RMS improvements would support meeting the Increment 1 LCS requirements, let alone provide the more robust capability the Navy expects to achieve with Increment 4 of the MCM mission package.

- The requirements, in the approved RMS Capability Development Document and Capability Production Document, are not consistent with the approved requirements for minehunting conducted by the LCS.
  - The RMS could meet all threshold requirements designated as Key Performance Parameters and Key System Attributes and still not support the LCS MCM mission because the RMS requirements lack the appropriate mission focus.
  - The RMS search rate requirement, for example, has no limit on false alarms and excludes time required for planning, transit to and from the search area, operator assessment, follow-on actions to reduce false classifications, and efforts to recover from failures. All of these factors directly affect the achievement of the required performance and timeliness of LCS MCM missions.
  - The reliability of the v4.2 RMMV during combined developmental and integrated testing completed in FY14 was 31.3 hours MTBOMF, which is well below the required reliability of 75 hours MTBOMF. Although the Program Office maintains that the RMMV reliability is substantially above that value and that a reliability growth program completed in FY13 was highly successful, the Navy's reliability analysis is fundamentally flawed because it overstates RMMV operating time and undercounts the number of operational mission failures. The RMMV reliability issue has been the principal reason that the program has not attempted to reenter operational test.
  - The vendor completed an RMMV growth program and has subsequently incorporated additional fixes to correct deficiencies observed during developmental testing and combined developmental/integrated testing in 2013.
  - The restoration from RMS failures/faults when operating from an LCS is reliant on intermediate- and depot-level (off-board) maintenance support. Organizational-level (shipboard) maintenance support to restore system availability necessary to complete timely and realistic operational scenarios is limited.

- The system's AN/AQS-20A sensor also has reliability problems.
- The results of combined developmental and integrated testing completed in FY14 continued to show that the 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 of area searched).
    - Contact depth (vertical localization) errors and false classification density exceeded Navy limits in all AQS-20A operating modes.
    - The sensor also has trouble meeting the probability of detection and classification requirement in shallow waters and RMS has difficulty guiding the sensor over bottom contacts for identification in deep water.
    - Although the Navy is working on pre-planned product improvements in the AN/AQS-20B version of the system, no test data are available to indicate that problems with false classifications and vertical localization errors have been mitigated. Delays in the delivery of AN/AQS-20B prototypes and problems discovered in early characterization testing in FY14 leave little time to complete necessary developmental and operational testing of the AN/AQS-20B prior to the planned operational testing of LCS equipped with the MCM mission package in FY15. If left uncorrected, AN/AQS-20A/B problems will reduce the minehunting and clearing capability of the MCM mission package and the LCS will not meet interim area clearance requirements in ideal conditions let alone more realistic area clearance needs for the threat scenarios the mission package was developed to counter in theater.
- The RMS program has not yet demonstrated that the system can meet its detection and classification requirements against moored and bottom mines spanning the portion of the shallow water regime not covered by the Airborne Laser Mine Detection System; the program anticipates that the AN/AQS-20B sensor will permit this capability. If this cannot be accomplished, the Navy will need to conduct additional search passes to achieve adequate coverage of the water column, resulting in increased detection and classification timelines and the LCS not meeting area clearance rate requirements.
- Testing completed in 1QFY14 indicates that fleet operators frequently misclassify moored mine targets as bottom objects during shallow water minehunting. These errors can increase the difficulty of reacquiring mines during the neutralization phase of MCM operations. The Navy is weighing the need for additional search passes to resolve mine position uncertainty before proceeding to mine clearance operations. Such tactics would require more time to accomplish, resulting in increased mine clearance timelines and the LCS not meeting area clearance rate requirements.
- RMS radios have had difficulty establishing reliable communications with the LCS during developmental testing, and once communications are established, the current communications systems do not support RMMV mine

identification operations beyond the horizon. Although the RMMV can search autonomously while operating over the horizon from the LCS, it currently only can conduct operations to reacquire and identify bottom mines within the range of Ultra High Frequency communications. This limitation will complicate MCM operations in long shipping channels, and may make it necessary to clear a series of LCS operating areas to allow MCM operations to progress along the channel. The cleared operating areas will be needed to keep the LCS and its crew out of mined waters. The additional effort required to clear these LCS operating areas would increase the demand for mine clearance and delay attainment of strategic objectives. This issue is not new to RMS; however, it did not become operationally significant until the Navy decertified the MH-60S helicopter for towing MCM devices, including the AN/AQS-20A/B sensor. The RMS communication range limitation was not an operational concern when the option existed for the helicopter with towed sensor to conduct identification operations beyond the horizon. The Navy has not yet identified a solution. The analysis of communications data collected during the most recent period of LCS developmental testing is still in progress, but test observers reported continued communications problems.
- The *Independence* class 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, which led to the Navy imposing a Sea State 3 limit on handling operations. Following changes to launch and recovery hardware, procedures, training, and RMMV hardware, the Navy demonstrated 16 RMMV launches and 14 RMMV recoveries during 23 days at sea in developmental testing during favorable sea state conditions and within the imposed weight loading restrictions in 1QFY15. Nonetheless, the most recent period of developmental testing witnessed several instances of equipment damage that delayed or prevented recovery of an off-board RMMV.
- Following the October 2014 phase of developmental testing, the Navy identified a new problem with the redesigned lifting structure used in the vehicle's launch and recovery. Deformation in the capture probe and corresponding latching mechanism in the vehicle (capture pawls) was observed following several failed attempts to recover the RMMV. This is significant because the entire weight of the vehicle is supported by these components during vehicle launch and recovery, and the defects pose a safety concern for mission package personnel who must work in close proximity to the suspended RMMV to secure it to the cradle pallet in the mission bay. The Navy identified substandard metallurgical strengthening as the root cause of observed deformation. In addition, non-load bearing components of the redesigned RMMV capture spine assemblies experienced multiple failures including several the test team attributed to substandard welds. In some cases, the team test was unable to continue RMS operations without replacement parts from shore, which

in theater would preclude sustained RMS operations without excessive reliance on shore-based support. The Navy must correct capture spine deficiencies to ensure safe and sustained RMMV launch and recovery in support of LCS MCM operations.

- Developmental testing conducted aboard LCS 2 in 1QFY15 also indicates that many RMS performance problems identified in earlier test phases have not been corrected and, in some cases, new problems have been introduced following changes to system configurations or tactics.
  - RMS reliability problems persisted in the recent phase of developmental testing (1QFY15) evidenced in part by fewer vehicle recoveries than vehicle launches. Problems observed include the inability to align the system's inertial navigational unit, intermittent communications, a lube oil pump failure that caused a mission abort, capture latch impairment that precluded shipboard recovery of the RMMV, degraded electro-optic identification resulting in a mission abort to replace the AN/AQS-20A towed body, tow cable damage following an apparent snag that rendered the system inoperable in the assigned mission until a replacement tow cable could be installed with the assistance of shore-based support, and multiple incidents of AN/AQS-20A stuck fins or fin actuation faults. Although the Navy demonstrated more frequent RMMV launches during this period of testing, continued RMS reliability problems limited system minehunting to less than 50 hours during the three weeks of most intensive testing (approximately 16 hours per week). LCS reliability problems also forced the ship to remain in port for repairs instead of conducting at-sea RMS testing as planned. Including an additional week spent in port for LCS repairs, RMS averaged approximately 12 hours of minehunting per week. This result is consistent with the assessment of RMS capability DOT&E provided to members of the DAB following RMMV v4.2 and AN/AQS-20A testing to indicate that the Navy had not yet demonstrated that it could sustain operations of more than one 14-hour RMMV sortie per week (i.e., 10 to 12 hours of RMS minehunting per week). Unless greater minehunting operating tempo is achieved the Navy will not meet its interim area clearance rate requirements.
  - The Navy reported that the RMS operated for approximately 140 hours during LCS developmental testing in 1QFY15. DOT&E's preliminary assessment of test data identified at least seven RMS failures that precluded vehicle recovery, required sensor replacement, or required assistance from shore-based support contractors to restore system availability. In operational testing, these failures would be assessed as operational mission failures. Thus, by operational criteria, RMS demonstrated reliability was no more than 20 hours MTBOMF during this phase of testing. Because much of the operating time cited by the Navy was not devoted to minehunting activities, this estimate should be considered an upper bound for current RMS operational reliability. Moreover, statistical analysis

of all existing data do not yet support the Navy's assertions of improving RMS reliability.
  - As in previous testing, fleet operators were unable to execute operationally-realistic, end-to-end mine reconnaissance and clearance without the assistance of testers with knowledge of ground truth target positions. Using mission package tools such as Organic Post Mission Analysis and the new Contact Management Tool (CMT) fleet operators failed to convey some mine targets correctly detected by the RMS in an initial search pass to the Airborne Mine Neutralization System (AMNS) for neutralization. The Navy continues to investigate the root cause of incorrectly dropped contacts, which will severely limit LCS MCM mission effectiveness unless corrected.
  - Multiple-pass tactics and the CMT were introduced to minimize the number of false classifications passed on for identification/neutralization. However, during the recent phase of testing, the number of in-volume RMS false classifications remaining in the contact list after multiple RMS search passes and contact correlation far exceeded Navy pre-test predictions indicating these tactics and tools have not yet achieved the desired result. The CMT also failed during the later stages of testing requiring operators to attempt the cumbersome task of manually tracking contacts between stages of the RMS mission before determining which contacts merited further investigation. If large numbers of RMS in-volume false classifications are passed to the AMNS for follow-on action, LCS mine clearance requirements will not be met. Large quantities of contacts generated by the RMS make manual correlation time consuming and increase the potential to drop correct classifications; both of these problems will limit LCS MCM effectiveness unless corrected.

- The Navy has not assessed radiated noise following recent vehicle configuration changes. Radiated noise measurements were last collected during developmental testing in 2007/2008, and indicated that existing RMMVs may be vulnerable to some mines.
- The RMS program has not conducted operational testing of cybersecurity of the RMS hardware and software configurations intended for Initial Operational Capability in the LCS MCM mission package in FY15/16.
- No RMMV launch and recovery operations have been conducted aboard a *Freedom* class LCS at sea.

Recommendations

- Status of Previous Recommendations. The Navy made progress on all four FY13 recommendations. Shore-based testing completed in 1QFY14 and shipboard testing completed in 1QFY15 provided additional information regarding RMS, RMMV, and AN/AQS-20A reliability; RMS operational availability; and RMMV launch, handling, and recovery system performance. Although the Navy continues to develop and test AN/AQS-20 upgrades, it has not demonstrated in developmental or operational testing that it has corrected

problems with false classifications and contact localization errors that will otherwise limit performance in the planned FY15 operational testing. The Navy expects to complete its update to the RMS TEMP, which now includes the AN/AQS-20 sonar, by 2QFY15.

- FY14 Recommendations. The Navy should:
  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 Technical Evaluation.
  2. Conduct testing of the RMS consisting of the v6.0 RMMV and AN/AQS-20B 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. Conduct cybersecurity testing of the RMS to identify risks associated with deploying the system planned for Initial Operational Capability in FY15/16.
  5. Document a robust reliability monitoring and growth strategy for any new LRIP vehicles procured following a planned FY15 Milestone C decision.
  6. Reassess RMMV v6.0 radiated noise following vehicle upgrades.
  7. 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.
  8. Reconsider RMS minehunting requirements in the context of expected LCS tactics and operations.
  9. Recognizing schedule constraints, continue to conduct ship-based testing of the RMS that includes end-to-end minehunting missions from an LCS as part of the MCM mission package to:
     - Assess fixes to resolve RMMV launch, handling, and recovery problems observed in FY14/15 testing and verify it can be handled safely in higher sea states once the ship's structure is repaired, the weight restrictions are lifted and the capture probe and latching mechanism (capture pawls) are corrected.
     - Assess fixes to resolve communications problems observed in FY13/14/15 testing.
     - Assess improvements to post mission analysis and contact management software and training to resolve problems observed in 1QFY15 testing when attempting to pass RMS contacts to another mission system for follow-on action.
     - Verify the RMS mission module is ready to support conduct of operational testing of the LCS MCM mission package in FY15.