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EMBEDDED COMPUTERS

Navy Not Ready to Buy Avionics Computers for Its LAMPS Mk I Helicopters



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Information Management and
Technology Division

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May 31, 1990

The Honorable John Conyers, Jr.
Chairman, Subcommittee on Legislation
and National Security
Committee on Government Operations
House of Representatives

The Honorable Frank Horton
Ranking Minority Member, Subcommittee
on Legislation and National Security
Committee on Government Operations
House of Representatives

The Navy plans to spend \$65.7 million for 150 avionics¹ computer systems as part of a \$896 million overall upgrade to its Light Airborne Multipurpose System (LAMPS) Mk I helicopter. This helicopter is used for antisubmarine warfare, and it will rely extensively on the new computer-based avionics system to perform this mission. This avionics computer system will allow in-flight processing of data from sensors that detect submarines. Currently, helicopters send the sensor data to shipboard computer systems, wait for the ship to analyze the data, and transmit it back to the helicopter.

The Navy has already spent \$5.3 million to buy 12 of the avionics computer systems, and in June 1990 it will decide whether to buy another 15 costing \$6.6 million. While the cost of all avionics computer systems to be bought is relatively small, these systems directly affect the mission effectiveness of an \$896 million program to upgrade the helicopters' airframes and avionics suites.

This report responds to your office's October 1989 request to review the Navy's acquisition of computer systems embedded in selected antisubmarine warfare systems, and is part of your overall request to review computer systems that are embedded in Defense weapon systems. Our

¹ Avionics (i.e., aviation electronics) computers receive data from sensors (e.g., sonobuoys, radar, cockpit switches, temperature probes, accelerometers, rate gyros, etc.), process the data on a "real time" basis and send the processed data to other systems (e.g., cockpit displays, aeronautical control surfaces, other computers, etc.).

testing requirements for the avionics computer system because of its early perception that the system was just a minor modification of an existing computer system. In light of the significant software and hardware changes the system requires and the program office's limited test plans, we believe that this oversight office should immediately begin supervising the program and ensuring that the requisite testing is performed.

Background

The Navy's LAMPS Mk I is a ship-based helicopter that will rely extensively on computer systems embedded in its avionics to perform its basic mission of antisubmarine warfare (i.e., locating, identifying, following, and engaging enemy submarines). The computer-based avionics system will keenly sharpen the helicopter crew's ability to find, recognize, and target submarines through the use of sensors, submarine identification software, and data display devices. The effectiveness of these computerized systems is a critical variable in determining how well the Navy's billion dollar fleet of LAMPS Mk I helicopters can meet its mission requirements.

The Navy introduced the LAMPS Mk I helicopter into its fleet in 1973 to collect sensor data on submarine activity and send it to the helicopter's home ship for analysis and display. In 1986, the Director of Naval Reserve, Chief of Naval Operations, changed the helicopter's operational requirement to include in-flight processing and display, thus reducing its reliance on the communication link between the helicopter and its ship. The reason for this expanded requirement was to improve the Navy's mission effectiveness by (1) saving critical seconds in detecting, identifying, and countering enemy submarines, and (2) allowing the helicopter to perform its mission beyond data-link range with its ship.

To meet the new requirement, the Navy is developing and installing a new avionics computer system—designated the AN/ASN-150A—as part of an overall program to upgrade the helicopters.⁴ The Navy plans to modify 103 helicopters,⁵ at an estimated cost of \$896 million.⁶ Of this,

⁴In addition to the avionics computer and related equipment, LAMPS Mk I helicopters will receive new engines, and some will also get airframe modifications and rotor blades.

⁵Includes 42 new helicopters under contract and 61 active helicopters currently in the fleet.

⁶Extrapolated from program manager's recurring cost estimate of \$8.7 million for each helicopter. According to the program manager, the total modification program cost is an estimate because the effort has not been programmed nor funded.

when they are cheaper to correct. Both developmental and operational testing are critical to demonstrate that a system is ready for production.

Navy Does Not Plan to Operationally Test the System Before Production

Despite its own requirements to operationally test systems and subsystems before either a limited production (milestone IIIA) or full-rate production (milestone IIIB) decision,⁸ the Navy does not plan to operationally test the AN/ASN-150A avionics computer system before a June 1990 decision to buy 15 of them and initially produce the modified helicopter. While the program manager admits that this testing approach falls short of Navy requirements and introduces increased risk into the program, this official stated that it strikes a realistic balance between a prudent system engineering approach and a need to obligate funds already appropriated by the Congress.

According to the current program manager, development of the AN/ASN-150A computer system was initially viewed as a low-risk modification of a computer system already approved for use in another aircraft. Accordingly, in April 1989, the previous program manager requested an extension of application⁹ for the computer system, and the Director, Research and Development, Test and Evaluation, Office of the Chief of Naval Operations, approved the extension in May 1989.

In our opinion, the Navy's portrayal of the AN/ASN-150A as a low-risk, minor modification of an existing and approved computer system was not accurate, and has placed the Navy in its current dilemma of whether or not to obligate funds already appropriated, buy the computer systems, and initially produce the helicopters, before it has first operationally tested them. We found that the AN/ASN-150A is significantly different from the already approved computer system. Specifically, the former computer system performed solely tactical navigation functions. In contrast, the modified computer system will perform not only navigation functions, but also in-flight sensor processing functions associated

⁸Office of the Chief of Naval Operations Instruction 3960.10C, Test and Evaluation, states that upgrades to production systems that incorporate new computer systems are to be operationally tested in order to ensure that system performance has been maintained or improved and meets Navy requirements. Further, Instruction 5000.42, Research, Development, and Acquisition Procedures, requires successful operational testing of subsystems, like the AN/ASN-150 avionics computer, before authority to buy the subsystem is granted.

⁹The extension of application is an exemption from the operational testing requirement. It is allowed for subsystems already in use for similar applications in other aircraft and when "there are no complicating circumstances such as software changes."

Developmental Testing Revealed Software Problems and Is Not a Substitute for Operational Testing

Even though the Navy has performed developmental testing, including laboratory integration testing, this testing is not a substitute for operational testing. Moreover, completed integration tests have revealed 250 uncorrected software discrepancies, 20 of which could severely affect the avionics computer system's ability to accurately locate a moving target and launch a torpedo.

The Navy has elected to treat the AN/ASN-150A as an extension of application and base its upcoming procurement decision solely on developmental testing in a laboratory. In our opinion, this developmental testing does not substitute for operational testing. Navy instructions require operational testing by an independent test activity, and nothing in these instructions indicates that developmental tests conducted by the contractor may be used in its place. Additionally, the official in the Navy's Operational Test and Evaluation Force who is responsible for coordinating operational testing of this program said that developmental testing in a laboratory is not an adequate substitute because it cannot fully simulate true operational conditions; and according to the program's test and evaluation master plan, one of the critical issues to be resolved for this system is whether the integrated avionics system (i.e., the computer and sensors) can detect a submarine under actual mission conditions. Additionally, the contractor, overseen by the program office, has performed all developmental testing to date. An independent test activity has not yet conducted any testing, and Navy instructions require independent testing prior to a production decision.

Moreover, we found that the Navy's laboratory integration testing on the AN/ASN-150A avionics computer system has in fact not realistically simulated the strain the software will be under while actually tracking submarines. That is, the laboratory stress and performance testing has not subjected the avionics system's software programs to the volumes of data that would be received simultaneously from three different types of sensors while tracking submarines under combat conditions. The reason is that the Navy does not have the capability to simulate all the sensor inputs, let alone simulate them simultaneously. Specifically, only data inputs from the acoustic sensor (device dropped from the helicopter into the water to detect underwater sounds) and the magnetic anomaly detector (sensing device towed behind the helicopter to detect the magnetic density of submarines) have been simulated. The radar data inputs have not. According to program officials, the radar inputs have not been evaluated because it would be too costly to expand developmental testing beyond what is already planned. In our opinion, such limitations to integration testing are all the more reason to ensure that

existing computer system. This office did, however, require that operational testing be conducted before deciding whether to deploy the modified helicopter, a decision currently planned for March 1991. As stated earlier, we believe that the Office of the Assistant Chief of Naval Operations (Air Warfare) decision to grant the extension of application and waive operational testing before a production decision was inherently risky and inappropriate.

We also found that the Office of the Assistant Chief of Naval Operations (Air Warfare) did not ensure there was specified performance criteria in the AN/ASN-150A development contract before allowing the program to proceed. Specifically, Defense Standard 2167A, Defense System Software Development, states that system specifications are provided to contractors as a requirements baseline for software development; and Navy Instruction 3960.10, Test and Evaluation, requires that software performance criteria be established and used as performance measures in testing. According to a Defense report on software development problems, if such criteria are not specified, the cost, schedule, and quality of the entire software development effort will be jeopardized.¹²

The Navy contracted for the LAMPS Mk I modification in February 1987 without a system specification that defined AN/ASN-150A performance requirements. In lieu of such a specification, the software subcontractor used a preliminary specification, and the Navy began testing the software in September 1989 without such criteria. In December 1989, the Navy finally incorporated the specification into the modification contract. However, these add-on requirements cost the Navy an extra \$2.1 million, and caused the modification program to slip 4 months.

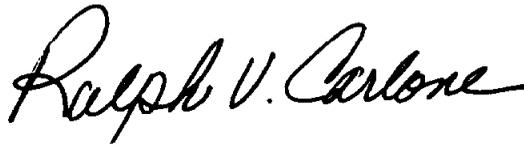
Conclusions

The Navy will soon face pivotal decisions on whether to buy more avionics computer systems and begin modifying its billion dollar fleet of LAMPS Mk I helicopters. These helicopters will heavily depend on their new avionics computer systems, which will ultimately cost the Navy \$65.7 million to buy and install on these aircraft as part of a \$896 million LAMPS Mk I modification program.

Clearly, making such a decision requires, at a minimum, sufficient testing to know whether the integrated avionics system will perform as intended. In our opinion, this information does not currently exist, and

¹²Proceedings of the Joint Logistics Commanders Joint Policy Coordinating Group on Computer Resource Management (Aug. 1979).

As arranged with your offices, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the date of this letter. At that time, we will send copies to the Chairman, Senate and House Appropriations Committees; the Secretaries of Defense and the Navy; and to other interested parties. We will also make copies available to others upon request. This report was prepared under the direction of Samuel W. Bowlin, Director, Defense and Security Information Systems, who can be reached at (202) 275-4649. Other major contributors are listed in appendix III.



Ralph V. Carlone
Assistant Comptroller General

Near-Term Funding Requirements for Modification Kits^a

In millions of dollars

Fiscal Year	Entire Kits	AN/ASN-150A
1989	\$45.0	\$2.6
1990	55.3	2.6
1991	54.8	2.6
1992	53.4	2.6
1993	48.8	2.6
1994	30.1	1.3
Total	\$287.4	\$14.3

^aDoes not include funding requirements for spares. Including spares, the combined fiscal year 1989/1990 funding requirements for the AN/ASN-150A would be \$6.6 million.

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Objectives, Scope, and Methodology

In October 1989, the Subcommittee on Legislation and National Security, House Committee on Government Operations, expressed interest in the Navy's plans to acquire embedded computer systems for selected anti-submarine warfare systems, and requested that we determine whether (1) the Navy plans to conduct adequate developmental and operational testing of these embedded computer systems before buying them, and (2) Navy management is overseeing the acquisition of them. This request relates to an overall request from the Chairman and the Subcommittee's Ranking Minority Member to review computer systems that are embedded in Defense weapon systems.

To accomplish our objectives, we reviewed Defense and Navy instructions and standards governing the development, testing, and management oversight of embedded computer systems for weapon systems. We also reviewed relevant program documentation addressing the acquisition strategy, test plans and results, and schedule and funding requirements for both the AN/ANS-150A avionics computer system as well as the entire helicopter modification program. Additionally, we interviewed program officials responsible for managing various aspects of the program, including the avionics computer system's development and testing. We also interviewed Chief of Naval Operations officials responsible for overseeing the program, and reviewed documentation relating to the discharge of this oversight responsibility. Further, we discussed test plans and results with officials from the Navy test activities involved in developmental (functional and integration) and operational testing, and we observed the execution of integration testing at the contractor's facilities.

We performed our work between October 1989 and March 1990, primarily at the LAMPS Mk I program office within the Naval Air Systems Command in Arlington, Virginia, and the Naval Air Development Center in Warminster, Pennsylvania. We also visited the Navy's Operational Test and Evaluation Force in Norfolk, Virginia, and the contractor's laboratory in Northridge, California.

As requested by the Chairman's office, we did not obtain official agency comments on a draft of the report. However, we discussed its contents with Navy and Office of the Secretary of Defense officials, and have incorporated their comments where appropriate. We conducted our review in accordance with generally accepted government auditing standards.

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Abbreviations

GAO	General Accounting Office
IMTEC	Information Management and Technology Division
LAMPS	Light Airborne Multipurpose System

the Navy's plans for testing prior to its computer system purchase and initial production decisions will not provide it. Further, the results of laboratory integration testing have revealed software discrepancies of such magnitude that the Navy cannot justify going beyond the laboratory test environment at this time, much less make a decision to buy more computer systems and initially produce the modified aircraft. Unless the Navy changes its approach to testing, discovery of AN/ASN-150A performance problems will likely be delayed to a time when their correction will be more costly than necessary. In fact, estimates show that software problems found late in the development process can cost six to ten times more to correct than if found early in the process. Moreover, they may prevent the system from ever performing as originally intended.

The Office of the Assistant Chief of Naval Operations (Air Warfare), the office responsible for overseeing the avionics computer system's development and testing, has not assured compliance with embedded computer system development and testing requirements because it agrees with the program office's initial position that the computer system is a minor modification. In our opinion, this position is inappropriate, and attention by the Office of the Assistant Chief of Naval Operations (Air Warfare) to the program office's approach to development and testing of the AN/ASN-150A may prevent further deviations from Navy requirements.

Recommendations

We recommend that the Secretary of the Navy direct the LAMPS Mk I program office to defer buying the AN/ASN-150A computer systems until complete and thorough operational testing demonstrates that the avionics systems will satisfy mission requirements. We further recommend that the Secretary direct the Assistant Chief of Naval Operations (Air Warfare) to take a more active role in overseeing the program and ensure that Navy requirements for AN/ASN-150A operational testing are met.

As requested by your offices, we did not obtain official agency comments on a draft of this report. However, we discussed its contents with Navy and Office of the Secretary of Defense officials, and have incorporated their comments where appropriate. Our work was performed in accordance with generally accepted government auditing standards, between October 1989 and March 1990.

operational testing precedes a decision to buy any more avionics computer systems to initially modify the helicopters.

Laboratory integration testing conducted by the program test team in October 1989 revealed hundreds of software discrepancies. In February 1990, we observed retests and found that while some discrepancies had been corrected, additional discrepancies were found. As of March 1, 1990, 250 of 536 cumulative discrepancies still were unresolved, and the Navy designated 20 of these as critical (i.e., they significantly degrade mission effectiveness). For example, data from one of the sensors could not be processed and displayed quickly enough to permit targeting of a submarine. Additionally, the computer system did not have to contend with concurrent inputs from multiple sensors during this testing scenario. Such multiple inputs could exacerbate this processing and display problem.

Navy Oversight Authorities Have Not Assured Compliance With Requirements

On at least two occasions, Navy management oversight authorities have not acted to ensure that the LAMPS Mk I modification complies with Navy system development and testing requirements. This inaction contributed to cost increases and schedule delays, and has allowed the program to assume an increased level of risk associated with not operationally testing the system before a production decision.

According to Office of the Chief of Naval Operations Instruction 5000.42, Research, Development, and Acquisition Procedures, the program sponsors within the Office of the Chief of Naval Operations are responsible for providing overall direction to the program and assuring that Navy requirements for development and testing of embedded computer systems are properly implemented. The level of oversight responsibility is determined by the cost of the program and other considerations, such as development risks. For the LAMPS Mk I modification program, management oversight responsibility resides with the Assistant Chief of Naval Operations (Air Warfare).

We found that the Office of the Assistant Chief of Naval Operations (Air Warfare) has elected not to focus on development and testing of the AN/ANS-150A avionics computer system because it was portrayed as a modification of an existing system. According to the official responsible for monitoring this LAMPS Mk I modification, the AN/ASN-150A computer system was exempted from operational testing by an extension of application because it was believed to be a low-risk modification of an

with the antisubmarine warfare mission, which were previously performed on the base ship. To provide for these new functions, 16 of the computer system's 23 circuit board cards¹⁰ were changed, and major changes to the software were made. In fact, only about 67 percent of the former system's 370,000 lines of software code remained intact—7 percent, or about 25,000 lines of code, was changed; 4 percent, or about 15,000 lines of code, was added; and 22 percent, or about 82,000 lines of code, was deleted.¹¹ Additionally, the 7 percent of software that was changed performs critical tactical functions such as in-flight processing of sensor data. Moreover, the Navy's test plan describes system software integration as a "critical issue." Also, the results of recently completed integration testing (see next section of the report) confirm that the modification is not a low-risk endeavor.

The current program manager agreed with our assessment that the AN/ASN-150A avionics computer system is not a minor software modification. According to this official, the avionics computer system is a complex software development effort requiring extensive software integration. However, this official also stated that the current testing approach does not introduce enough risk into the program to justify postponing a limited production decision until after operational testing. This testing is currently scheduled to begin in September 1990. The program manager added that (1) funds have already been appropriated for buying 15 avionics computer systems and modifying 12 more helicopters, and (2) establishing the production line requires over 2 years, which is sufficient lead time to correct any computer system problems discovered during operational testing. In our opinion, the mere availability of appropriated funds does not justify prematurely obligating them. Further, the sufficiency of lead time to correct computer system problems at this point in time is purely speculative, and cannot be accurately determined until complete and thorough testing discloses the extent of any problems.

¹⁰Circuit boards and cards are part of the computer system's hardware. Collectively, they provide the vital internal circuitry for the computer, and consist of the mounting boards and the components that are mounted on the boards. The cards are specialized groups of components that provide some specialized function, such as central processing, internal memory, and display screen control and resolution.

¹¹The former system included software for processing data from a dipping sonar sensor, which is not being used on the LAMPS Mk I. Therefore, this code was not needed. According to the avionics system project officer, such changes in functionality account for the reduced number of lines of code in the modified system.

\$65.7 million will be spent to buy 150 avionics computer systems.⁷ To date, the Navy has bought 12 of the new computer systems costing \$5.3 million. Appendix II contains the funding requirements for the modification program, as well as the avionics computer system portion of the program, through fiscal year 1994.

In June 1990, the Navy plans to decide whether to begin the limited production phase of the modification program. This entails deciding whether to buy 15 more computer systems (12 for immediate installation and 3 as spares) costing \$6.6 million, and begin installing these computer systems, along with new engines, rotor blades, and other avionics equipment on 12 aircraft. In March 1991, the Navy plans to decide whether to buy the remainder of the 150 computer systems and begin fully producing the modified helicopter.

Navy's Planned Testing of the Avionics Computer System Is Inadequate

The Navy plans to decide whether to purchase 15 more AN/ASN-150A avionics computer systems and begin initially producing the modified helicopter before operationally testing the system. By doing so, the Navy is disregarding its own software development requirements, and greatly increasing the risk that operational problems—those that cannot be anticipated and tested for in a simulated environment—will not be discovered until later in the system development process, when the Navy will have modified an additional 12 helicopters. As a result, correcting these problems will be more difficult and costly than if they were found before any further computer purchases and helicopter modifications. Moreover, should the system fail to perform as required, the Navy may find that it has spent money unnecessarily.

Computer system testing is incremental, with early developmental tests focusing on whether system components and subcomponents perform the functions they are designed to do. Later developmental tests build on early tests, and address the ability of the components and subcomponents to perform their intended functions as integrated units. Still later developmental testing addresses how well the integrated units perform (i.e., how fast, how reliable, how accurate, how often) in a laboratory that realistically simulates the stress the system will be under. Following developmental testing, the complete system is tested in a true operational setting, with actual users. This testing progression emphasizes the benefits of finding problems early in the development process

⁷ Estimate based on the 103 helicopters to be modified plus the program manager's estimate of another 47 computers as spares for helicopter maintenance and training purposes.

objectives were to determine whether (1) the Navy plans to conduct adequate developmental² and operational³ testing of the helicopters' embedded computer systems before buying them, and (2) Navy management is overseeing the acquisition of these embedded computer systems. A detailed explanation of our objectives, scope, and methodology is contained in appendix I.

Results in Brief

In June 1990, the Navy plans to decide whether to buy \$6.6 million worth of upgraded avionics computer systems as part of a program to modify 12 LAMPS Mk I helicopters. These upgraded systems, although initially thought to only require minor modifications to a system already approved for another helicopter, actually require extensive software and hardware changes. However, the Navy has chosen not to operationally test the system before its June 1990 decision.

In our opinion, omitting operational testing greatly increases the risk that system performance problems will not be detected and resolved until later in the development process. History has shown that the longer a software problem goes undetected, the more expensive it is to fix, assuming that it can be fixed.

Developmental testing done to date on the new avionics computer system revealed significant software problems that cast doubt on whether the Navy should proceed until the problems are corrected. The program manager agreed that operational testing should precede a production decision, but the Navy is faced with the need to quickly obligate funds appropriated by the Congress for fiscal years 1989 and 1990. We believe that the Navy should not buy any more avionics computer systems until it has completed operational testing.

The Office of the Assistant Chief of Naval Operations (Air Warfare) has management oversight responsibility for the modification program. However, this office has not assured compliance with development and

²Defense Directive 5000.3, Test and Evaluation, defines developmental testing as testing associated with the engineering design and development of a system to verify attainment of performance and functional specifications, objectives, and supportability. It adds that this testing addresses system components and their integration, and involves the use of models, simulations, and testbeds.

³Defense Directive 5000.3, Test and Evaluation, defines operational testing as field testing, under realistic conditions, of any item or component of a weapons system, to determine its effectiveness and suitability for combat use. It further states that this testing is to be conducted in an environment that is operationally realistic, including having typical users operate and maintain the system in a setting representative of combat stress conditions.
