Audit Report

OFFICE OF THE INSPECTOR GENERAL

AV-8B AIRCRAFT CLASS A MISHAPS AND ENGINE PROBLEMS

Report Number 92-126 July 23, 1992

Department of Defense

The following acronyms are used in this report.

DECS.....Digital Electronic Control System
GAO.....General Accounting Office
HPT.....High Pressure Turbine
IGV.....Inlet Guide Vane
LP.....Low Pressure
LPT.....Low Pressure Turbine

Office of the Inspector General

AUDIT REPORT NO. 92-126 July 23, 1992
(Project No. 2AS-5013)

AV-8B AIRCRAFT CLASS A MISHAPS AND ENGINE PROBLEMS

EXECUTIVE SUMMARY

Introduction. The Marine Corps' AV-8B (Advanced Harrier II) aircraft is a vertical short take-off and landing tactical aircraft designed for close air support for ground operations, intermediate range intercept, and attack missions. Through FY 1992 the Marine Corps has procured 283 AV-8Bs, in various configurations, costing about $8.6 billion.

Objective. We audited selected facets of the AV-8B Aircraft Program as requested by Congress in Conference Report 102-311, "National Defense Authorization Act for Fiscal Years 1992 and 1993," November 13, 1991. Congress requested that we conduct a comprehensive investigation into the high incidence of AV-8B mishaps classified as class A and the chronic AV-8B engine problems. Congress also requested that the General Accounting Office and the Inspector General review the management and the funding of the AV-8B Program. House and Senate Committee staff members agreed to have the General Accounting Office review the management and funding of the AV-8B program and keep the Inspector General abreast of their audit results.

Audit Results. The audit showed that the Navy and Marine Corps are acting to prevent future AV-8B class A mishaps. Also, the Navy and Marine Corps are acting to end known Rolls-Royce F-402 engine problems. The Navy and Marine Corps are ensuring that the 408 upgrade of the Rolls-Royce F-402 engine is thoroughly operationally tested before it is reinstalled in AV-8B aircraft operational squadrons. As a result, this report does not include recommendations and does not identify any internal control weaknesses or any potential benefits.

Management Comments. We provided a draft of this report to the addressees on June 9, 1992. Because no comments were required of management, none were received. Therefore, management comments to this final report are not required. If you choose to comment, please do so by August 24, 1992.

INSPECTOR GENERAL
DEPARTMENT OF DEFENSE
400 ARMY NAVY DRIVE
ARLINGTON, VIRGINIA 22202-2884

REPORT
NO. 92-126

July 23, 1992

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE FOR ACQUISITION
ASSISTANT SECRETARY OF THE NAVY (FINANCIAL MANAGEMENT)

SUBJECT: Report on the Audit of AV-8B Aircraft Program Class A Mishaps and Engine Problems (Project No. 2AS-5013)

Introduction

This final audit report is provided for your information and use. We reviewed the causes for the high incidence of AV-8B mishaps classified as class A and the chronic AV-8B engine problems as requested by Congress in Conference Report 102-311, "National Defense Authorization Act for Fiscal Years 1992 and 1993," November 13, 1991. Although Congress also requested that we and the General Accounting Office (GAO) review the management and the funding of the AV-8B program, House and Senate Committee staff members agreed that the General Accounting Office would conduct the review and keep the Inspector General apprised of the audit results.

The Naval Air Systems Command manages the AV-8B Aircraft Program for the Marine Corps. Through FY 1992 the Marine Corps has procured 283 AV-8Bs, in various configurations, costing about $8.6 billion total or $30 million per aircraft.

Scope of Audit

This program results audit followed auditing standards issued by the Comptroller General of the United States as implemented by the Inspector General, DoD, and included tests of internal controls. We performed the audit from January through April 1992.

We determined if the Navy and the Marine Corps had identified the causes for the AV-8B class A mishaps and taken appropriate actions to prevent future mishaps. We also determined if the Navy had an effective program to address AV-8B engine problems. We reviewed the Navy's process for investigating AV-8B class A mishaps. Also, we reviewed AV-8B contracts; contract proposals; test plans and results; maintenance, personnel, and management reports; and warranty reports from October 1984 through March 1992. Enclosure 7 lists the activities visited or contacted.

The GAO completed its audit on the AV-8B program in March 1992. They submitted their draft report to the DoD and Navy on July 13, 1992.

Internal Controls

We reviewed relevant internal controls for reporting causes of AV-8B class A mishaps, taking corrective actions to prevent future mishaps, and resolving AV-8B engine problems. We determined internal controls from applicable DoD and Navy directives, instructions, and manuals. The internal controls applicable to the AV-8B Aircraft Program were deemed to be effective in that no material deficiencies were disclosed by the audit. Although earlier internal control problems on the performance of adequate operational tests before the installation of F-402 engine upgrades helped cause AV-8B class A mishaps, we found that the Navy and Marine Corps are fully assessing the operational performance of the latest F-402 engine upgrades before installing them in AV-8B operational aircraft.

Background

The AV-8B aircraft (Advanced Harrier II) is a single cockpit, single turbo fan jet engine aircraft flown exclusively by the Marine Corps. It is a vertical/short take-off and landing tactical aircraft designed for close air support for ground operations, intermediate-range intercept, and attack missions.

Since 1983, the Marine Corps has replaced all of its AV-8A aircraft (Harrier Jump-Jets) with the AV-8B. In 1987 a two-seat trainer version of the AV-8B was introduced to the Marine Corps Training Squadron. Also, a Night Attack version of the AV-8B with a built-in, forward-looking infrared sensor was introduced to AV-8B operational squadrons in September 1989. In FY 1990 a cooperative program with the governments of Spain and Italy was begun to develop and produce a radar-equipped version of the AV-8B (Harrier II Plus), scheduled for initial delivery in FY 1993. Because of the radar, the AV-8B (Harrier II Plus) requires an upgraded F-402 engine, designated the 408, to give added engine thrust to the AV-8B. Enclosure 1 shows the procurement and delivery schedule for each version of the AV-8B aircraft.

McDonnell Douglas Corporation produces the airframe and system integration; Rolls-Royce PLC, Military Engine Group (Rolls-Royce), produces the F-402 engine.

Prior Audits and Other Reviews

There have not been any prior audits on AV-8B aircraft safety and engine performance.

Discussion

The Navy defines a class A mishap as an incident where:

o the total cost of property damage is $1 million or more,

o an aircraft is destroyed or missing, or

o a fatal injury or permanent total disability occurs with direct involvement of the aircraft.

From January 1985 through December 1991, the AV-8B aircraft experienced 34 class A mishaps (excluding the 6 class A mishaps experienced in the Persian Gulf conflict) that resulted in 8 fatalities (Enclosure 2). Compared to other Navy and Air Force tactical aircraft during that same period, the AV-8B aircraft has experienced more than two to three times as many class A mishaps per 100,000 flight hours (Enclosure 3). Also, the number of AV-8B class A mishaps identified as engine-related mishaps also greatly exceeded the number of engine-related mishaps per 100,000 flight hours for the other aircraft (Enclosure 4).

Despite this flight hour performance data, 85 AV-8B aircraft flew more than 10,500 flight hours, including more than 4,100 combat flight hours during Operations Desert Shield and Desert Storm. In particular, the AV-8B:

o flew more than 3,000 combat sorties and delivered nearly 6 million pounds of ordnance;

o achieved a mission-capability effectiveness rate of 90 percent; and

o achieved an engine-removal rate of 2.2 engines per 1,000 flight hours, based on 23 engine removals, compared to the peacetime engine-removal rate of 3.6 engines per 1,000 flight hours.

The Navy and Marine Corps had identified causes for 33 of the 34 AV-8B class A mishaps. In most cases, the mishaps were caused by multiple factors. The Navy and Marine Corps concluded that they could have prevented most of the mishaps by:

o more thoroughly testing engine upgrades,

o correcting airframe and engine design problems,

o improving training and operating procedures,

o examining the qualitative effects of maintenance actions,

- emphasizing pilot situational awareness, and
- exercising prudent judgment.

Based on our review of the primary and secondary causes for the 33 mishaps, we concluded that the above actions by the Navy and Marine Corps organizations could have prevented 26 mishaps.

More thoroughly testing engine upgrades. DoD Directive 5000.2, "Defense Acquisition Management Policies and Procedures," February 23, 1991, states that a nondevelopmental item will be evaluated for operational use by considering all aspects of the item's effectiveness and suitability, including operational performance, safety, reliability, maintainability, and compatibility.

Since the F-402 engine was placed in service in 1970, the Navy and Marine Corps have upgraded the engine seven times to improve its reliability and performance (Enclosure 5). The enclosure shows that they have improved the 1970 engine baseline design rather than develop and procure a new engine to satisfy AV-8B aircraft requirements. Despite these improvements, the F-402 engine ranks low in reliability, measured by mean engine flight hours between failures, when compared to other tactical aircraft in the Navy and Marine Corps inventory (Enclosure 6). For example, the F/A-18 engine is five times more reliable than the AV-8B engine (19.2 engine flight hours between failures for the AV-8B engine versus 98.1 engine flight hours between failures for the F/A-18 engine).

The Navy and the Marine Corps concluded that more thoroughly testing the 406A and 408 upgrades to the F-402 engine may have prevented three class A mishaps. Navy and Marine Corps test organizations did not perform comprehensive tests of the 406A and 408 upgrades to the F-402 engines because they believed that the configuration changes would not harm demonstrated engine performance.

F-402-RR-406A engine. The F-402-RR-406A engine is distinguished from the F-402-RR-404A engine by the addition of the Digital Electronic Control System (DECS). Like electronic fuel-injection systems in cars, the DECS maintains engine fuel-flow control with sensors and computer chips. The Navy and Marine Corps accepted the F-402-RR-406A engine with the DECS, based on the proven performance of the F-402-RR-404A engine and bench test runs of the F-402-RR-406A engine. They also operationally tested one F-402-RR-406A engine and partially tested one other engine. Based on positive test results, the 406A engine upgrade was approved for installation in AV-8B operational aircraft.

Problems with the DECS were found when the F-402-RR-406A engine was installed in AV-8B operational squadrons. On reviewing the problems, the Navy and Marine Corps determined that the DECS, when integrated, was incompatible with the configuration of some AV-8B engines. Because of these incompatibilites, the DECS sensors sent erroneous messages to the computer causing the aircraft fuel flow to shut down. As a result of limiting operational tests to two 406A engines, the F-402-RR-406A engine ranks as a major cause for AV-8B engine downtime, unscheduled maintenance hours, maintenance actions, and flight aborts.

The Navy, the Marine Corps, and Rolls-Royce have taken correction actions. Specifically, they have updated the DECS software to make it more compatible when integrated with the various configurations of the AV-8B aircraft. Although the changes have not eliminated all DECS malfunctions, they have been reduced by one-third from CY 1990 to CY 1991.

F-402-RR-408 engine. The F-402-RR-408 engine is distinguished from the F-402-RR-406A engine by a redesigned fan and combustor, an improved high-pressure turbine, and modular design features to give added engine thrust for the Night Attack AV-8B. The Navy accepted the F-402-RR-408 engine based on the performance of the F-402-RR-406A engine and bench test runs of the F-402-RR-408 engine. Before acceptance, the Navy also operationally tested two upgraded engines with compressor blade-tolerance levels set to maximize the effects of engine surge. Although the operational tests showed that the upgraded engines could tolerate the effects of surge, they did not show their vulnerability when compressor blades were set at other acceptable-tolerance levels.

Problems with the compressor blades were identified when the F-402-RR-408 engine was installed in AV-8B operational squadrons. On reviewing the problem, the Navy and Marine Corps determined that the compressor blades rubbed when operational aircraft pulled transient gravity forces during close air support maneuvers. Because of a class A mishap and a malfunction of another 408 engine, the Navy and Marine Corps removed all F-402-RR-408 engines from Night Attack AV-8Bs and returned the engines to Rolls-Royce for repair under contract-warranty provisions.

Rolls-Royce changed the 408 engine and gave it to the Marine Corps for retesting. Unlike the earlier operational test of the 408 upgrade, the Navy and Marine Corps planned and conducted a comprehensive operational test of the modified 408 engine to ensure the end of the compressor blade-rubbing problem. The modified 408 engine failed the test. As of April 30, 1992, Rolls-Royce had made further changes to the 408 engine and was about to give it to the Navy and Marine Corps for retesting.

Correcting airframe and engine design problems. The Navy and Marine Corps concluded that AV-8B aircraft airframe and engine design problems helped cause seven class A mishaps. They determined that design defects with the flap electronic controller, the nosewheel steering control valve solenoid, and inlet guide vane (IGV) control-unit signal spool valve assembly caused premature component and parts fatigue, resulting in the mishaps.

Flap electronic controller. Two mishaps were caused by the aircraft flaps becoming locked in the down position. This condition existed because design specifications did not require the flap electronic controller to be moisture proof. As a result of the flaps being locked, the engine exhaust hit the flaps, forcing the aircraft to pitch out-of-control. The Navy corrected the design problem by requiring the McDonnell Douglas Corporation and the Naval Aviation Depot, Cherry Point, NC, to weatherproof connections in the controllers and to drill holes in the unit to eliminate condensation. Since these fixes, the flap electronic controller has not caused further mishaps.

Nosewheel steering control valve solenoid. Three mishaps occurred because the nosewheel steering control valve solenoid failed. Because of the failures, pilots could not control the aircraft nosewheel during conventional landings. The Navy and Marine Corps have removed the cause of nosewheel malfunctions by redesigning the solenoid.

The IGV control unit signal spool valve assembly. Two mishaps occurred when the AV-8B aircraft's IGV locked in a fully closed position. When the IGVs are closed, the jet pipe temperature increases, causing engine compressor failure. The Navy and Marine Corps found that the IGV design let contaminants in the IGV lubrication, locking the IGV in a fully closed position.

The Navy and Rolls-Royce have determined that the IGVs require a major redesign rather than system improvements. In the interim, the Navy and Marine Corps have started maintenance procedures to increase engine surveillance and to ensure that replacement parts satisfy more stringent tolerances. Also, the "Naval Air Training and Operating Procedures Standardization Manual," September 1988, was revised to instruct pilots on how to recover the aircraft when the IGV fails.

Improving training and operating procedures. The Navy and Marine Corps concluded that improved training and operating procedures may have prevented 3 of the 10 class A mishaps due to engines and equipment design problems. Also, they concluded that improved maintenance operating procedures may have prevented a class A mishap caused by engine foreign-object damage.

Pilot training and aircraft operating procedures. The two class A mishaps caused by DECS equipment failures could have been prevented by pilot training and more comprehensive aircraft operating procedures. The mishaps occurred because the pilots were unaware that the aircraft throttle reacted differently in the manual mode than in the electronic mode. As a result, the pilots overfueled the aircraft in the manual mode, causing the aircraft engine to catch fire. Since the mishaps, the Navy and Marine Corps have changed AV-8B aircraft ground and flight-simulated training to emphasize the reaction differences between engine throttle control settings in the electronic and manual modes. Also, they revised flight operation manuals to emphasize that engine throttle setting differences exist when the engine manual-throttle control is engaged.

Maintenance operating procedures. One of the three class A mishaps caused by the nosewheel steering control valve solenoid could have been prevented by up-to-date maintenance operating procedures. Because of an earlier nosewheel steering failure, the Navy and Marine Corps modified the aircraft antiskid warning light to also indicate when a problem existed with the nosewheel steering unit. However, they did not update AV-8B aircraft operating and maintenance procedures to show this change.

For the one class A mishap, the pilot noted that the nosewheel warning light was illuminated before takeoff. The maintenance crew, unaware that the nosewheel warning light had more than one warning function, cleared the pilot for takeoff after checking the nosewheel antiskid control unit. The mishap occurred when the pilot, believing that the nosewheel was functioning properly, tried a conventional landing and could not control the aircraft nosewheel. Since the mishap, AV-8B aircraft operating and maintenance procedures were revised to show the dual functions of the nosewheel warning light.

Examining the qualitative effects of maintenance actions. The Navy and Marine Corps concluded that Naval Aviation Depot maintenance actions affecting the service life of compressor blades, turbine blades, and the accessory gearbox contributed to four class A mishaps.

Compressor blades. Two accidents occurred because of premature compressor-blade failures. During periodic rework cycles, the Naval Aviation Depot routinely recoated compressor blades to retard rubbing. Before recoating, the blades were electrolytically cleaned to reduce contamination. Unknown to the Naval Aviation Depot, properties in the blades were altered by the cleaning method, causing fatigue and shorter service lives. The effect was unknown because the Naval Aviation Depot had not performed quality-assurance tests to determine if its cleaning process affected the properties of the blades. The Navy and

Marine Corps are modifying design specifications for the compressor blades to improve reliability and maintainability. The redesigned compressor blades will be installed in AV-8B aircraft when the F-402-RR-406A engine is upgraded to the F-402-RR-406B engine. In the interim, the cleaning method has been changed and quality checks initiated to reduce contamination causing compressor-blade fatigue.

Turbine Blades. Many engine failures and one class A mishap occurred because of premature failure of the turbine blades. During periodic rework cycles, the Naval Aviation Depot improperly heat-treated High Pressure Turbine (HPT) 2 blades on F-402-RR-406A engines. Rolls-Royce maintenance procedures require that HPT 2 blades be heat-treated to assure that they are resistant to fatigue and possible failure. According to Rolls-Royce, the type of heat treatment given by the Naval Aviation Depot increased the blades' susceptibility to fatigue and shortened their service lives. In all cases, the HPT 2 blades failed after being heat-treated by the Naval Aviation Depot. The Navy and Marine Corps are modifying design specifications for the HPT 2 blades to improve reliability and maintainability. The redesigned HPT 2 blades will be installed in AV-8B aircraft when the F-402-RR-406A engine is upgraded to the F-402-RR-406B engine.

Accessory Gearbox. One accident occurred because of an accessory gearbox failure. Because the Naval Aviation Depot improperly torqued the accessory gearbox retaining nut, the splines between the horizontal bevel gear and the starter shaft failed in an engine accessory gearbox, resulting in engine failure and the loss of an aircraft. Although the accessory gearbox failure was an anomaly, the Naval Aviation Depot and Rolls-Royce modified the maintenance procedures to increase torquing of the accessory gearbox retaining nut.

More emphasis on pilot situational awareness. Five class A mishaps occurred when pilots lost control of their AV-8B aircraft by misjudging their flight envelopes or by attention-span lapses. For example, a pilot returning from a night sortie misjudged the distance between the AV-8B aircraft and the ship deck and landed in the sea. In another example, an experienced pilot activated the AV-8B aircraft's throttle rather than the nozzle controls during a ship launch causing the aircraft to drop off the ship's deck into the sea. Through training and constant management emphasis, the Navy and Marine Corps are reducing the incidences of pilot error.

Exercising prudent judgment. Six class A mishaps occurred when pilots and command personnel did not exercise prudent judgment. For example, a pilot intentionally maneuvered an AV-8B aircraft outside its operational envelope, lost consciousness, and then lost the aircraft. In another example, an experienced pilot, who was observed to be noticeably fatigued, was allowed to fly an AV-8B aircraft and then lost it.

One other AV-8B class A mishap occurred because maintenance crews did not pull engines when unusual noises were heard during maintenance checks. Before the mishap, the night maintenance crew heard an unusual engine noise during a maintenance check. They investigated the noise but could not locate the source of the problem. Although the engine noise problem was communicated to the day crew, they released the aircraft for flight when the noise did not reoccur during further maintenance checks. Without pulling the engine from the aircraft, the maintenance crews could not discover that the unusual noise was caused by foreign-object damage. Although maintenance operating procedures did not require maintenance crews to pull engines in such cases, the Navy and Marine Corps officials concluded that the release of this aircraft for flight was a lapse of supervisory judgment rather than a procedural shortcoming.

Conclusion

The Marine Corps has sufficient AV-8B airframes and engines to maintain the mission readiness of its operational squadrons, despite the high occurrence of AV-8B aircraft class A mishaps. Also, the AV-8B aircraft class A mishap rate appears to be decreasing as a result of Navy and Marine Corps corrective actions taken in response to and lessons learned from earlier class A mishaps. In CY 1991, the AV-8B aircraft experienced more than a 50 percent reduction in class A mishaps per 100,000 flight hours from CY 1990. However, the ability of the Navy and Marine Corps to reduce the AV-8B aircraft mishap rate to a rate more comparable to the rate experienced on other tactical aircraft will be unknown until all planned corrective actions are implemented. Concerning the F-402 engine, the Navy and Marine Corps are ensuring that the 408 upgrade is thoroughly tested before it is reinstalled in AV-8B operational squadrons. In our opinion, the Navy and Marine Corps are taking appropriate actions to reduce future AV-8B class A mishaps.

We provided a draft of this report to the addressees on June 9, 1992. No management comments were required, and none were received. This report identifies no potential benefits. Any comments on this final report should be provided by August 24, 1992.

We appreciate the courtesies you extended to our audit staff. If you have any questions on this audit, please contact

Mr. John E. Meling, Program Director, at (703) 697-8056 (DSN 227-8056) or Mr. David Wyte, Project Manager, at (703) 614-6300 (DSN 224-6300). Enclosure 8 lists the distribution of this report.

Edward R. Jones
Deputy Assistant Inspector General
for Auditing

Enclosures

cc:
Secretary of the Navy
Commandant of the Marine Corps

PROCUREMENT AND DELIVERY SCHEDULES FOR AV-8B AIRCRAFT

Aircraft Procurement by Fiscal Year

	79	80	81	82	83	84	85	86	87	88	89	90	91	92	Total
AV-8B (Advanced Harrier II)	4			12	21	26	29	40	33						165
TAV-8B (Trainer)						1	2	6	6	0	6	3			24
Night Attack							1		3	24	17	21			66
Radar (Harrier II Plus)											1		21	6	28
Total															283*

Aircraft Deliveries by Fiscal Year

	82	83	84	85	86	87	88	89	90	91	92	93	94	95	Total
AV-8B (Advanced Harrier II)	4		9	22	26	31	39	34							165
TAV-8B (Trainer)						2	6	4	4	5	3				24
Night Attack						1		1	25	18	12	9			66
Radar (Harrier II Plus)												15	7	6	28
Total															283*

* Two aircraft procured in FY 1989 were sold to Italy and one aircraft procured in FY 1990 will be sold to Spain.

ENCLOSURE 1

AV-8B AIRCRAFT CLASS A MISHAPS

Calendar Year	Flight Hours	Class A Mishaps	Mishaps Per 100,000 Flight Hours
1985	11,142	1	
1986	19,404	3	
1987	25,169	4	
1988	39,662	5	
1989	44,473	5	
1990	45,243	11	
1991	57,543	5	
Total	242,636	34	14.01

TACTICAL AIRCRAFT ENGINE-RELATED CLASS A MISHAPS COMPARISONS
(Calendar Years 1985 through 1991)

Aircraft	Flight Hours	Engine-Related Mishaps	Engine-Related Mishaps per 100,000 Flight Hours
F/A-18	1,101,749	9	.817
F-14	847,019	8	.944
A-6	730,357	8	1.100
A-7*	590,488	7	1.185
F-16*	2,352,453	47	1.998
TA-4	755,807	17	2.249
A-4	351,613	11	3.128
AV-8B*	242,636	13	5.358

* Single Engine Aircraft

TACTICAL AIRCRAFT CLASS A MISHAP COMPARISONS
(Calendar Years 1985 Through 1991)

Aircraft	Flight Hours	Mishaps	Mishaps Per 100,000 Flight Hours
TA-4	755,807	29	3.84
F/A-18	1,101,749	47	4.27
A-7*	590,488	26	4.40
F-16*	2,352,453	106	4.51
F-14	847,019	39	4.61
A-6	730,357	39	5.34
A-4	351,613	26	7.39
AV-8B*	242,636	34	14.01

* Single engine aircraft

HISTORY OF F-402 ENGINE UPGRADES

Engine Number	Date Placed in Service	Engine Changes	Estimated Effect of Change: Inspection Intervals*	Estimated Effect of Change: Engine Thrust (Pounds)
F402-RR-401	1970	Baseline engine	200 Hours	20,500
F402-RR-402	1971	Increased mass flow fan Improved turbine cooling Wire-laced low pressure turbine (LPT)	300 Hours	21,500
F402-RR-404	1979	Zero scarf front nozzles Changes to gearbox drives Segmented HPT liner Modified stage 1 fan blades Trunnion-mounted low pressure (LP) compressor vanes	300 Hours	21,700
F402-RR-404A	1983	Swan neck duct intermediate case Forged aluminum fan case Improved combustion chamber Leading edge film cooling HPT-1 vanes Improved HPT nozzle guide vane	400 Hours	22,000
F402-RR-406	1985	Shrouded LPT Triple interstage labyrinth seal in turbine	500 Hours	22,000
F402-RR-406A	1986	DECS	500 Hours	22,000
F402-RR-408	1990	Redesigned fan and combustor Improved HPT Modular design features	1,000 Hours	23,800
F402-RR-406B	1992	LPC-1 vane bushing in vespel material LPT-1 blades with stellite 12 antiwear coating Improved combustion chamber inner case, stator support cone, and inner seal LPT-2 blades with stellite 12 antiwear coating HPT-2 blades in single crystal material Improved LPC-1 and -2 vane inner ring securing bolts LP delivery duct combustion chamber improvements Improved exhaust diffuser Thermal barrier-coated HPT-2 vane segments	750 Hours	22,000

* Hot Section Inspections

COMPARATIVE PERFOMANCE OF TACTICAL AIRCRAFT ENGINES

(July 1990 Through June 1991)

	Aircraft						Comparative AV-8B Ranking[3]
	A-4	A-6	F-14[1]	F-14[2]	F/A-18	AV-8B	
Engine Flight Hours (thousands)	115	297	237	62	436	40	6th
Engine Flight Hours between Failures	20.8	26.6	35.7	45.5	98.1	19.2	6th
Foreign Object Damage per 1,000 Engine Flight Hours	1.1	1.0	0.8	0.3	0.4	2.1	6th
Component Removals per 1,000 Engine Flight Hours	6.3	5.9	5.8	8.4	7.1	36.7	6th
Failure Aborts per 1,000 Engine Flight Hours	1.5	0.4	0.9	0.4	0.8	3.5	6th
Engine Failure Removals per 1,000 Engine Flight Hours	0.7	0.3	0.3	0.1	0.2	0.4	5th
Total Engine Removals per 1,000 Engine Flight Hours	3.5	2.1	1.8	1.0	1.3	3.6	6th

1 Pratt-Whitney TF-30 Engine
2 General Electric 110 Engine
3 AV-8B engine performance compared to the other five tactical aircraft engines

ENCLOSURE 6

ACTIVITIES VISITED OR CONTACTED

Office of the Secretary of Defense

Office of the Under Secretary of Defense for Acquisition, Washington, DC
Office of the Comptroller of the Department of Defense, Washington, DC

Department of the Navy

Office of the Secretary of the Navy, Washington, DC
Office of the Commandant of the Marine Corps, Arlington, VA
Office of the Assistant Secretary of the Navy (Financial Management), Washington, DC
Headquarters, United States Marine Corps, Arlington, VA
Office of the Assistant Chief of Naval Operations (Air Warfare), Washington, DC
Naval Air Systems Command, Washington, DC
Naval Air Warfare Center, Patuxent River, MD
Naval Safety Center, Norfolk, VA
Naval Aviation Depot, Cherry Point, NC

Department of the Air Force

Office of the Deputy Chief of Staff Logistics, Washington, DC
Air Force Safety, Washington, DC

Defense Logistics Agency

Defense Contract Management Office, Bristol, England

REPORT DISTRIBUTION

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Assistant Chief of Naval Operations (Air Warfare)
Naval Air Systems Command
Naval Air Warfare Center
Naval Safety Center
Naval Aviation Depot, Cherry Point, NC

Non-DoD Organizations

Office of Management and Budget
U.S. General Accounting Office, NSIAD Technical Information Center

Congressional Committees:

Senate Subcommittee on Defense, Committee on Appropriations
Senate Committee on Armed Services
Senate Committee on Governmental Affairs
Ranking Minority Member, Senate Committee on Armed Services
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