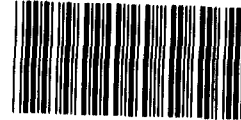United States General Accounting Office

GAO

Report to the Chairman, Subcommittee on Research and Development, Committee on Armed Services, House of Representatives
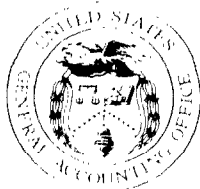
EMBEDDED COMPUTER SYSTEMS

F-14D Aircraft Software Is Not Reliable

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GAO

United States
General Accounting Office
Washington, D.C. 20548

Information Management and
Technology Division

B-246599

April 2, 1992

The Honorable Ronald V. Dellums
Chairman, Subcommittee on
    Research and Development
Committee on Armed Services
House of Representatives

Dear Mr. Chairman:

This report responds to your January 1991 request that we review the
Navy's development of on-board computer software for its $6.1 billion
upgrade of the F-14D "Tomcat" fighter aircraft. Our review is part of the
House Armed Services Committee's overall request that we review
embedded computer systems in Defense weapon systems. As with other
mission-critical Navy weapon systems, the F-14D's effectiveness and
readiness depend heavily on the proper functioning of its computer
systems.

Our objective in this review was to determine the status of software
development for the Navy's F-14D aircraft. A detailed discussion of our
objective, scope, and methodology is contained in appendix I.

Results in Brief

The Navy's F-14D aircraft cannot meet its intended mission due in part to
software problems. The Navy has identified serious software problems that
prevent the aircraft from functioning properly. For example, defects in the
F-14D's embedded software caused cockpit displays to go blank and
erroneous data to be supplied to the mission computer. In addition, some
originally planned software needed to support additional avionics and
weapons capability was deferred due to development problems.

Furthermore, the Navy's software development testing approach was
inadequate, increasing the risk that some serious software defects may still
be unidentified. The Navy did not follow software development standards
that recommend independent testing of a contractor's product before
acceptance, the use of detailed design specifications as criteria for testing,
and thorough testing of each function for compliance with design
requirements.

The Navy is correcting F-14D software problems now. However, before
completing these efforts the Navy plans to develop and add the deferred
software functions to the aircraft. This new software depends on the

stability and reliability of the existing software. Proceeding with the deferred software development effort before ensuring that the existing software is reliable will complicate and make it more costly and time-consuming to detect and correct software problems.

Background

The Navy's F-14D "Tomcat" fighter aircraft—a $6.1 billion upgrade of the F-14A—is designed for missions involving air defense, fighter escort, and air-to-surface weapons delivery. The F-14D upgrade program, initiated in December 1982, includes developing extensive software for a new computer-intensive avionics system to improve mission capability. The Navy and its contractor did not track and report the costs of developing this software; however, a detailed summary of F-14D funding by congressional account is provided in appendix II. The Secretary of the Navy is responsible for program oversight.

The F-14D depends greatly on its computers to perform mission functions. The primary mission computer, designated the AN/AYK-14, integrates 30 subsystems. These subsystems require over 1 million lines of code to perform functions such as communications, navigation, surveillance, electronic countermeasures, and weapons control.

The Navy awarded a contract in July 1984 to develop new F-14D avionics hardware and software, and an upgraded engine. At that time, Navy acquisition planners considered software development to have high technical risk. However, the Navy's original acquisition plan provided for concurrent development and production because the Navy wanted to keep the contractor's F-14 production line open at a rate of one aircraft per month. In 1987 the Navy decided to defer development of software for selected weapons and sensors and extended the program schedule because it was experiencing technical problems and a $60 million cost overrun. The Navy began its "predeployment update" in September 1988 to implement these deferred functions.

As part of the F-14D upgrade, 37 new aircraft will be purchased and 18 existing F-14A aircraft will be modified into the F-14D configuration, for a total of 55 aircraft. The Navy originally planned to cancel further F-14D procurement after a total of 43 aircraft were ordered, but in April 1991 the Congress directed the Navy to order the 12 additional aircraft using fiscal year 1991 appropriated funds. In November 1991, the Congress decided to terminate the F-14D program, although there is ongoing debate within the Congress about additional F-14D funding.

F-14D Software Does Not Meet Operational Requirements

F-14D software contains serious defects that prevent the aircraft from meeting its operational requirements. The Navy's March 1991 operational test report stated that the F-14D aircraft was "potentially effective," meaning the aircraft could work as planned with additional development and testing. The report identified serious software and hardware problems that prevented the F-14D from functioning properly and recommended these problems be corrected before deployment. Table 1 summarizes the software defects reported by the Navy and the status of corrective action.

Table 1: Summary of Software Defects As of September 30, 1991

Degree of Severity	Number of Software Defects		
	Closed	Open	Total
High priority-	43	91	134
Error prevents or degrades accomplishing an essential mission function or jeopardizes flight safety			
Medium priority-	39	170	209
Error degrades performance of an essential mission function			
Low priority-	37	78	115
Operator inconvenience, plus all other errors			
Totals	**119**	**339**	**458**

As of September 30, 1991, 43 high-priority defects had been resolved, while 91 remained open. The Navy and its contractor plan to correct 83 of the 91 open high-priority software defects before the first software version is released to the fleet in January 1993. The remaining defects are to be resolved in subsequent software versions.

An example of a serious problem disclosed by testing is that numerous software defects corrupted data supplied to the mission computer and made it impossible to recognize engine failures. Another example is that the cockpit displays frequently went blank during missions due to faulty software design in the display processor.

The Navy has already procured 43 F-14Ds. All of these aircraft will be delivered to the Navy without software required to meet mission objectives.

F-14D Software Was Not Thoroughly Tested During Development

Navy policy states that software quality should be a major consideration during all development phases, and testing to assess quality should be continually performed.[1] Developmental testing is comprised of both laboratory and flight tests to determine if the system meets specified requirements. Development standards require various levels of specifications for use as testing criteria[2] (as well as other important purposes), such as detailed software design specifications for each module of code.[3] In addition, early independent testing is beneficial to detect and correct serious errors earlier in development when they are cheaper to correct.

The Navy did not approve detailed design and performance specifications prior to testing F-14D software. These specifications were not approved until November 1990, 1 month after testing began. Further, the lack of these specifications precluded the contractor from formally testing each software module, as recommended by federal guidelines. This formal testing involves detailed analysis of software and documentation of deficiencies. If such testing is not performed, there is no assurance that each software module will operate reliably and satisfy requirements.

In addition, the Navy planned to perform independent testing to verify that the software developed by its contractor met design requirements. However, the Navy did not perform this testing as soon as originally planned because test facilities were not available. Performing this testing as planned could have increased the (1) reliability of the software by finding and resolving errors earlier in the program and (2) assurance that other defects have not remained undetected.

Navy program officials acknowledge software reliability may be a problem due to these shortcomings, but they stated that its current testing efforts will mitigate this risk. They agree, however, that conducting earlier and more thorough testing would have resulted in earlier identification and correction of software defects.

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[1]Chief of Naval Operations Instruction 5200.28,Life Cycle Management of Mission-Critical Computer Resources For Navy Systems Managed Under The Research, Development, And Acquisition Process, September 1986.

[2]The F-14D full-scale development contract refers to Department of Defense Standard 1679A, titled Military Standard Software Development, October 1983. This standard defines design specification requirements and the test process to be followed.

[3]A module is a discrete and identifiable unit of software.

Operational Tests Used Incomplete Software

In addition to having numerous defects and not being fully tested during development, the software and hardware used in the Navy's operational tests was incomplete. Defense policy requires that operational tests be conducted to evaluate mission effectiveness, determine readiness for procuring the system at a full production rate, and assess suitability for service use. The system tested should be complete and representative of the version being considered for production.

Contrary to Defense policy, the software that was operationally tested was incomplete; therefore, the results of this testing are not valid for use in deciding to procure at a full production rate. According to the Navy's test report, the aircraft evaluated was a development model that was not ready for operational testing. The aircraft tested lacked both software and hardware for avionics subsystems such as an infrared sensor, communications, and a countermeasures device. When operational tests were completed in December 1990, these subsystems were still under development.

Navy officials approved the operational testing of an incomplete aircraft because test reports stated that the F-14D had the potential to meet its requirements. Navy officials told us that operational testing will be repeated during the summer of 1992 using hardware and software intended for deployment.

Risk Involved in Continuing Software Development

The Navy is currently resolving F-14D software defects disclosed in its tests, while concurrently developing previously deferred software functions under the predeployment update program, estimated to cost about $240 million through fiscal year 1994. This additional software must be integrated with existing software in the mission computer, as well as other processors on the aircraft. Since the Navy's testing approach during development was not thorough enough, and numerous high-priority defects have not been corrected, the existing software is not reliable enough to add more functions.

The predeployment software update will result in three new software versions being issued annually to the fleet, beginning in January 1993. Each version will include new software functions to improve radar performance, integrate missile systems, and add communications features. The contractor has been tasked to design changes to integrate new software functions with existing software in the mission computer, display

processor, and radar. If this software contains logic errors, it could hamper the integration of new software functions.

A Navy program official said the risk of continuing software development now is mitigated by Navy testing of the new software as it is being delivered. However, existing F-14D software contains serious defects, and it would be a sounder approach to ensure existing software is reliable before contracting for additional development.

Recommendations

We recommend that the Secretary of the Navy direct the F-14D program office to (1) defer development of additional software functions until existing software is thoroughly tested and serious defects have been resolved and (2) comply with official Defense software development standards as software development efforts continue.
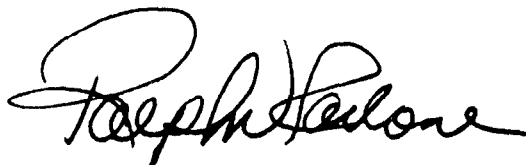
Matter for Congressional Consideration

If the Congress considers any further F-14D procurements in the future, it should wait until Navy developmental and operational testing verifies the correction of software discrepancies and F-14D mission effectiveness. We believe it is risky to procure additional F-14Ds before the aircraft has been proven mission effective and software is proven reliable.

As requested, we did not provide a draft of this report to the Department of Defense for its review and comment. Instead, we discussed the report's facts with officials involved and incorporated their views as appropriate. These officials generally agreed with the facts as presented. Our work was performed between January 1991 and January 1992, in accordance with generally accepted government auditing standards.

As arranged with your office, unless you publicly announce the report's contents earlier, we plan no further distribution until 30 days from the date of this letter. At that time, we will send copies to the Chairmen, Senate and House Appropriations Committees; the Secretaries of Defense and Navy; the Director, Office of the Management and Budget; and 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) 336-6240. Other major contributors are listed in appendix III.

Sincerely yours,

Ralph V. Carlone
Assistant Comptroller General

Contents

Objective, Scope, and Methodology

In January 1991, the Subcommittee on Research and Development, House Committee on Armed Services, expressed interest in the Navy's acquisition of computer systems embedded in tactical aircraft systems. We determined the status of software development for the Navy's F-14D aircraft. Our review is part of the House Armed Services Committee's overall request to review computer systems that are embedded in Defense weapon systems.

To accomplish our objective, we reviewed Defense and Navy instructions and standards governing the development, testing, and management oversight of embedded computer systems. We also reviewed F-14D program documentation, such as operational requirements; acquisition plans; test plans and reports; Navy briefing documents and decision meeting reports; development schedules and funding requirements; as well as the development and production contracts, mission computer software specifications, and related documents for the avionics program. In addition, we interviewed officials in the Chief of Naval Operations and the Program Executive Office, Tactical Aircraft, who are responsible for program oversight. We also interviewed F-14D program officials responsible for managing software development and laboratory officials responsible for software testing. Further, we discussed software development practices with contractor officials and interviewed officials at the Navy test activity participating in the test program.

We performed our work primarily at the F-14D program office within the Navy Program Executive Office, Tactical Aircraft, Arlington, Virginia. We also visited the Pacific Missile Test Center, Point Mugu, California; the Naval Air Development Center, Warminster, Pennsylvania; and the contractor's software development facility.

F-14D Funding Requirements

Dollars in millions Fiscal Year	Research & Development	Procurement	Military Construction	Totals
1983-1990	$1,370.8	$3,241.3	$12.5	$4,624.6
1991	116.6	978.9	3.7	1,099.2
1992	116.2	0.0	0.0	116.2
1993	100.3	0.0	3.6	103.9
1994-1998	139.1	0.0	2.6	141.7
Totals	$1,843.0	$4,220.2	$22.4	$6,085.6

Major Contributors to This Report

Information Management and Technology Division, Washington, D.C.

John B. Stephenson, Assistant Director
Leonard J. Latham, Technical Assistant Director
Kirk J. Daubenspeck, Assignment Manager
David Chao, Technical Adviser

Philadelphia Regional Office

Harry E. Benchoff, Jr., Regional Management Representative
Norman C. Berman, Evaluator-in-Charge
D. Richard Stengel, Staff Evaluator

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Washington, D.C. 20548

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