IDA

INSTITUTE FOR DEFENSE ANALYSES

Remote Minehunting System: Root Cause Analysis

John W. Bailey
Alexander O. Gallo
Tzee-Nan K. Lo
Caolionn L. O’Connell
Thomas P. Frazier, Project Leader
Patricia F. Bronson, Task Leader

June 2010

IDA Paper P-4600
Log: H 10-000525
Copy

About This Publication

This work was conducted by the Institute for Defense Analyses (IDA) under contract DASW01-04-C-0003,Task AY-7-3223, "WSARA 2009: Root Cause Analysis of Programs in Nunn-McCurdy Breach," for the Director, Program Assessment and Root Cause Analyses (D, PARCA), Office of the Under Secretary of Defense (Acquisition, Technology and Logistics). The views, opinions, and findings should not be construed as representing the official position of either the Department of Defense or the sponsoring organization.

Acknowledgments

Stanley A. Horowitz, Gene H. Porter, and David M. Tate of IDA were the technical reviewers.

Copyright Notice

INSTITUTE FOR DEFENSE ANALYSES

IDA Paper P-4600

Remote Minehunting System: Root Cause Analysis

John W. Bailey
Alexander O. Gallo
Tzee-Nan K. Lo
Caolionn L. O'Connell
Thomas P. Frazier, Project Leader
Patricia F. Bronson, Task Leader

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The Remote Minehunting System (RMS) is a mine reconnaissance system for the detection, classification, identification, and localization of bottom and moored mine-like objects in shallow and moderately deep water. In December 2009 the Navy notified Congress of a critical Nunn-McCurdy breach in both the Program Acquisition Unit Cost (PAUC) and Average Procurement Unit Cost (APUC). The Navy reported that the PAUC had risen 85.1 percent, from $12.1 million in the October 2006 Acquisition Program Baseline (APB) to $22.4 million. Over the same time span the APUC rose 51.2 percent, from $8.4 million to $12.7 million.

The analysis revealed three major reasons for the cost growth. First, the Navy reduced its planned procurement quantity from 106 to 52, as it decided to limit the RMS to the Mine Countermeasure mission on the Littoral Combat Ship (LCS) and no longer procure the system for the Anti-Submarine Warfare mission package. The quantity reduction accounted for over 40 percent of the reported PAUC cost growth and 18 percent of the APUC cost growth. Second, the design fell far short of its reliability and availability requirements, thus requiring additional funding to improve reliability and correct flaws, and delays to production to implement the changes. The associated development cost and delays increased PAUC and APUC by 22 percent and six percent, respectively. Third, the Acquisition Program Baseline (APB) cost estimate did not include some cost data from a negotiated contract. The cost estimate was based on the average price of only the recurring hardware production for the Low Rate Initial Production (LRIP) units and did not include hardware and software engineering, integration and testing, or program management costs. However, the contract price for those units includes those elements and is significantly higher. Fixing this mistake increased the PAUC by 14 percent and the APUC by 21 percent. Table S-1 apportions the cost growth to the major drivers. The paper will detail the rationale and calculations behind each of the major cost drivers.

The analysis also examined the root causes behind the three proximate causes. Two root causes are directly related to their proximate causes (procurement reduction and a baseline cost error). The decision to reduce the procurement quantities appears to be exogenous to the program and unrelated to the reliability issues. The baseline cost estimate was unrealistic, since the original official estimate did not include some cost data. The final root cause—failure of government oversight—manifested itself in reliability issues.

Table S-1. 2009 Nunn-McCurdy Cost Growth Apportioned among the Major Drivers

In $M BY FY 2006	Original APB	Current Navy Estimate	Delta	% Growth
PAUC	**12.1**	**22.4**	**+ 10.3**	**85.1%**
	Qty Reduction & Profile Change		**+ 5.17**	**43%**
	Quantity Reduction		*+ 4.24*	35%
	Reduced Production Rate		*+ 0.93*	8%
	Reliability Issues		**+ 2.71**	**22%**
	Reliability Growth Program		*+ 2.22*	18%
	Five-year Gap		*+ 0.49*	4%
	Unrealistic unit cost estimation		**+ 1.68**	**14%**
	Other		**+ 0.74**	**6%**
APUC	**8.4**	**12.7**	**+ 4.3**	**51.2%**
	Qty Reduction & Profile Change		**+ 1.52**	**18%**
	Quantity Reduction		*+ 0.54*	6%
	Reduced Production Rate		*+ 0.98*	12%
	Reliability Issues: Five-year Gap		**+ 0.51**	**6%**
	Unrealistic unit cost estimation		**+ 1.74**	**21%**
	Other		**+ 0.53**	**6%**

I. BACKGROUND

The Remote Minehunting System (RMS) is a system for the detection, classification, identification, and localization of bottom and moored mines in shallow and deep water. It is intended to keep ships and sailors out of a minefield and will be installed on the Littoral Combat Ship (LCS) as part of the ship's Mine Warfare Mission Package. In December 2009, the Navy notified Congress of a critical Nunn-McCurdy breach in both the Program Acquisition Unit Cost (PAUC) and Average Procurement Unit Cost (APUC).

A. NAVY'S MINEHUNTING MISSION

Mine Countermeasures (MCM) can be divided into two types: passive and active. Passive countermeasures involve reducing a ship's acoustic and magnetic signature to prevent mines from detecting it. Active countermeasures involve minesweeping or minehunting. Minesweeping is the clearing of a pre-defined area, whereas minehunting involves systematic detection and elimination of mines one at a time.

MCM techniques the Navy currently uses include:

- Degaussing to reduce the ship's effect on the Earth's magnetic field, thereby reducing the possibility of detection by mines
- Detection of mines in shallow and deep waters using unmanned vehicles towing sensors, such as the remote minehunting system (RMS)
- Remote detonation of mines using a standard mechanical minesweep towed behind a ship or helicopter which emits a ship-like magnetic and/or acoustic signal

MCM remains an essential naval mission when operating in the littorals and is of critical importance in "choke points," such as the Straits of Hormuz or the approaches to most US commercial ports. Accordingly, the Navy continues to invest in new and increasingly complex systems to identify, detect, and destroy sea mines.

1. System Description

The RMS will be an organic, off-board system that will be launched, operated, and recovered from a host surface ship and will employ mine reconnaissance sensors that are intended to locate and identify mine-like objects. Destruction of mines, if appropriate, would depend on other non-RMS systems. The AN/WLD-1(V)1 RMS consists of a set of five major subsystems: (1) a Remote Minehunting Vehicle (RMV), (2) a Variable Depth Sensor (VDS), (3) a Data Link Subsystem (DLS), (4) a Remote Minehunting Functional Segment (RMFS), and (5) a Launch and Recovery Subsystem (L&RS). Figure 1 illustrates these five subsystems.

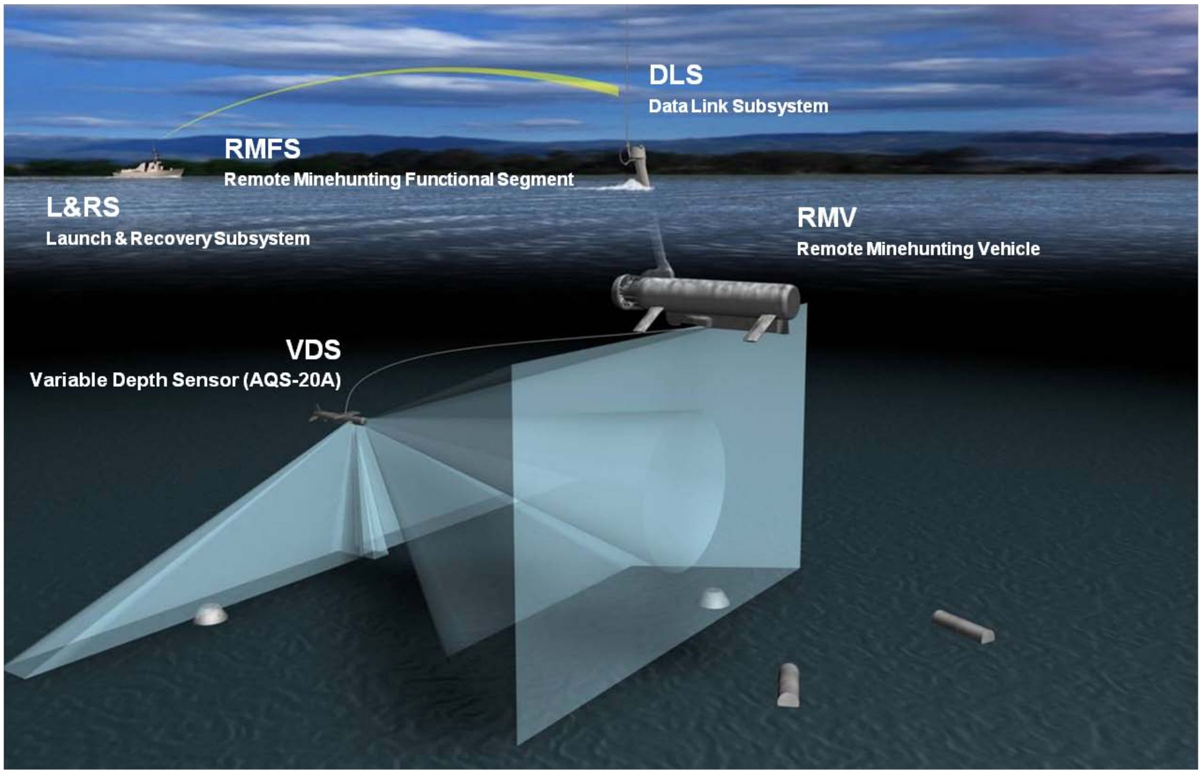

Figure 1. The Five Major Subsystems of the Remote Minehunting System

The RMV is an unmanned, high-endurance, radio-controlled, semi-submersible vessel that will conduct off-board mine reconnaissance at extended ranges from the host LCS. The only part of the unmanned semi-submersible vehicle visible above the waterline is the antenna mast, equipped with a video camera and snorkel. The RMV subsystem transports the sensors, processors, and data link equipment to the operations area where mine reconnaissance data will be collected, recorded, and transmitted via a data link to the LCS. The RMV tows the VDS.

The VDS is an actively controlled towed body (AQS-20A), providing a stable platform for the mine reconnaissance sensors and capable of both depth-specified and altitude-specified operation. The VDS houses acoustic sensor subsystems for detection, classification, and localization of bottom and moored mines and an electro-optic sensor for identification of bottom and moored mines. The AQS-20A was originally developed for, and is used by, the Navy's MCM helicopters.

The DLS consists of communications equipment and software that provides the Line-Of-Sight and Over-The-Horizon radio telemetry functions between the RMV and LCS.

The RMFS provides the capability to command and monitor the RMV; receive, process, and display mission data; conduct post-mission analysis; monitor performance, fault detection, and fault location; and provide network communications to the DLS.

The L&RS is composed of equipment located on the host ship designed to safely launch the RMV into the water, and then to recover the RMV. In addition, the L&RS will host the mission support equipment, which is composed of a facility and the necessary equipment to provide turn-around and component repair or replacement for the RMV, VDS, and DLS subsystems.

2. Timeline of Major Events

Figure 2 depicts the timeline of major events of the RMS program from Milestone II in 1999 through the Nunn-McCurdy breach in late 2009. The graphic is intended to portray the Navy's program management, the major milestones and designation decisions, contractual actions including reviews and deliveries of LRIP units, and development and operational test events.

Note that the test events are annotated with two metrics: availability and reliability. The operational availability (A_0) is a key performance parameter, and the mean time between operational mission failures (MTBOMF) is a key system attribute. For reference, the threshold values for A_0 and MTBOMF are 80 percent and 150 hours, respectively. The timing of these tests in relation to LRIP decisions is one of the major topics of this analysis.

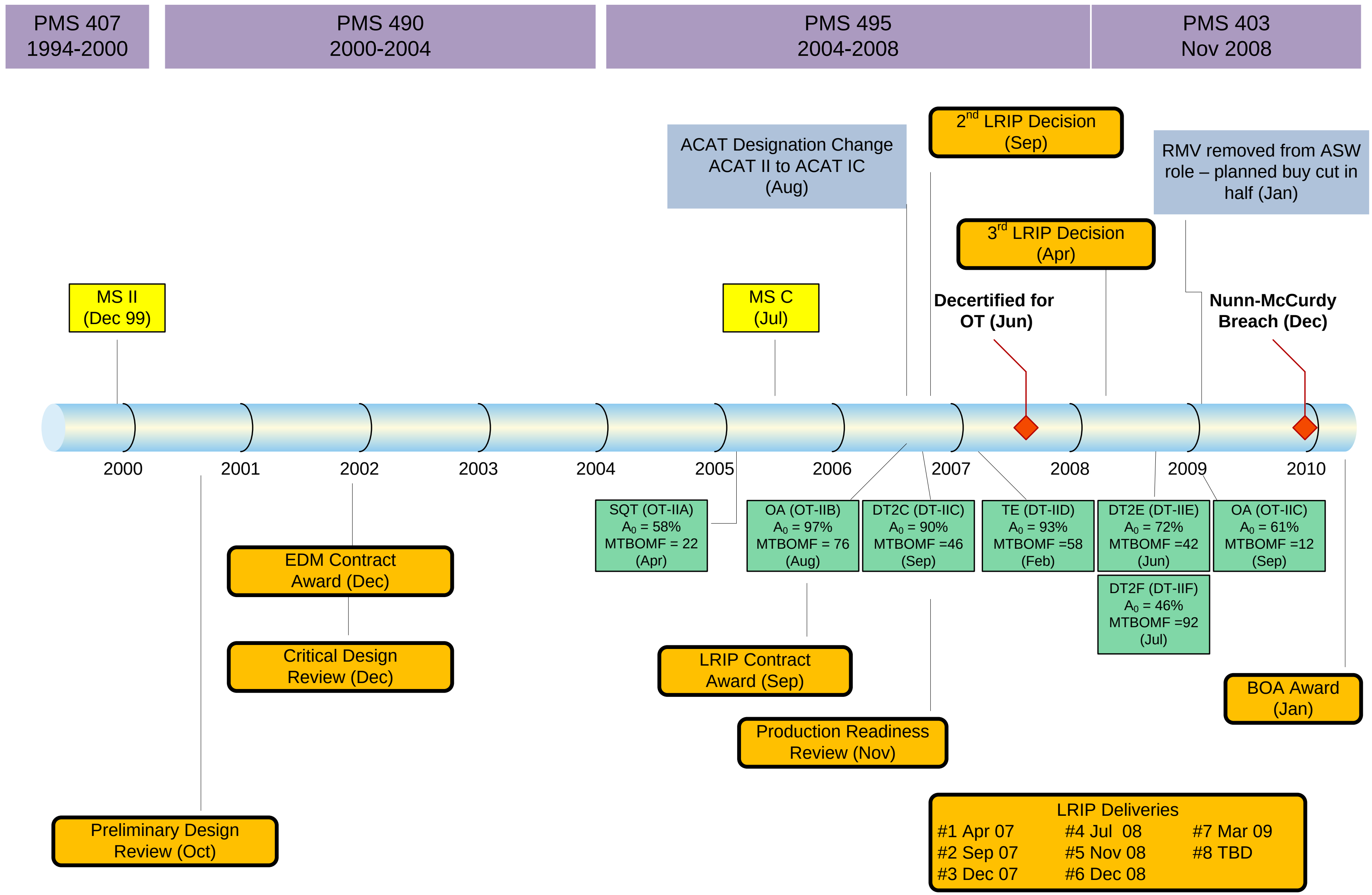

Figure 2. Timeline of Major Events

II. COST GROWTH AND NUNN-MCCURDY BREACH

As shown in Figure 2, RMS became an ACAT I program in August 2006. The program surpassed the ACAT I Research, Development, Test & Evaluation (RDT&E) cost threshold due to cost growth associated with unanticipated reliability issues.[1] In a memorandum dated 3 March 2006, the Navy submitted a reprogramming request to the Under Secretary of Defense Acquisition, Technology and Logistics (USD(AT&L)) to transfer $28 million into RDT&E. In the memo, the Assistant Secretary of the Navy (Research, Development & Acquisition) wrote, "During subsequent system qualification tests, reliability and suitability issues associated with the RMS vehicle were uncovered that now require additional manpower and validation testing to correct software and hardware in the RMS vehicle prior to commencing formal DT/OT [Developmental Testing/Operational Testing]."[2]

After becoming an ACAT I program, no additional cost growth was reported until the December 2009 Selected Acquisition Report (SAR). At that time, the Navy notified in a memo to Congress of a critical Nunn-McCurdy breach, reporting that the PAUC and APUC had risen 85.1 percent and 51.2 percent, respectively, since the October 2006 Acquisition Program Baseline (APB). In the December 2009 SAR, the program explained, "The breach in [PAUC] and [APUC] was caused by a reduction in production quantities and the use of an incorrect average unit cost as a basis of estimate in the 2006 APB. An additional contributing factor to the PAUC breach was the increase in RDT&E costs from the RGP [Reliability Growth Program]." IDA concurs with this assessment.

There are three relevant cost estimates for the RMS program: the 2006 APB, the 2009 SAR, and the 2009 memo to Congress. All calculations for cost growth are relative to the 2006 APB. The 2009 SAR reported cost growth from the 2006 APB of 79.5 percent in PAUC and 54.6 percent in APUC. The 2009 SAR, however, did not accurately capture the program's actual cost growth because the Presidential Budget Request (PBR) did not fully fund the RGP and did not delay production long enough to implement it successfully. (Note that DOD policy requires that SAR estimates comply with the PBR). The Navy's 2009 memo to Congress was not constrained

---

1 Delores M. Etter, ASN(RDA), Memo to USD(AT&L), 13 March 2006.

2 James E. Thomsen, PEO LMW, Memo to USD(AT&L) via ASN(RDA), 3 March 2006.

to match the budget request and was somewhat higher. IDA used the estimates from the Navy's Nunn-McCurdy report to Congress in its analysis, shown in Table 1.

Table 1. Cost Growth from 2009 Nunn-McCurdy Report to Congress

	APB 10/06	2009 SAR	2009 SAR %Δ	Navy's Estimate	Navy's Estimate %Δ
RDT&E	418.0	498.8	19%	548.1	31%
Procurement	886.6	672.4		660.3	
TOTAL	1,304.6	1,171.2		1,208.4	
EDM*	2	2		2	
Production	106	52	-51%	52	-51%
Total Qty	108	54	-50%	54	-50%
PAUC	12.1	21.7	79.5%	22.4	85.1%
APUC	8.4	12.9	54.6%	12.7	51.2%

***** Engineering Design Model

III. PROXIMATE CAUSES FOR COST GROWTH

A. REDUCED PROCUREMENT QUANTITY

The Littoral Combat Ship (LCS) is intended to be a small, fast, maneuverable, and relatively inexpensive member of the DD(X) family of ships. The ship will be reconfigurable for different roles, including anti-submarine warfare, mine countermeasures, anti-surface warfare, intelligence, surveillance and reconnaissance, homeland defense, maritime intercept, special operations, and logistics. Initially, the Navy intended to procure the RMS for both the mine countermeasures and anti-submarine warfare mission modules. Recently, the Navy decided to procure a different, more advanced system for anti-submarine warfare modules, thereby reducing its planned procurement quantity for the RMS from 106 to 52, resulting in higher average unit costs for the RMS. Many reasons factored into this decision, although according to internal Navy briefs regarding the FY 2010 President's Budget decisions, the issue with the system's reliability was not among them. Figure 3 shows the change in procurement quantities between the APB and the most recent Navy plan.

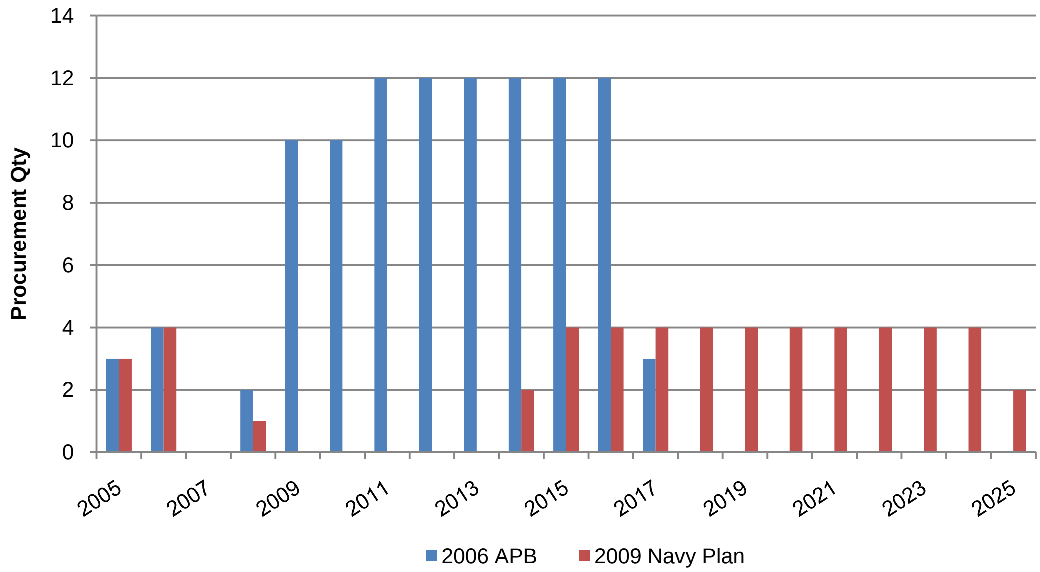

Figure 3. Procurement Quantities by Fiscal Year for the APB and New Navy Plan

A secondary effect of the reduced procurement quantities is a change to the procurement profile. The production rate fell from an average of 10 per year down to a maximum of four. The change to the procurement profile also introduced a five-year production gap. This gap is explained in the next section.

B. RELIABILITY ISSUES

The RMS has yet to successfully achieve its availability and reliability requirements. Due to the system's problems with availability and reliability, the Navy initiated an RGP in 2009 and added $120 million in RDT&E funding to support it. In order to fully execute the RGP, the program will cease production for five years.

C. INCORRECT ACQUISITION PROGRAM BASELINE ESTIMATE

The program office estimate of $6.3 million in the original APB was low compared to the actual $8 million average unit cost of the first two lots. Thus, the cost growth stemming from this is actually a cost correction; the original official estimate did not include some cost data from a negotiated contract. The contract costs and the APB estimates are listed in Table 2.

Table 2. The Actual Costs and APB Estimates for the First Eight LRIP Units

		TY$M	TY$M	TY$M	BY06$M	BY06$M	
LRIP	Lot #	Contract (9/05)	Actual Cost	APB (10/06)	Actual Cost	APB (10/06)	Δ
1	1	6.04	6.04	5.86	6.03	5.86	
2	1	9.48	9.48	5.87	9.47	5.87	
3	1	9.48	9.48	6.92	9.47	6.92	
4	2	7.48	7.48	6.93	7.24	6.70	
5	2	7.48	7.48		7.24		
6	2	8.48	8.48		8.20		
7	2	8.48	8.48		8.20		
		Average Actual (LRIP 1-7) =			7.98	6.34	+ 1.64
LRIP 8	3	10.80					

IV. ROOT CAUSES FOR COST GROWTH

IDA’s analysis traced the above proximate causes of cost growth to three root causes, two of which are directly related to their proximate causes (procurement reduction and the baseline cost error) and one that stems from poor government oversight, a symptom of which is the reliability issues mentioned above.

A. CHANGES IN PROCUREMENT QUANTITY

The Navy reduced its planned procurement quantity from 106 to 52, as it decided to procure a different, more advanced system for anti-submarine warfare mission module on the Littoral Combat Ship. The decision was exogenous to the program; however, the reduced procurement quantity was a significant root cause for the higher average unit costs for the RMS.

The original RDT&E cost estimate of $418 million is now spread over half as many units, which also includes both the production and two Engineering Development Model (EDM) units. This leads to a PAUC increase of $3.87 million. The reduced procurement also truncates the learning curve from 106 units to 52, increasing the PAUC by $0.22 million and the APUC by $0.37 million. A learning curve plot is shown later (Figure 5). Additionally, there is an annual fixed cost of $5.28 million associated with the program that needs to be considered in this truncation. The original program was intended to run for 13 years to complete 106 units. If we assume the same production ramp, the program would only require eight years to complete 52 units. This fixed cost spread among fewer units increases the PAUC by $0.15 million and the

APUC by $0.17 million. These factors together contribute to an increase in PAUC by $4.24 million and an increase to APUC by $0.54 million.[3]

Furthermore, the Navy lowered the planned production rate from an average of 10 per year down to a maximum of four, adding $0.93 million to the PAUC and $0.98 million to the APUC. The reason for reducing the production rate is not known to us.

The combined effect of the reduced quantity and the change to the procurement profile increases the PAUC by $5.17 million, or 43 percent, and the APUC by $1.52 million, or 18 percent. The cost effect of the five-year gap in production is related to the RGP and will be addressed in the next section.

B. POOR PERFORMANCE BY THE GOVERNMENT

The Navy failed to follow appropriate acquisition policies and procedures in three significant ways. First, inadequate contract planning, due to schedule pressure and personnel shortages, caused the government to bear the majority of the cost and risk during the abnormally long, 385-day undefinitized period for the 2005 Low Rate Initial Production (LRIP) letter contract. The Federal Acquisition Regulation Defense Supplement states that letter contracts should be definitized within 180 days.[4]

Second, the Navy awarded the LRIP contract based on build-to-print terms that was Firm Fixed Price (FFP) for the hardware and Cost Plus Fixed Fee (CPFF) for engineering services, without adequately reviewing the contractor drawings, resulting in subsequent engineering change proposals and delays at government expense. The Program Manager in the Mine Warfare Office (PMS 495) approved the total technical data package submitted by Lockheed Martin in September 2007; however, the program office individually approved and signed less than 10% of the drawings that composed the data package.[5]

Third, the immature design resulted in early developmental and production units falling short of the system's performance thresholds for availability and reliability during testing. Although the reliability issues became apparent as early as 2005, the program office did not sufficiently address them before awarding any of the three LRIP contracts. The effectiveness of

---

3 The calculation assumes a 95 percent learning curve, a fixed cost of $5.28 million per year, and a first unit cost of $9.25 million. These values are consistent with the computation method used by the Navy. All costs are given in 2006 base year dollars. The complete calculation is included in Appendix A.

4 U.S. Government Accountability Office, "DEFENSE CONTRACTING: Use of Undefinitized Contract Actions Understated and Definitization Time Frames Often Not Met," GAO-07-559, June 2007.

5 G. B. Saroch, PEO LMW, PMS 495, Memo to Lockheed Martin Maritime Systems & Sensors. 18 Sept. 2007. CAPT Paul Siegrist, PEO LMW, PMS 403. Meeting, Navy Yard, 9 April 2010.

the program's test-fix-test reliability improvements can be assessed using a Duane Plot, as shown in Figure 4. The dashed red line indicates the threshold value of 150 hours for the system's MTBOMF as defined in the Operations Requirements Document (ORD). The Navy states the 150 hour threshold requirement is outdated, since it did not consider the RMS role on the Littoral Combat Ship, and a more recent assessment of requirements places the threshold value at 75 hours, which is represented by the solid red line. The solid blue line indicates the reliability growth of the RMS since testing began in 2005. There are two key features to note: first, the system's reliability is below the minimum requirement of 75 hours and, second, the rate of reliability growth is slow. The maximum likelihood estimate of reliability growth is 0.23, according to the Crow-AMSAA model, and the 90 percent upper and lower confidence bounds are 0.32 and 0.18, respectively. Generally, the reliability improvement slope across almost all reliability improvement tests should fall between 0.3 and 0.6, where the lower end describes a minimally effective test and the higher end approaches the state of the art for reliability improvement activities.[6] On this standard, the RMS program's reliability growth since 2005 can be considered only marginal at best, especially during the later period of testing.[7] Some in the Navy might reason that the Duane methodology for accessing reliability growth is inaccurate, but the fact remains that after five years, the system has been unable to achieve an even minimally acceptable level of reliability.

The $120 million RGP was instituted as a consequence of the reliability problems and increased the PAUC by $2.22 million, and the five-year gap in procurement necessitated by the RGP further increases the PAUC by $0.49 million and the APUC by $0.51 million. The combined effects on cost growth due to reliability issues are an increase in the PAUC of $2.71 million, or 22 percent, and an increase in the APUC of $0.51 million, or 6 percent.

---

6 *NIST/SEMATECH e-Handbook of Statistical Methods*, http://www.itl.nist.gov/div898/handbook/, February 2010.

7 Although the slope through all the points is 0.23, the improvement after the first two points is considerably lower.

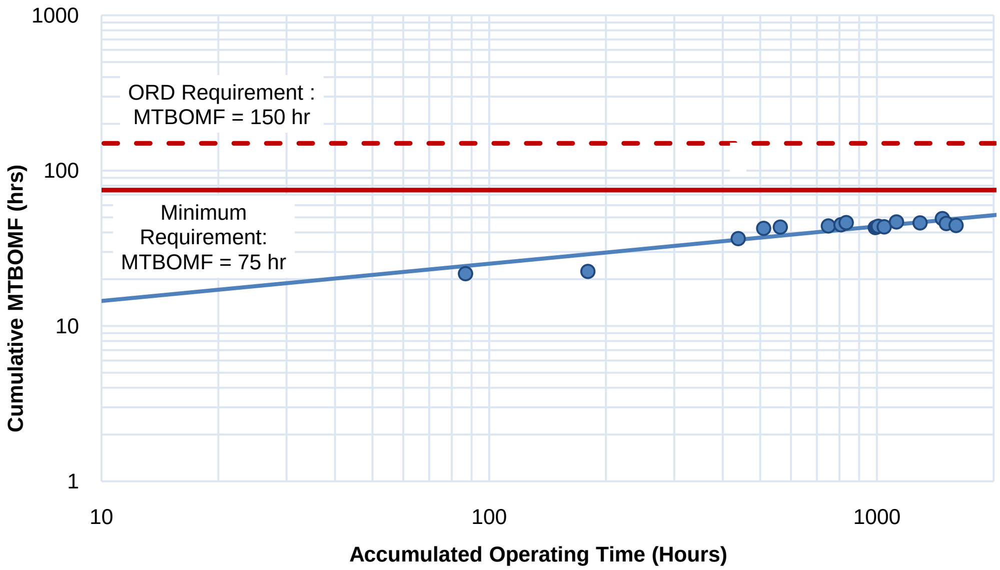

Figure 4. Duane Plot of RMS Test Data Since 2005

C. ERRONEOUS BASELINE ESTIMATES FOR COST

The APB cost estimates used unreasonably optimistic production projections based on an erroneous first unit cost. The program based the estimate on the average price of only the recurring hardware production for the four LRIP units in Lot 2 (LRIP 4-7). This price did not include sustaining hardware engineering, software engineering, integration and testing, or program management. However, the contract price for those units includes those elements and is significantly higher.

Figure 5 plots the hardware unit cost as a function of cumulative quantity using a 95 percent learning curve.[8] The plot shows the difference between the APB assumption using the incorrect first unit cost (lower solid curve) and actual unit cost based on the contract (upper dashed curve). In addition to neglecting the engineering and integration costs, the first unit cost estimate also did not account for cost associated with some government furnished equipment (GFE) in early lots. The plot shows the actual cost of LRIP 1 when accounting for the additional $4 million of GFE.

The unrealistic hardware cost estimate erroneously reduced the APB numbers, causing the current estimates to indicate cost growth. This effectively increased the PAUC by $1.68 million,

8 Note the hardware unit cost does not include support cost, which the Navy estimates as $2.7 million per unit. Taking this additional cost into consideration would indicate that the overall cost growth due to reduced quantities is under-reported.

or 14 percent, and the APUC by $1.74 million, or 21 percent. This omission was not corrected by the Navy Acquisition Executive when the program was upgraded to ACAT 1C in 2007.

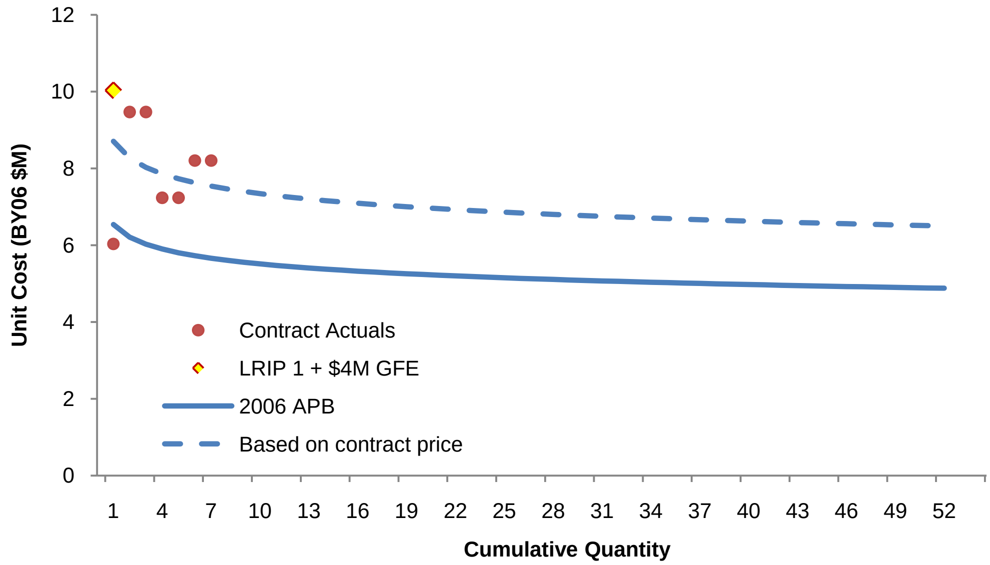

Figure 5. Actual Contract Prices Shown with APB-assumed Learning Curve (solid) and Corrected Curve (dashed)

V. CONCLUSION

In December 2009 the Navy notified Congress of a critical Nunn-McCurdy breach in both the PAUC and APUC thresholds of the RMS program. The Navy reported that the PAUC and APUC had risen more than 85 percent and 50 percent, respectively, from the APB.

IDA's analysis traced this cost growth to three root causes, two of which are directly related to their proximate causes (procurement reduction and a baseline cost error) and one that manifested itself in reliability issues (government failure of oversight).

Table 3 apportions the cost growth to the major drivers and their constituent components.

Table 3. 2009 Nunn-McCurdy Cost Growth Apportioned among the Major Drivers

In $M BY FY 2006	Original APB	Current Navy Estimate	Delta	% Growth
PAUC	**12.1**	**22.4**	**+10.3**	**85.1%**
	Qty Reduction & Profile Change		**+ 5.17**	**43%**
	Quantity Reduction		*+ 4.24*	35%
	Reduced Production Rate		*+ 0.93*	8%
	Reliability Issues		**+ 2.71**	**22%**
	Reliability Growth Program		*+ 2.22*	18%
	Five-year Gap		*+ 0.49*	4%
	Unrealistic unit cost estimation		**+ 1.68**	**14%**
	Other		**+ 0.74**	**6%**
APUC	**8.4**	**12.7**	**+ 4.3**	**51.2%**
	Qty Reduction & Profile Change		**+ 1.52**	**18%**
	Quantity Reduction		*+ 0.54*	6%
	Reduced Production Rate		*+ 0.98*	12%
	Reliability Issues: Five-year Gap		**+ 0.51**	**6%**
	Unrealistic unit cost estimation		**+ 1.74**	**21%**
	Other		**+ 0.53**	**6%**

APPENDIX A:
CALCULATIONS

The Navy reduced its planned procurement quantity from 106 to 52, as it decided to procure a more advanced system for the Littoral Combat Ship (LCS) Anti-Submarine Warfare modules. Additionally, the Navy will require an additional $120 million in RDT&E to execute the Reliability Growth Program (RGP) and will cease production of the RMS for five years to implement it. This Appendix details the cost growth associated with these decisions.

All costs are in 2006 base year dollars.

Changes in Procurement Quantity: First, the original RDT&E cost estimate of $418 million is now spread over half as many units. Since the program includes two engineering design models in addition to the procurement quantity, the total program acquisition fell from 108 to 54.

$$\Delta \text{ PAUC from RDT\&E} = +\left(\frac{\$418\text{M}}{54} - \frac{\$418\text{M}}{108}\right) = +\$3.87\text{M}$$

The second aspect of unit cost growth is related to the learning curve being truncated at 52 rather than 106 units.[1] The standard learning curve is given by the formula

$$\text{Cost of Unit } Q = T_1 Q^{\beta},$$

where T_1 is the theoretical first unit cost, Q is the cumulative quantity, and β is the learning curve exponent defined as $ln(slope)/ln(2)$. Assuming that T_1 is $9.25 million and the learning slope is 95 percent, the increase in the unit cost because of the learning slope truncation is

$$\Delta \text{ PAUC from learning curve} = +\left(\frac{\sum_{i=1}^{52} T_1 Q_i^{\beta}}{54} - \frac{\sum_{i=1}^{106} T_1 Q_i^{\beta}}{108}\right) = +\$0.22\text{M}$$

$$\Delta \text{ APUC from learning curve} = +\left(\frac{\sum_{i=1}^{52} T_1 Q_i^{\beta}}{52} - \frac{\sum_{i=1}^{106} T_1 Q_i^{\beta}}{106}\right) = +\$0.37\text{M}$$

[1] The learning curve calculation assumes that the EDMs are not considered as part of the learning curve since they are built by engineers, not technicians.

Additionally, there is an annual fixed cost of $5.28 million associated with the program that needs to be considered in this truncation. The original program was intended to run for 13 years to complete 106 units. If we assume the same production ramp, the program would only require eight years to complete 52 units.

$$\Delta \text{ PAUC from fixed cost} = +\left(\frac{\$5.28\text{M}*8}{54} - \frac{\$5.28\text{M}*13}{108}\right) = +\$0.15\text{M}$$

$$\Delta \text{ APUC from fixed cost} = +\left(\frac{\$5.28\text{M}*8}{52} - \frac{\$5.28\text{M}*13}{106}\right) = +\$0.17\text{M}$$

Although the original program intended to complete 106 production units in 13 years, the new plan will produce 52 units over 21 years. We will account for the production gap of five years in the next section, so for the purpose of reduced production rate, we will consider the 52 units to be produced over 16 years. The relative increase due to the fixed annual costs is

$$\Delta \text{ PAUC from changed rate} = +\left(\frac{\$5.28\text{M}*16}{54} - \frac{\$5.28\text{M}*13}{108}\right) = +\$0.93\text{M}$$

$$\Delta \text{ APUC from changed rate} = +\left(\frac{\$5.28\text{M}*16}{52} - \frac{\$5.28\text{M}*13}{106}\right) = +\$0.98\text{M}$$

Consequently, the total change in PAUC and APUC due to the reduced quantity is:

$$\begin{aligned}\Delta \text{ PAUC} &= \text{RDT\&E} + \text{Learning Curve} + \text{Fixed Cost} + \text{Rate Change} \\ &= +(\$3.87 + \$0.22 + \$0.15 + \$0.93) \\ &= +\$5.17\text{M}\end{aligned}$$

$$\begin{aligned}\Delta \text{ APUC} &= \text{Learning Curve} + \text{Fixed Cost} + \text{Rate Change} \\ &= +(\$0.37 + \$0.17 + \$0.98) \\ &= +\$1.52\text{M}\end{aligned}$$

Reliability Issues: The problems in reliability affect the program in two ways. First, an increased investment in RDT&E of $120 million and, second, the program production is delayed five years to allow time to execute the reliability growth program. First the additional $120 million is spread across 54 units.

$$\Delta \text{ PAUC from RDT\&E} = +\left(\frac{\$120\text{M}}{54}\right) = +\$2.22\text{M}$$

Second, the annual fixed cost for the program is $5.28 million, so the five-year delay results in an increase in unit cost of:

$$\Delta \text{ PAUC from delay} = \frac{\$5.28\text{M}*5}{54} = \$0.49\text{M}$$

$$\Delta \text{ APUC from delay} = \frac{\$5.28\text{M}*5}{52} = \$0.51\text{M}$$

Consequently, the total change in PAUC and APUC due to the reliability issues is:

$$\begin{aligned} \Delta \text{ PAUC} &= \text{RDT\&E} + \text{Delay} \\ &= +(\$2.22 + \$0.49) \\ &= +\$2.71\text{M} \end{aligned}$$

$$\begin{aligned} \Delta \text{ APUC} &= \text{Delay} \\ &= +\$0.51\text{M} \end{aligned}$$

APPENDIX B:
PROBABILITY RATIO SEQUENTIAL TESTING

The standard Probability Ratio Sequential Test (PRST) should be applied when a sequential test with normal (10 percent to 20 percent) producer's and consumer's risk is desired. Consumer's risk (β) is the probability of accepting equipment with a true mean-time-between-failure (MTBF) equal to the lower test MTBF (θ_1). The probability of accepting equipment with a true MTBF less than θ_1 is less than β. Producer's risk (α) is the probability of rejecting equipment which has a true MTBF equal to the upper test MTBF (θ_0). The probability of rejecting equipment with a true MTBF greater than θ_0 is less than α.

The sequential test is based on the assumption that the underlying distribution of times-between-failures is exponential. PRST plans will accept material with a high MTBF or reject material with a very low MTBF more quickly than fixed-duration test plans having similar risks and discrimination ratios, where the discrimination ratio is defined as $d = \theta_0/\theta_1$. Total test time may vary significantly; therefore, program cost and schedule must be planned to truncation.

Using the PRST technique shown in Figure B-1, the Navy had sufficient information after the first system qualifying test (SQT I) in 2005 to conclude that the initial design did not meet the reliability requirements. The plot assumes a consumer and producer risk of 10 percent. The lower test MTBOMF is 60 hours and the upper test MTBOMF is 150 hours.[1] The data points are labeled with test names and dates. Because reliability was clearly unsatisfactory, the program should not have proceeded to LRIP without a robust RGP in place. Nevertheless, despite the system's poor test performance and minimal reliability growth, the Navy committed to an initial and two subsequent LRIP buys. The Navy procured three units in July 2005, four units in September 2006, and one unit in April 2008, at a total cost of $103.7 million.

---

1 These levels were chosen for illustrative purposes, but for any reasonable combination of values, the data indicate the system should have been rejected, or, at best, testing should have continued.

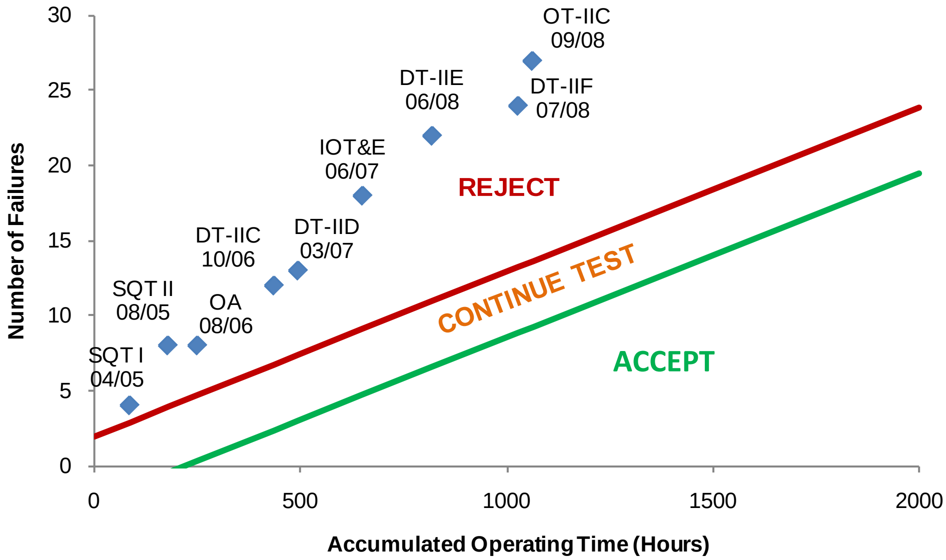

Figure B-1. Probability Ratio Sequential Test Results

APPENDIX C:
ACRONYMS

APB	Acquisition Program Baseline
APUC	Average Procurement Unit Cost
ASN(RD&A)	Assistant Secretary Navy Research, Development & Acquisition
CPFF	Cost Plus Fixed Fee
DLS	Data Link Subsystem
DT	Development Test
FFP	Firm Fixed Price
GFE	Government Furnished Equipment
IDA	Institute for Defense Analyses
L&RS	Launch and Recovery Subsystem
LCS	Littoral Combat Ship
LRIP	Low Rate Initial Production
M	million
MCM	Mine Countermeasures
MTBOMF	Mean Time Between Operational Mission Failures
OT	Operational Test
PAUC	Program Acquisition Unit Cost
RGP	Reliability Growth Program
RMFS	Remote Minehunting Functional Segment
RMS	Remote Minehunting System
RMV	Remote Minehunting Vehicle
SAR	Selected Acquisition Report
USD(AT&L)	Under Secretary of Defense Acquisition, Technology and Logistics
VDS	Variable Depth Sensor

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
xx-06-2010	Final	Apr - May 2010

4. TITLE AND SUBTITLE
"Remote Minehunting System: Root Cause Analysis"

5a. CONTRACT NUMBER
DASW01-04-C-0003

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Bailey, John, W.
Bronson, Patricia, F.
Frazier, Thomas, P.
Gallo, Alexander, O.
Lo, Tzee-Nan K.
O'Connell, Caolionn, L.

5d. PROJECT NUMBER

5e. TASK NUMBER
AY-7-3223

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Institute for Defense Analyses
4850 Mark Center Drive
Alexandra, VA 22311-1882

8. PERFORMING ORGANIZATION REPORT NUMBER
IDA Paper P-4600

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Director, Performance Assessments and Root Cause Analyses
Office of the Assistant Secretary of Defense for Acquisition
3620 Defense Pentagon
The Pentagon, Room 5A1082
Washington, DC 20301-3620

10. SPONSOR/MONITOR'S ACRONYM(S)
D, PARCA

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited. (September 1, 2011)

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Remote Minehunting System (RMS) is a mine reconnaissance system for the detection, classification, identification, and localization of bottom and moored mine-like objects in shallow and moderately deep water. In December 2009 the Navy notified Congress of a critical Nunn-McCurdy breach in both the Program Acquisition Unit Cost (PAUC) and Average Procurement Unit Cost (APUC). The Navy reported that the PAUC had risen 85.1 percent, from $12.1 million in the October 2006 Acquisition Program Baseline (APB) to $22.4 million. Over the same time span the APUC rose 51.2 percent, from $8.4 million to $12.7 million.
A root cause analysis revealed three major reasons for the cost growth. First, the Navy reduced its planned procurement quantity from 106 to 52 as it decided to procure a different, more advanced system for the Littoral Combat Ship (LCS) Anti-Submarine Warfare modules. Second, there were significant failures of governance by the Office of the Assistant Secretary of the Navy (OASN) (Research, Development & Acquisition (RDA)). Third, the APB cost estimates used unreasonably optimistic production projections based on an erroneous first unit cost.

15. SUBJECT TERMS
Remote Minehunting System (RMS); Nunn-McCurdy Breach; Program Acquisition Unit Cost (PAUC); Average Procurement Unit Cost (APUC); Root Cause Analysis; Cost Analysis; Cost Growth; Availability; Reliability

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
Unclassified	Unclassified	Unclassified	Same as Report	27	Bliss, Gary, R.

19b. TELEPHONE NUMBER *(Include area code)*
571-256-0646

Reset

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18