Audit Report

OFFICE OF THE INSPECTOR GENERAL

ENGINE MONITORING SYSTEMS FOR JET AIRCRAFT ENGINES

Report No. 96-195 July 17, 1996

Department of Defense

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Acronyms

ATCOM	Aviation and Troop Command
CEMS	Comprehensive Engine Management System
ECAMS	Enhanced Comprehensive Asset Management System
EMS	Engine Monitoring System
NALDA	Naval Aviation Logistics Data Analysis
TAM	Tactical Aircraft Maintenance

INSPECTOR GENERAL
DEPARTMENT OF DEFENSE
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July 17, 1996

MEMORANDUM FOR DEPUTY UNDER SECRETARY OF DEFENSE FOR LOGISTICS
ASSISTANT SECRETARY OF THE NAVY (FINANCIAL MANAGEMENT AND COMPTROLLER)
ASSISTANT SECRETARY OF THE AIR FORCE (FINANCIAL MANAGEMENT AND COMPTROLLER)
AUDITOR GENERAL, DEPARTMENT OF THE ARMY

SUBJECT: Audit Report on Engine Monitoring Systems for Jet Aircraft Engines (Report No. 96-195)

We are providing this report for your review and comment. Management comments on a draft of this report were considered in preparing the final report.

DoD Directive 7650.3 requires that all recommendations be resolved promptly. The Deputy Under Secretary of Defense for Logistics comments were responsive and additional comments are not required. The Army concurred or partially concurred with all recommendations, but its comments on Recommendation 2. and Recommendation 4. did not fully address the issues. The Navy and the Air Force did not respond to the draft of this report. We request that the Army, the Navy, and the Air Force provide comments on the unresolved recommendations by August 19, 1996.

We appreciate the courtesies extended to the audit staff. Questions on the audit should be directed to Mr. John A. Gannon, Audit Program Director, at (703) 604-9427 (DSN 664-9427) or Mr. Joseph M. Austin, Audit Project Manager, at (703) 604-9424 (DSN 664-9424). Copies of the report will be distributed to the organizations listed in Appendix E. The audit team members are listed on the inside back cover.

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Office of the Inspector General, DoD

Report No. 96-195 **July 17, 1996**
(Project No. 5LB-0046)

Engine Monitoring Systems for Jet Aircraft Engines

Executive Summary

Introduction. An engine monitoring system (EMS) is a maintenance tool used to determine the condition of jet aircraft engines as they accumulate hours of operation. The purpose of engine monitoring is to assist in identifying and correcting problems before they result in engine failures. Specifically, an EMS is designed to detect malfunctions during normal aircraft operations (event detection) and to gather information for engine performance analysis during take off and flight operations (trend recording).

Audit Objectives. The objectives were to evaluate the effectiveness of DoD systems being developed and systems being used to monitor the conditions of jet aircraft engines, including the ability of the monitoring systems to provide accurate and reliable engine performance data about the condition of the engines, and the cost-effectiveness of the systems. We also evaluated the overall management of the systems. In addition, we evaluated management controls applicable to the audit objectives.

Audit Results. The Military Departments needed to improve their EMS programs. Specifically, existing systems do not provide all the information needed to diagnose, monitor, and trend the condition of the engines. With effective oversight, systems being developed will correct some of the identified deficiencies. Additionally, the Army and the Navy centralized collection of EMS data was not consistent and timely, and the Military Departments lacked performance measures for determining the cost and operational effectiveness of EMS. Further, updating technical data in the Air Force and EMS training in the Military Departments needed improvement. As a result, existing EMS programs do not ensure that maintenance personnel are provided with the necessary data and trained on the systems to improve the efficiency of maintenance on jet aircraft engines. See Part I for a discussion of the audit results.

The audit identified material management control weaknesses in that controls were not in place to ensure that existing EMS programs provided maintenance personnel with the necessary data and training on the systems to improve the efficiency of maintenance on jet aircraft engines. See Appendix A for management controls assessed and for a discussion of material weaknesses identified.

Summary of Recommendations. We recommend that the Deputy Under Secretary of Defense for Logistics provide management oversight over the collection, processing, recording, and use of data that the proposed Joint Advanced Health and Usage

Monitoring System generated. We also recommend that the Army, the Navy, and the Air Force issue guidance to require performance specifications for EMS equipment under development and guidance to establish performance measures. Additionally, we recommend that the Army and the Navy selectively test the timeliness of EMS data reported by maintenance organizations and provide additional training where necessary to maintenance personnel on timely reporting of EMS data. Further, we recommend that the Navy provide additional training to maintenance personnel on the operation of systems used to collect and report EMS data. We also recommend that the Air Force initiate a review of the EMS technical order change process, determine EMS training requirements, establish follow-on training, and make the required training available to EMS users.

Management Comments. The Deputy Under Secretary of Defense for Logistics concurred with our recommendation to provide management oversight on the Joint Advanced Health and Usage Monitoring System program. The Deputy Under Secretary of Defense for Logistics stated that, in the case of the Joint Advanced Health and Usage Monitoring System, the Deputy Under Secretary of Defense for Logistics will provide management oversight in coordination with the Deputy Under Secretary of Defense (Advanced Technology). The Army concurred with the recommendation to issue guidance requiring that performance specifications be developed for all EMS under development. The Army also concurred with the recommendation to selectively test the consistency and timeliness of EMS data being reported by maintenance organizations. The Army partially concurred with the recommendation to develop guidance to establish useful performance measures to determine the cost and operational effectiveness of EMS programs already in existence and those under development. The Army stated that EMS programs under development are being developed to performance specifications that will ensure that the appropriate data are generated to monitor engine condition, diagnose faults, and trend engine performance. The Army also stated that action had been initiated to improve data reporting for the T-700 engine. Additionally, the Army stated that analyses will be performed on the T-800 engine, currently being developed, to assess the value added by the diagnostic system. However, the response stated that an analysis on the T-700 engine is not feasible because it does not have an EMS installed on it. See Part I for a discussion of management comments and Part III for the complete text of the management comments.

The Navy and the Air Force did not comment on a draft of this report.

Audit Response. Comments from the Deputy Under Secretary of Defense for Logistics were responsive. The Army's comments were not fully responsive because the comments did not address the need to issue guidance requiring performance specifications for current and future EMS developments and the need to develop guidance to establish useful performance measures for determining the cost and operational effectiveness of EMS. Additionally, the Army did not indicate a completion date for each action to be taken. We request that the Army, the Navy, and the Air Force provide comments on the final report by August 19, 1996.

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Part I - Audit Results

Audit Background

An engine monitoring system (EMS) is a maintenance tool used to determine the condition of jet aircraft engines as they accumulate hours of operation. The purpose of engine monitoring is to assist in identifying and correcting engine problems before they result in engine failures. Specifically, an EMS is designed to detect malfunctions during normal aircraft operations (event detection) and to gather information for engine performance analysis during take off and flight operations (trend recording). Data that EMS collect are used to isolate faulty engine components and systems, forecast engine deterioration and failure, and predict the life remaining on engines and their components.`

Technologically, engine monitoring of jet aircraft is an evolving concept and a single, standard EMS has not been developed. As a result, each EMS that DoD acquires and operates is unique to a specific jet aircraft engine. Further, EMS hardware used by DoD ranges from a simple history recorder that registers hours of operation to very complex equipment that generates diagnostic trouble codes and records internal engine performance data. Generally, an EMS consists of an engine-mounted recorder that uses sensors to gather data on specified performance characteristics, and a ground system that processes and stores the data. Data gathered by the recorder are transferred to a ground computer system using a downloading device, such as a laptop computer, hand-held scanner, or floppy disk.

EMS Evaluated. During the audit, we evaluated the history recorder installed on the Army Apache and Blackhawk helicopter engines. We also evaluated more complex EMS, which were installed on the Navy F-14B/D and F/A-18A/D aircraft engines, and on the Air Force B-1B, F-15E, and F-16C/D aircraft engines.

Maintenance Concepts and Objectives. Each EMS employed has, as its objective, the support of the maintenance concept established for that engine. The maintenance support concept of aircraft engines has typically included three levels of maintenance: organizational (on-aircraft), intermediate (base maintenance shops), and depot (complete disassembly, repair, modification incorporation, reassembly, and performance tests). Base maintenance objectives were to identify the malfunctioning module or accessory with a high degree of assurance to minimize faults that cannot be corroborated when engine modules or assemblies were returned to depot. The requirement for fault isolation and early detection of malfunctions established the need for EMS. The maintenance concept of an engine must consider maintenance actions that can generate scheduled and unscheduled engine removals.

The maintenance concept for an engine with components that have limited life is driven by the percent of life remaining for those components. The integrity of the recording of life cycle fatigue and hour life consumption is the basis for the engine maintenance concept. The maintenance concept for an engine with trending capabilities is driven by the ability to record and analyze shifts (trends) in the performance of the engine. Monitoring and selective documentation of performance shifts can provide information to be used for making maintenance decisions. Engine trending is a maintenance process of structured analysis of operational and historical aircraft engine data to provide insight to forecast engine component failures and deterioration using the engine's own signature characteristics and performance data. Trending includes monitoring the performance of engines and identifying limits of operating parameters. Trending supports scheduled maintenance performed on the engine because it defines performance degradation. Trending also produces unscheduled maintenance requirements because trend alarms are generated when predetermined parameter thresholds are approached or exceeded. See Appendix C for a description of the mechanics of EMS.

Audit Objectives

The primary audit objectives were to evaluate the effectiveness of DoD systems being developed and used to monitor the condition of jet aircraft engines, including the ability of the systems to provide accurate and reliable engine performance data about the condition of the engines, and the cost-effectiveness of the systems. We also evaluated the overall management of the systems. In addition, we evaluated the adequacy of the Military Departments' management control programs applicable to the audit objectives. See Appendix A for a discussion of the scope, methodology and management control program coverage, and Appendix B for a summary of prior audit coverage related to the audit objectives.

Management of Engine Monitoring Systems Programs

The Military Departments needed to improve their EMS programs. Specifically, existing EMSs did not provide all the information needed to diagnose, monitor, and trend the condition of the engines. With effective oversight by the Deputy Under Secretary of Defense for Logistics and the Military Departments, the EMS being developed will correct some of the identified deficiencies. Additionally, the Army and the Navy centralized collecting and reporting of EMS data were not consistent and timely, and the Military Departments lacked performance measures for determining the cost and operational effectiveness of EMS. Further, updating technical data in the Air Force and EMS training in the Military Departments needed improvement. Those conditions were attributed to inadequate guidance on performance specifications and to inadequate management oversight. As a result, existing EMS programs did not ensure that maintenance personnel were provided with the necessary data and trained on the systems to improve the efficiency of maintenance on jet aircraft engines.

Policy and Guidance for Engine Maintenance Programs

DoD Directive 4151.18, "Maintenance of Military Materiel," August 12, 1992, establishes policies and assigns responsibilities for performance of DoD materiel maintenance at all levels (organizational, intermediate, and depot) and for both organic and contractor organizations. The Directive requires DoD Components to provide an adequate program for the maintenance of assigned materiel.

Department of the Army Technical Bulletin 1-2840-248-20-18, "Life-limits for T700-GE-700 and T700-GE-701 Engine Components," provides instructions for determining and recording the life-limits for gas generator turbine rotor components. The technical bulletin states that an engine history recorder will be used for tracking life-limited components. It assigns the maintenance units the responsibility of ensuring that component life-limits are not exceeded.

Department of the Army Pamphlet 738-751,"Functional Users Manual for the Army Maintenance Management System-Aviation," June 15, 1992, prescribes procedures for collection and submission of history recorder data to the Aviation and Troop Command (ATCOM). The pamphlet states that the data should be

collected monthly and recorded on the Engine Operating Hours Record (DA Form 2408-19-3), then submitted to ATCOM for updating the central data base used for storing historical engine data.

The Naval Air Systems Command Instruction 4790.21, "Flight Information Recording and Monitoring Systems," October 4, 1989, states that a standardized intermediate level software package for a common intermediate level ground station will be developed that will interface with the organizational level aircraft data systems and allow for reporting and storing of historical data. The Naval Aviation Logistics Data Analysis (NALDA) system will be used for reporting and storing of historical data. Where practical, the intermediate level and organizational level organizations will use common hardware.

Commander Naval Air Atlantic Instruction 4790.38, "Enhanced Comprehensive Asset Management System," October 25, 1990, and Commander Naval Air Pacific Instruction 4790.33, "Enhanced Comprehensive Asset Management System," April 15, 1988, state that intermediate level maintenance organizations will transmit all parts life tracking system data through electronic networking to the NALDA central data base daily.

Air Force Instruction 21-104, "Selective Management of Selected Gas Turbine Engines," June 17, 1994, attachment 2, "Engine Management," states that engine trending and diagnostics must be used for all engines. The Instruction establishes the Comprehensive Engine Management System (CEMS) IV as the Air Force standard system for processing, correlating, and plotting engine performance, oil analyses, and maintenance data used to diagnose the condition of engines.

Effective EMS Programs

Public and private sector experts agree that, for an EMS to be effective, it must perform certain functions, including real-time detection of malfunctions, recording and storing of trend data, recording parts life tracking data, and interfacing with aircraft ground equipment to transfer collected data. The ability of an EMS to accomplish diagnostic functions includes the capability to record fault information, present advisory information to the maintenance technician, and document performance parameters after corrective maintenance actions have been taken.

Existing and Planned EMS Development

Military Departments needed to improve their EMS programs because the existing programs did not provide all the information needed to diagnose, monitor, and trend the condition of engines. The condition existed because of inadequate guidance and management oversight. With effective oversight, new systems being developed will correct some of the deficiencies.

Existing EMS Programs. The EMS installed on military aircraft included in our review did not provide the information needed to better evaluate the condition of engines.

Army. The history recorder installed on the engine of the Army Apache and Blackhawk helicopters was designed to provide parts life tracking, but not diagnostic and trending capabilities. The recorder did not provide data concerning the condition of the engine and did not provide maintenance personnel with tools to assist in troubleshooting problems associated with engine or engine components. Further, the recorder had no in-flight data collection and analysis capability. It measured only mechanical and thermal stress, time temperature index, and actual engine operating hours. The number of operating hours that the recorder accumulated were used to compute the remaining life of specific components. In addition, the Army had no ground computer system to capture and process the data recorded during flight. When the Army acquired the engines in 1978, Army guidance did not define development standards for the systems and did not address requirements for diagnostics and trending.

Navy. The Navy in-flight EMS records engine status, tracks engine use, records pre-event and post-event engine data that alert the pilot during flight to serious engine anomalies, and provides maintenance codes for the ground crew. Navy ground-based computer systems download, process, and store engine performance data recorded during flight. They also produce maintenance reports to be used for troubleshooting and calculate and store engine data for parts life tracking. Because of inadequate guidance and oversight, the Navy ground computer systems, however, lacked trending capabilities. The Navy also did not establish a standard ground computer system for processing in-flight EMS data. For example, the F-14B/D and F/A-18A/D aircraft had different ground computer systems. The F-14B/D aircraft used the preproduction maintenance data processing system, while the F/A-18A/D aircraft used the enhanced comprehensive asset management system (ECAMS). Neither ground system was designed to produce trending data to predict imminent engine failure or to allow enhanced scheduling of maintenance actions.

Air Force. The Air Force EMS provided full diagnostics and parts life tracking capabilities and limited trending capabilities. The Air Force B-1B,

F-15E, and F-16C/D aircraft each used a different in-flight EMS. Although the three in-flight EMS had full diagnostic and parts life tracking capabilities, none had full trending capabilities, either because of limitations of the in-flight EMS or because of the ground processing system. For example, the F-15E in-flight EMS recorded only eight raw data elements that could be used for trending. The limited raw data elements that the EMS recorded permitted trending only for warranted performance measures, and the Air Force could not use the data for maintenance purposes. In contrast, the in-flight EMS on the F-16C/D aircraft recorded 48 raw data elements that were used for trending. As a result, the F-16C/D in-flight EMS provided Air Force maintenance personnel with trendable data for three types of engine malfunctions, while the F-15E did not provide any trending capabilities that were useful for maintenance purposes. The difference in EMS capability resulted from the Air Force acquiring engines without developing EMS performance specifications for trending. For example, the original specifications for the F-15E EMS were very general and required only that the system should detect and isolate faults. The Air Force did not incorporate a requirement for trending in the engine or EMS performance specifications. Therefore, Air Force guidance and management oversight for the EMS program was insufficient to ensure that engines were procured with EMS capable of performing trending.

Additionally, while the EMS on the B-1B and F-16C/D aircraft recorded enough data for trending, CEMS IV could not fully process and analyze the data to trend for more than three types of engine malfunctions. The CEMS IV limitation occurred because the Air Force did not provide the CEMS IV program office with trend signatures (trend profiles) of impending failures for the B-1B, F-15E, and F-16C/D aircraft engines. CEMS IV had the capability to pattern match the trend signatures; however, the signatures needed to first be identified and made available.

Planned EMS Development. The EMSs planned for the military aircraft will improve the capability of EMS programs if the Deputy Under Secretary of Defense for Logistics and the Military Departments ensure adequate management oversight.

Deputy Under Secretary of Defense for Logistics. On March 19, 1996, the Naval Air Systems Command briefed the Deputy Under Secretary of Defense for Logistics on the proposed Joint Advanced Health and Usage Monitoring System. The proposed system is an advanced concept technology demonstration that the Army and the Navy will jointly develop for installation and testing on six Army and six Navy helicopters. The system is designed to detect and predict both dynamic component and structural failures before the failures occur. The system will monitor the helicopter drive, engine, rotor, and structure subsystems. The objectives of the system are to improve aircraft

safety and reliability, increase operational availability, reduce life-cycle costs, and streamline maintenance and logistics infrastructure. If approved, the system is scheduled to be developed over a 4-year period (1997 through 2000) at a cost of about $16 million.

The joint program, as presented, shows a great deal of promise. For the program to be successful, the Deputy Under Secretary of Defense for Logistics needs to provide management oversight of its design, manufacture, and implementation. The Deputy Under Secretary of Defense for Logistics agreed with the need for a cost benefit analysis and the need for performance specifications and standards for measuring cost and operational effectiveness. However, the Joint Advanced Health and Usage Monitoring System will generate large amounts of data; therefore, adequate collecting, processing, recording, and using the data are crucial. As a result, the Deputy Under Secretary of Defense for Logistics should work with the Military Departments to provide adequate management oversight of those functions.

Army. In 1993, the Army contracted with General Electric to develop the Turbine Engine Diagnostic System to replace the history recorder on future helicopter engine buys. The objective of the program was to develop improved diagnostic and fault isolation capabilities that would result in reduced false engine removals, low maintenance time, and decreased operating costs. However, the Turbine Engine Diagnostic System will not have the capability to perform trending. General Electric gathered and analyzed data from maintenance units and identified areas where improvements could be made. Areas identified included changes in on-board recorders, test equipment, troubleshooting manuals, and training. The Army suspended the development effort in November 1995 until the Army completes a cost benefit analysis.

Navy. In 1991, the Navy started using the preproduction maintenance data processing system for processing F-14B/D in-flight EMS data. In August 1995, the Navy replaced the preproduction maintenance data processing system with the new maintenance data processing system. The new maintenance data processing system was designed to support the on-condition (change components only when necessary) maintenance concept for the engines and will be the standard ground computer system that will support F-14B/D, F/A-18A/D, and V-22 aircraft maintenance data processing requirements at the organizational, intermediate, and depot levels of maintenance. In addition to diagnostic capability and tracking of components with limited life, the system will provide trending capability. In September 1995, the Navy discontinued use of the new maintenance data processing system because the experienced personnel who developed the system retired or left the Navy when they learned that the Naval Air Warfare Center in Indianapolis, Indiana, was scheduled to close because of downsizing. The Navy is resolving that problem by hiring new data processing specialists.

Air Force. The Air Force used CEMS IV to collect and analyze EMS-generated data for the B-1B, F-15E, and F-16C/D aircraft engines, as well as for six additional types of aircraft engines. However, CEMS IV provided only limited trending capabilities. For example, CEMS IV automatically generated only three trend caution codes for all of the possible malfunctions on the F-16C/D aircraft engine, compared to the 80 diagnostic fault codes that the system generated. To correct that deficiency, the Air Force developed a software enhancement to CEMS IV that was intended to further optimize trending capabilities. The new software, intelligent trending and diagnostic system, was designed to operate in concert with CEMS IV to automatically perform complex analyses of raw data. Its trend analysis and processing capabilities should identify potential problems and produce automatic codes that will alert maintenance personnel of impending engine malfunctions. The software enhancement will initially allow trending for 12 more types of engine malfunctions than CEMS IV alone provides for the F-16C/D aircraft engine. In its intelligent trending and diagnostic system implementation, the Air Force plans to develop intelligent trending and diagnostic system modules for four additional types of engines to be used on six types of aircraft.

The analytical capability that the intelligent trending and diagnostic system added will provide little or no trending capability for aircraft with EMS that record only a few trendable parameters. The only way to expand the potential of the in-flight EMS for the F-15E aircraft, for example, would be to upgrade the in-flight EMS hardware or software. Both the Air Force and Pratt and Whitney, the engine manufacturer, contended that an upgrade to the F-15E aircraft EMS would have little or no impact on engine maintenance. However, Pratt and Whitney assessed the operational impact of only one type of potential upgrade. It evaluated 3 years of field-level trending and performance data under a component improvement task. The task focused on the development of two algorithms for using take-off data to trend engine performance. The study concluded that performance trending of engine diagnostic take-off data would not enhance the maintenance process for the F-15E engine. In 1994, the Air Force discontinued funding for the task. However, the component improvement task was a review of only one alternative for providing trend capabilities. Neither the Air Force nor Pratt and Whitney conducted a cost benefit analysis of other trend alternatives, such as those identified in the July 1991 Pratt and Whitney study, "Investigation of Trending Applications for the F-100 Engine Using the CEMS IV Computer System." Therefore, practical trend applications for the F-15E engine had not been fully explored. As a result, the Air Force did not definitely know the impact that upgrading the F-15E EMS for trending would have on establishing cost-effective trend analyses and consequently on improving maintenance capabilities.

EMS Data Collection and Performance Measures

Collection and Reporting of EMS Data. The Army and the Navy centralized collecting and reporting of EMS data were not consistent and timely. However, the Air Force centralized collecting and reporting of data were well managed.

Army. Within the Army, ATCOM is responsible for the management and oversight of the EMS program. Department of the Army Pamphlet 738-751 states that maintenance personnel at intermediate and organizational level maintenance organizations should collect the history recorder data monthly and record the data on the Engine Operating Hours Record (DA Form 2408-19-3). Maintenance personnel should provide the data to ATCOM to update the central data base that is used for storing historical engine data. ATCOM used the history recorder data, along with data recorded in the engine log book and data received from maintenance organizations, to reconstruct component and module historical records. ATCOM also used the data to determine the causes of engine removals through maintenance analysis, to determine age distribution, and to control the maximum allowable operating time between overhaul of the Apache and Blackhawk helicopters. Additionally, ATCOM used the historical analysis stored data and determined that field maintenance organizations removed 67 engines from helicopters because of low engine pressures and removed 41 engines because of foreign object damage. In addition to reporting the collected data to ATCOM, maintenance personnel at intermediate and organizational level maintenance organizations furnished the data to General Electric to determine useful life of engine components.

As of August 1995, about 1,956 Apache and Blackhawk helicopters were in the Army inventory. A total of 213 field organizations were required to collect history recorder data from the helicopters and submit the data to ATCOM monthly. Our examination of monthly reports showed that although 213 field organizations were required to report history recorder data to ATCOM, only 50 regularly reported to ATCOM. The remaining 163 field organizations reported 1 to 7 times during January through August 1995. For example, 32 field organizations reported history recorder data to ATCOM once in 8 months.

We attributed the inconsistent reporting of data to the lack of ATCOM oversight. ATCOM personnel did not monitor the collection of the history recorder data, stating that data collection was not monitored because it was a low priority. Field maintenance personnel did not submit data because they believed the data were not used, and ATCOM had not provided them feedback concerning the data. As a result, for engines in which history recorder data were not reported, ATCOM lacked the necessary data to reconstruct component or module historical records. ATCOM was unable to present the true picture of

the causes of engine removals and the age of helicopter engine components with limited life because only 24 percent of the Army field organizations were reporting history data to ATCOM regularly. The Army spent approximately $91,000 annually for collecting, processing, and reporting history recorder data. Despite all that the Army spent, ATCOM had no up-to-date information on whether helicopters were flying over the maximum operating hours limit and thereby exposing the crew and aircraft to unnecessary risks.

Navy. The Naval Air Systems Command is responsible for the management and oversight of the Navy's EMS program. Naval Air Systems Command Instruction 4790.21 states that the NALDA system will be used to report and store historical data. The NALDA system is the Navy's major logistics information system used by the Naval Air Systems Command. It provides remote hardware, telecommunications, central computing, and a database management system for fleet support operations. The NALDA system receives configuration, maintenance, material, operations, readiness, safety, supply, and other logistics data from existing data collection systems. It places the data in a central, integrated data bank especially developed and structured for the Naval Air Systems Command application programs. The NALDA system reformats EMS data received from the Navy intermediate level maintenance before transmitting the data to the central data base. However, the Naval Air Systems Command provides little oversight over the EMS program.

The ECAMS, a ground based computer, transmitted EMS data to the NALDA system. ECAMS provided a direct communications link between organizational and intermediate level maintenance organizations. As of September 1995, 18 intermediate level maintenance organizations were supporting the Navy F/A-18 aircraft. Of the 18 organizations, 7 (39 percent) were not reporting their data daily to the central data base. The seven organizations were from 15 days to 207 days late in reporting their data. Personnel at the central collection point indicated that late reporting of ECAMS data adversely affected logistics management. Late submissions caused information on monitoring of engines components with life limits to be outdated, obscured unit ownership of engines, and reduced the quality and quantity of engineering data available for analysis at specific intervals. Further, the fleet commanders' efforts to determine the state of aircraft readiness were hindered because outdated data did not disclose actual engine conditions and events. For example, at Naval Air Station Atsugi, Japan, the intermediate level maintenance units did not report EMS data from February 27 to September 21, 1995. The Naval Air Station was 207 days late in reporting engine data. As a result of not reporting engine data, the Navy did not have sufficient logistics visibility over 47 engines, valued at $97 million, and 19 aircraft, valued at $817 million. Personnel at the Naval Air Station stated that squadron ECAMS operators did not have time to enter transactions in the ground computer systems because the squadron's main priority was

preparing the aircraft to accomplish its assigned mission. The Navy spent approximately $8.2 million annually for collection, processing, and reporting of EMS data.

Air Force. The propulsion product group manager at the San Antonio Air Logistics Center is responsible for the management and oversight of the Air Force EMS program. Air Force Instruction 21-104 assigns EMS management responsibility; however, Technical Order 00-25-254-2, "Comprehensive Engine Management System," February 15, 1993, states that the Air Force Materiel Command is the functional manager of the comprehensive engine management system, which is the Air Force central data bank for engine management. The Oklahoma City Air Logistics Center is the system manager of the central data bank.

The CEMS IV, the Air Force standard ground system for EMS, is a part of the comprehensive engine management system. CEMS IV extracts parts life tracking data from the inflight EMS data during engine download processing. The data include engine operating times and cycle counts, and allow the calculation of the time remaining on major assemblies and subassemblies. The base-level engine management branches reported 81 percent of the data directly on-line by computer and batch reported the remaining 19 percent on a daily basis to the central data bank. We reviewed the parts life tracking reports for 34 engines at Dyess Air Force Base and 10 engines at Shaw Air Force Base. Each of the bases reported directly on-line to the central data bank, and none of the engine components had reached the maximum life limits. Therefore, the reporting and reconciling of parts life tracking data from the bases to the central data bank was adequate. The central data bank's cost for configuration management and parts life tracking in FY 1995 was $632,000. The Air Force did not track the cost to collect and process CEMS IV data on an Air Force-wide basis; however, the cost for the combined CEMS IV data collection and processing costs for Dyess, Seymour Johnson, and Shaw Air Force Bases was about $175,000 for 1995. Overall, the Air Force centralized collecting and reporting of EMS data were well managed.

EMS Performance Measures. The Military Departments had not developed useful performance measures for determining the cost and operational effectiveness of EMS. The Military Departments had no criteria or guidance for determining whether the EMS met program needs or were cost-effective. For example, the Military Departments did not have measurement criteria to determine whether the EMS reduced unscheduled engine removals, maintenance manhours, or air and ground aborts. Additionally, they did not have tracking measures to determine the success or failure of maintenance actions based on EMS generated data. As a result, the Military Departments had no means of determining the effectiveness of their EMS programs.

EMS Technical Data and Training

EMS technical data updating procedures in the Air Force and EMS training in the three Military Departments needed improvement. The condition existed because of inadequate guidance and management oversight.

Updating EMS Technical Data. The Army and the Navy provided current and complete technical data to organizational level maintenance personnel, but the Air Force can improve in this regard. The technical orders for the EMS on the Army Apache and Blackhawk helicopters and the Navy F-14, F/A-18, and the Air Force F-16 aircraft engines were current and complete. However, the Air Force did not ensure that the technical orders for the EMS on the F-15E and B-1B aircraft engine provided current and complete procedures for fault isolation.

The purpose of EMS technical orders is to provide technical information and directions required to perform fault isolation procedures on engine malfunctions (faults) that EMSs detect. Each fault isolation procedure for an automated EMS begins with a recorded fault message and terminates with corrective action instructions. Troubleshooting procedures contained in the technical orders are based on the analysis of EMS and engine malfunctions and reflect the knowledge gained from field experience. Another purpose of the technical orders is to guide the user in trend data analysis, if applicable, for an engine type. Technical orders for EMS were designed to lead the user through the trend analysis process from data collection to troubleshooting.

The Air Force did not ensure the timely incorporation of technical order changes resulting from software logic upgrade 2.3.OA, "Intermittent Logic," for the F-15E engine diagnostic unit. The upgrade was installed in May 1993. However, the contractor did not submit a request to change the applicable technical order until January 1995. The Air Force did not provide maintenance personnel at Seymour Johnson Air Force Base with the changes in fault isolation and troubleshooting procedures until August 1995. The delay occurred because the Air Force did not ensure that the contractor issued the requests to change the technical orders on time. As a result, maintainers had nothing to direct them to delay noncritical repairs (deficiencies not critical enough to ground the aircraft) until the end of the day.

The Air Force did not publish a technical order for the EMS on the B-1B aircraft until July 1995, even though the EMS was fielded in 1986. Air Force personnel have been responsible for B-1B maintenance at the organizational level since the aircraft was fielded and have collected the performance trend data needed to develop the EMS technical orders. However, the data served primarily as a tool for the contractor to develop a trend monitoring program

rather than to develop Air Force EMS technical orders. As a result, from 1986 to 1995, the Air Force did not have EMS technical orders for the B-1B engines and could not optimize the use of the B-1B trending data to make maintenance decisions.

Training in the Use of Ground Processing Systems. The Military Departments did not emphasize training on EMS issues. The Military Departments needed additional training to collect and report accurate EMS data, use ground-based computer systems and download devices, and use EMS trending data, where available, to monitor for performance degradation and the associated engine degradation.

Army. Maintenance personnel within the Army received some training on EMS issues. However, Army maintenance personnel needed refresher training on the importance of reporting timely data to the central data base. For example, the Army used the history recorder for tracking life-limited components, a process requiring accurate and timely reporting. However, only 50 of 213 maintenance organizations that were required to submit reports to the central data base regularly submitted the data.

Navy. Although the Navy maintenance personnel received formal training on the operation of the ECAMS ground-based computer, they needed additional training on reporting and using data generated by ECAMS. For example, on September 21, 1995, Naval Air Station Rota, Spain, maintenance personnel transmitted five transactions involving engine number E310900 to the central collection point. The central collection point did not accept the five transactions because maintenance personnel at the Naval Air Station Rota, Spain, did not correct prior errors on the engines, such as incorrect component number, incorrect serial number, and incorrect asset locations. The original transactions with errors were transmitted on July 24, 1995. Because the errors were not corrected, all transactions transmitted after that date for engine number E310900 were not processed. Because the central data base was updated daily, data concerning the specific engine was not complete, and the status of the engine remained in doubt. We also analyzed the frequency of use of ECAMS reports for the period May through September 1995. Of the 12 different types of reports that could be generated from the ECAMS ground computer, the Navy used only 3 of the reports on a consistent basis. It used the reports to obtain engine hardware configuration without having to visually inspect the engine, to estimate spare parts, and to locate alternate sources of spare parts. However, the Navy seldom used the report that would resolve data entries flagged as errors in the data base. Central collection point personnel indicated that the low use of the error correction report was caused by a lack of adequate training in understanding and using various reports available through the ECAMS ground computer.

Air Force. Air Force maintenance personnel had limited training on EMS data collection and analysis procedures. The Air Force used tactical aircraft maintenance (TAM) personnel to perform aircraft engine maintenance and EMS duties. Air Force Manual 36-2108, "Airman Classification Manual," October 31, 1994, states that the job responsibilities of TAM personnel include maintaining tactical aircraft, support equipment, and forms and records. The manual also states that the TAM personnel must use technical data to diagnose and solve maintenance problems on the majority of systems within the aircraft, including engines. However, TAM personnel did not receive extensive basic engine training to become proficient in engine maintenance or in EMS duties. Additionally, the overall aircraft systems orientation of the Air Force specialty code did not permit the depth of engine work experience necessary to establish proficiency in those two areas. Further, TAM personnel assigned as EMS monitors generally did not have specialized training in the use of the CEMS IV, the Air Force standard ground system for EMS.

Basic Engine Training. The TAM personnel who operated the Air Force EMS equipment were not adequately trained to interpret and properly use diagnostic data from the EMS download devices or to use CEMS-IV. However, they had to use the fault codes produced by the EMS hardware to identify the appropriate maintenance procedures and to troubleshoot engine problems. For instance, at Seymour Johnson and Shaw Air Force Bases, only 266 (35 percent) of the 757 TAM personnel assigned had attended courses for EMS familiarization, fault isolation, or maintenance procedures for the specific engines that they repaired. Additionally, of the one bomber and two fighter wings that we visited, only one of the 20 TAM technicians acting as EMS monitors had attended the formal CEMS IV course.

Neither the TAM personnel at the organizational level who used diagnostic data to troubleshoot engine discrepancies nor the EMS monitors who operated CEMS IV received adequate training. The units allowed the maintenance personnel to attend training as the unit work load permitted. However, workload demands and a workforce composed of 237 (31 percent) of 757 entry-level airmen resulted in training receiving less emphasis. Inadequate engine-specific training was not an issue at Dyess Air Force Base, which used engine specialists at the organizational level. Dyess Air Force Base was also the only installation of the three reviewed that had an EMS monitor who had attended the formal CEMS IV course.

Engine Maintenance. During May 1995, the fielded engine supportability integrated product team chartered by the designated acquisition commander at the San Antonio Air Logistics Center began assessing the use of TAM personnel to perform engine maintenance at the organizational level. The consensus of the team was that the TAM concept did not work for engine maintenance; therefore, trained propulsion technicians should support the

flightline. As a result, the program manager for engine trending and diagnostics contracted with the Science Applications International Corporation to determine the best way to train both the existing TAM workforce and engine specialists to achieve full proficiency. The study is being conducted, with an estimated completion date of August 1, 1996.

Summary

The Military Departments needed to improve their EMS programs. EMS used within the Military Departments did not provide the information needed to fully evaluate the condition of the engines. For an EMS to be effective, it must provide information needed to diagnose, monitor, and trend the condition of engines. The requirements should be addressed in the guidance and performance specifications used for developing the system. The EMSs used on engines of the Army Apache and Blackhawk helicopters was limited and did not provide critical diagnostic and trending data. Also, the Navy EMS ground system for the F-14 and F/A-18 aircraft had diagnostic and parts life tracking capabilities, but no trending capabilities, and the EMSs on the Air Force B-1B, F-15E, and F-16C/D did not have full trending capabilities. However, with effective oversight by the Deputy Under Secretary of Defense for Logistics and the Military Departments, EMS under development will correct some of the EMS deficiencies. The Army and Navy need to ensure consistent and timely collection of EMS data, and the Military Departments need to determine the cost and operational effectiveness of the EMS programs. Finally, the Air Force needs to ensure timely and complete updating of technical data, and all Military Departments need to improve EMS training programs.

Recommendations for Corrective Action

1. We recommend that the Deputy Under Secretary of Defense for Logistics provide management oversight of the Joint Advanced Health and Usage Monitoring System program to ensure that the Army and the Navy collect, process, record, and effectively use data generated from the system to detect and predict engine, component, and structural failures before they occur.

Deputy Under Secretary of Defense for Logistics Comments. The Deputy Under Secretary of Defense for Logistics concurred with the recommendation and stated that, in the case of the Joint Advanced Health and Usage Monitoring

System, the Deputy Under Secretary of Defense for Logistics will provide management oversight in coordination with the Deputy Under Secretary of Defense (Advanced Technology). The Deputy Under Secretary of Defense for Logistics also stated that the Joint Advanced Health and Usage Monitoring System is scheduled for initiation in FY 1997. Specific plans are dependent upon FY 1997 funding.

2. We recommend that the Commander, Aviation and Troop Command; Commander, Naval Air Systems Command; and the Air Force Propulsion Product Group Manager issue guidance requiring that performance specifications be developed for all engine monitoring systems under development. The specifications should ensure that the systems generate the data needed to monitor, diagnose, and trend the condition of engines.

Army Comments. The Army concurred with the recommendation, stating that the current EMS program for the T800 engine is being developed to performance specifications that will ensure that the appropriate data are generated to monitor the engine condition, diagnose fault, and trend engine performance.

Audit Response. We consider the Army's comments regarding the development of performance specifications for the EMS program currently under development to be positive a step. However, the Army's comments were not fully responsive because the comments did not address the need to issue guidance requiring performance specifications for current and future EMS developments and did not indicate a completion date for actions being taken. The intent of our recommendation was to ensure that future engine monitoring systems are not developed without performance specifications. We request that the Army provide additional comments and a completion data for actions to be taken in its response to the final report.

Navy and Air Force Comments. The Navy and the Air Force did not respond to the draft report. We request that the Navy and the Air Force provide comments in response to the final report.

3. We recommend that the Commander, Aviation and Troop Command, and the Commander, Naval Air Systems Command, selectively test the consistency and timeliness of engine monitoring system data reported by maintenance organizations. Where determined necessary, additional training should be provided to maintenance personnel on timely reporting of engine monitoring system data.

Army Comments. The Army concurred, stating that action had been initiated to improve EMS data reporting for the T-700 engine. The Army also stated that requirements had been submitted to the program manager for development and

fielding of the Unit Level Logistics System-Aviation for automated electronics transmission of EMS data. The system is currently being fielded and electronic transmission of data should begin in FY 1998.

4. We recommend that the Commander, Aviation and Troop Command; the Commander, Naval Air Systems Command; and the Air Force Propulsion Product Group Manager develop guidance to establish useful performance measures to determine the cost and operational effectiveness of the engine monitoring system programs already in existence and those under development. Special emphasis should be placed on criteria for determining whether the engine monitoring system reduces unscheduled engine removals, maintenance manhours, or air and ground aborts.

Army Comments. The Army partially concurred, stating that with regard to the new system under development, ATCOM will perform an analysis of the T800 EMS data to assess the value added by the diagnostic system. The analysis will require the engines to be fielded for some period of time to develop failure diagnostic history and will be contingent upon funding support. With regard to the system in existence, the history recorder (counter) is not an EMS and was not designed to provide diagnostics and trending capabilities; therefore, analysis to assess value added is not feasible.

Audit Response. The Army's comments addressing the analysis that will be performed on the T800 EMS data to assess the value added by the diagnostic system will be quite beneficial to the Army. However, the Army's comments were not fully responsive because the comments did not address the need to develop guidance establishing useful performance measures for determining the cost and operational effectiveness of EMSs and did not indicate a completion data for actions being taken. The intent of our recommendation was to ensure that useful performance measures are put in place for measuring the effectiveness of EMSs. While it is recognized that the history recorder (counter) is not an EMS, there should be performance measures for determining its cost and operational effectiveness because the history recorder (counter) is widely used on the Army's helicopters. We request that the Army provide additional comments and a completion date for actions to be taken in response to the final report.

Navy and Air Force Comments. The Navy and the Air Force did not respond to the draft report. We request that the Navy and the Air Force provide comments in response to the final report.

5. We recommend that the Air Force Propulsion Product Group Manager initiate a review of the engine monitoring system technical order change process. The technical orders should be reviewed for the timely incorporation of changes to maintenance procedures.

6. We recommend that the Commander, Naval Air Systems Command, provide additional training to maintenance personnel on the operation of systems used to collect and report engine monitoring systems data. Special emphasis should be placed on correcting errors in data generated by the systems.

7. We recommend that the Air Force Propulsion Product Group Manager:

a. Determine engine monitoring system training requirements.

b. Establish follow-on training for personnel performing engine maintenance. The training should cover engine-specific maintenance and engine monitoring system requirements for each engine maintained.

c. Work with the Air Force Education and Training Command to provide the required training to engine monitoring system users.

Navy and Air Force Comments. The Navy and the Air Force did not respond to the draft report. We request that the Navy and the Air Force provide comments in response to the final report.

Part II - Additional Information

Appendix A. Audit Process

Scope

We performed the audit at the Office of the Deputy Under Secretary of Defense for Logistics, Army, Navy, and Air Force organizations with responsibilities related to EMS programs. We reviewed policies, procedures, and practices for developing new EMS and for managing existing EMS. We evaluated the history recorder installed on the Army Apache and Blackhawk helicopter engines. We also evaluated more complex EMS, which were installed on the Navy F-14B/D and F/A-18A/D aircraft engines, and on the Air Force B-1B, F-15E, and F-16C/D aircraft engines. Additionally, we reviewed a proposed monitoring system that the Army and the Navy will jointly develop for installation on Army and Navy helicopters. Further, we evaluated training practices for personnel assigned to EMS related duties. Army, Navy, and Air Force records reviewed covered calendar years 1994 and 1995. We also reviewed a briefing on the Joint Advanced Health and Usage Monitoring System that was presented to the Deputy Under Secretary of Defense for Logistics on March 19, 1996. In addition, we discussed the benefits of EMS and overall management of the EMS program with responsible officials at all organizational levels.

Methodology

We judgmentally selected eight aircraft engines and evaluated EMS used on those engines. We also reviewed the EMS that are under development in each Military Department and a proposed joint Army and Navy monitoring system. Specifically, we evaluated practices for gathering engine performance data, transmitting the data to ground processing systems, and analyzing the data to detect engine-related problems and identify required maintenance. We also reviewed judgmentally selected samples of records for maintenance history, engine health profiles, time changes and inspections, and manpower and training. We did not attempt to correlate engine failure data with the management of EMS, because we did not collect data that suggested failures could have been prevented.

Use of Computer-Processed Data. Except to verify the accuracy of judgmentally selected samples of records for maintenance history, engine health profiles, time changes and inspections, and manpower and training, we made no independent assessment of the overall reliability of computer-processed data used in managing EMS. As discussed in the report, there were problems in the Army and Navy with consistent and timely input of data to centralized data bases. Reliability problems with computer-processed data would not have affected the results of our audit.

Technical Assistance. Technical assistance was provided by the Analysis, Planning and Technical Support Directorate, Technical Assessment Division. Technical assistance was provided in evaluating the effectiveness of EMS being developed and systems being used to monitor the condition of jet aircraft engines.

Audit Period, Standards, and Locations. We performed this economy and efficiency audit from May 1995 through March 1996 in accordance with auditing standards issued by the Comptroller General of the United States, as implemented by the Inspector General, DoD. Accordingly, we included tests of management controls considered necessary. Appendix E lists the organizations we visited or contacted.

Management Control Program

DoD Directive 5010.38, "Internal Management Control Program," April 14, 1987, requires DoD organizations to implement a comprehensive system of management controls that provides reasonable assurance that programs are operating as intended and to evaluate the adequacy of the controls.

Scope of Review of Management Controls. The audit evaluated management controls related to the development and management of EMS within the Military Departments. Specifically, we examined the management control procedures for ensuring that maintenance personnel were provided with the necessary data and adequately trained on the systems to perform maintenance on jet aircraft engines. We did not assess the adequacy of management's self-evaluation of those controls because management did not identify its EMS programs under one or more of its assessable units.

Adequacy of Management Controls. We identified material management control weaknesses as defined by DoD Directive 5010.38. The Military Departments had not established effective management controls to ensure that existing EMS programs provided maintenance personnel with the necessary data and adequate training on the systems for performing maintenance on jet

aircraft engines. All recommendations, if implemented, will correct the material weaknesses. A copy of this report will be provided to the senior officials in charge of management controls in the Office of the Secretary of Defense and the Military Departments.

Adequacy of Management's Self-Evaluation. The Military Departments did not identify development and management of EMS as assessable units, and therefore, did not identify or report the material management control weaknesses identified by the audit.

Appendix B. Prior Audits and Other Reviews

The Inspector General, DoD, issued Report No. 94-133, "Obtaining the Maximum Life From F-404 Jet Engine Components," on June 14, 1994. The report stated that the Navy replaced F-404 life-limited engine components even though a high probability (99.9 percent) existed that the components had additional life remaining. We estimated that by using an inspection program to manage the engines, the Navy could avoid the procurement of $75.5 million of replacement components and achieve a net savings of $52.4 million over the remaining life cycle of the F/A-18 aircraft (15 years). The report recommended that the Navy establish a program of periodic inspections of F-404 engine components to optimize engine component life and to ensure efficient use of resources. The Navy nonconcurred with the recommendation. Although the Navy will not implement an inspection program for F-404 engines, in the future the Navy will evaluate the use of an inspection program, such as the retirement for cause program, for newly developed and redesigned engines (including the F-404 engine). Whenever feasible and advantageous, the Navy will incorporate an inspection program into the maintenance concept for engines.

The Inspector General, DoD, Report No. 94-045, "Life Reduction of T700 Aircraft Engine Components," was issued on February 25, 1994. The report stated that Army and Marine Corps operational units were flying 78 helicopters with T700 components that had exceeded manufacturer's revised recommended interim life limits. If the interim limits are proved to be correct, possible failure of the engine components could result in damage to the aircraft and loss of life. The report recommended that the Army and Navy issue appropriate safety of flight messages to field units informing field maintenance personnel of the new interim life limits that General Electric is recommending for the T700 engine and require maintenance units to remove from aircraft engines those components that have reached the new interim life limits recommended by General Electric.

The Army partially concurred with the recommendations and planned to publish a revised technical bulletin and to remove from its engines any T700 components that have exceeded the limits published in the bulletin. Technical Bulletin 1-2840-248-20-18 was issued on May 31, 1994. The technical bulletin is sufficient to accomplish the intended outcome. It requires all T700-GE-700 and T700-GE-701 engine components that exceeded the applicable life limits to be removed.

The Navy nonconcurred with the recommendations, but stated it would leave current life limits in effect while General Electric and the Navy review the assumptions of the methodology. A dialogue with Navy officials to resolve that matter was ongoing as of March 1996.

The Inspector General, DoD, Report No. 94-041, "Warranties for the Navy F-404 Jet Aircraft Engine," was issued on February 14, 1994. The report stated that although the Navy invoked the warranty provisions to obtain reimbursement for the life it will not achieve from nine defective F-404 engine components, it had not invoked the warranty provisions to obtain compensation (including redesign costs) for other defective components that are covered by warranty. As a result, the Navy can seek an estimated $10.6 million of additional compensation from General Electric for replacement and redesign of engine components. The report recommended that the Navy invoke the provisions of the warranty that require General Electric to redesign or replace all F-404 engine components that were defective. The Navy agreed to take the recommended actions.

Appendix C. Mechanics of Engine Monitoring Systems

Engine Monitoring System

The EMS isolates engine control system and EMS detected faults during engine operation to aid maintenance personnel during engine troubleshooting. It generates significant maintenance reports that can be used for making timely decisions about whether aircraft should fly. The EMS helps to reduce engine maintenance manhours and to increase aircraft availability. The EMS consists of the in-flight EMS and ground support equipment EMS.

Army

Apache and Blackhawk Helicopter EMS. The history recorder is a very valuable and critical instrument for the safe operation of the T-700 helicopter engine series used on the Army Apache and Blackhawk helicopters. It is used in tracking components with contractor established limited life. The recorder provides data for maintenance personnel to compute the time remaining on those components before being replaced.

Navy

F-14 and F/A-18 Aircraft EMS. The in-flight EMS for the F-14 and F/A-18 records engine status and tracks engine life cycle usage, and records pre-event and post-event engine data. An engine event is an occurrence of any of the following conditions: abnormal inlet temperature, abnormal oil pressure, flameout, or overspeed. The in-flight EMS is located in the cockpit and alerts the pilot during flight to serious engine anomalies. It also sets maintenance codes for the ground crew. The EMS provides ground crewmen with a 3-digit number called maintenance monitor panel codes for each event detected by the EMS during the flight.

Enhanced Comprehensive Asset Management System. The ECAMS is a ground computer system that was developed to support on-condition maintenance for the Navy F/A-18 aircraft and its engine. The on-condition maintenance concept is based on the Parts Life Tracking System that specifies items that are tracked by their useful life rather than a fixed number of hours. The outcome is higher aircraft availability and lower maintenance costs.

Maintenance Data Processing System. The Navy is developing the maintenance data processing system to replace the preproduction maintenance data processing system and ECAMS. The system will greatly enhance the tracking, trending, and diagnostic capabilities of the in-flight EMS. The in-flight EMS for the F-14B/D aircraft uses the preproduction maintenance data processing system for data processing and analysis.

Air Force

B-1B Aircraft EMS. The central integrated test system is the EMS for the B-1B engine. It was fielded on the first B-1B aircraft introduced into operational service and currently operates on all B-1B aircraft. The Rockwell manufactured system monitors a number of aircraft subsystems. The components of the B-1B aircraft EMS include the engine mounted processor, an airframe mounted computer, a maintenance recorder, an airborne printer, a data acquisition unit, and CEMS IV. The system records several EMS data types, including manually entered aircraft and engine identification, failure messages, failure data snapshots, and engine trend data. Capabilities of the system include providing in-flight data to the B-1B crew members as well as storing engine fault and trend data on magnetic tape recorder cartridges.

F-15E Aircraft EMS. The F-15E aircraft EMS is composed of two main in-flight subsystems, the digital electronic engine control and the engine diagnostic unit, and two main ground subsystems, a download device called the comprehensive engine diagnostic system and CEMS IV. The digital electronic engine control continuously evaluates the health of the engine by controlling and monitoring engine operation. The data flow from the digital electronic engine control to the engine diagnostic unit alerts the system when (and tells where) an anomaly has occurred. In addition to detecting failures, the digital electronic control unit provides the engine diagnostic unit with engine raw data such as pressures, speed signals, and temperatures. The engine diagnostic unit continuously reviews the digital electronic engine control output and stores data useful to the maintenance crew, such as engine time and cycle data, engine performance parameters, fault codes, and transient data. It also stores and records engine problem data and assigns a time stamp (number of minutes after engine start) that the fault or event occurred. Additionally, the engine diagnostic unit monitors operating parameters that are not directly measurable by the digital electronic engine control, such as oil pressure.

F-16C/D Aircraft EMS. The F-16C/D aircraft EMS is composed of an engine mounted digital electronic control; the comprehensive engine diagnostic system, which is a download device; and the CEMS IV ground computer system. The EMS collects and transfers parts life tracking information, performance trending information and fault detection data to the organizational level maintenance units for immediate use and subsequent transfer to the base level engine management branch.

Comprehensive Engine Management System IV. The CEMS IV is an Air Force managed computer system used to support engine trending and diagnostics at the base level. The system was designed to improve maintenance efficiency through consolidation of engine diagnostic resources into a single useful data product presented in a convenient format for maintenance personnel. It is used for fault or event detection, performance trending, and multi-source data correlation. It accomplishes fault and event detection and trending by comparing input parameters to limits and by providing plotting capabilities to facilitate human interpretation of adverse trends. CEMS IV collects, stores, analyzes, and presents data from the on-board EMS and maintenance data collection systems to distribute a comprehensive view of engine information to all users located at the base level.

Appendix D. Organizations Visited or Contacted

Office of the Secretary of Defense

Office of the Assistant Deputy Under Secretary of Defense (Maintenance Policy, Plans, and Resources), Washington, DC

Department of the Army

Headquarters, Deputy Chief of Staff (Logistics), Washington, DC
Headquarters, Army Materiel Command, Alexandria, VA
Aviation and Troop Command, St. Louis, MO
18th Airborne Corps, Fort Bragg, NC
Corpus Christi Army Depot, Corpus Christi, TX
Aviation Applied Technology Directorate, Fort Eustis, VA

Department of the Navy

Office of the Deputy Chief of Naval Operations (Logistics), Washington, DC
Naval Air Systems Command, Arlington, VA
- Naval Air Station Cecil Field, Jacksonville, FL
- Naval Air Station Lemoore, Lemoore, CA
- Naval Air Station Oceana, Virginia Beach, VA
- Naval Air Station Patuxent River, Patuxent River, MD
- Naval Aviation Maintenance Office, Patuxent River, MD
- Naval Air Warfare Center, Aircraft Division, Indianapolis, IN
- Naval Air Warfare Center, Patuxent River, MD

Department of the Air Force

Office of the Deputy Chief of Staff (Logistics), Washington, DC
Air Combat Command, Langley Air Force Base, VA
- Dyess Air Force Base, Abilene, TX
- Seymour Johnson Air Force Base, Goldsboro, NC
- Shaw Air Force Base, Sumter, SC

Air Force Materiel Command, Wright-Patterson Air Force Base, OH
- Oklahoma City Air Logistics Center, Tinker Air Force Base, OK
- San Antonio Air Logistics Center, San Antonio, TX

Contractors

American Airlines, Tulsa, OK
General Electric Corporation, Cincinnati, OH

Appendix E. Report Distribution

Office of the Secretary of Defense

Under Secretary of Defense for Acquisition and Technology
  Deputy Under Secretary of Defense for Logistics
  Director, Defense Logistics Studies Information Exchange
Under Secretary of Defense (Comptroller)
  Deputy Chief Financial Officer
  Deputy Comptroller (Program/Budget)
Under Secretary of Defense for Policy
Assistant to the Secretary of Defense (Public Affairs)

Department of the Army

Assistant Secretary of the Army (Financial Management and Comptroller)
Auditor General, Department of the Army

Department of the Navy

Assistant Secretary of the Navy (Financial Management and Comptroller)
Auditor General, Department of the Navy

Department of the Air Force

Assistant Secretary of the Air Force (Financial Management and Comptroller)
Deputy Chief of Staff (Logistics)
Auditor General, Department of the Air Force

Defense Organizations

Director, Defense Contract Audit Agency
Director, Defense Logistics Agency
Director, National Security Agency
  Inspector General, National Security Agency
Inspector General, Defense Intelligence Agency

Non-Defense Federal Organizations and Individuals

Office of Management and Budget
General Accounting Office
National Security and International Affairs Division
Technical Information Center

Chairman and ranking minority member of each of the following congressional committees and subcommittees:

Senate Committee on Appropriations
Senate Subcommittee on Defense, Committee on Appropriations
Senate Committee on Armed Services
Senate Committee on Governmental Affairs
House Committee on Appropriations
House Subcommittee on National Security, Committee on Appropriations
House Committee on Government Reform and Oversight
House Subcommittee on National Security, International Affairs, and Criminal Justice, Committee on Government Reform and Oversight
House Committee on National Security

Part III - Management Comments

Deputy Under Secretary of Defense for Logistics Comments

OFFICE OF THE UNDER SECRETARY OF DEFENSE

3000 DEFENSE PENTAGON
WASHINGTON DC 20301-3000

ACQUISITION AND TECHNOLOGY

14 JUN 1996

MEMORANDUM FOR DEPARTMENT OF DEFENSE INSPECTOR GENERAL

Subject: Department of Defense Inspector General "Audit Report on Engine Monitoring Systems for Jet Aircraft Engines," Project No. 5LB-0046

This is the Deputy Under Secretary of Defense (Logistics) response to subject audit.

DUSD(L) concurs with recommendation (1). Detailed comments are provided in the attachment.

John Phillips

John F. Phillips
Deputy Under Secretary
of Defense (Logistics)

Attachment:
As stated

RECOMMENDATION: The DoDIG recommends that the Deputy Under Secretary of Defense for Logistics provide management oversight of the Joint Advanced Health and Usage Monitoring System program to ensure that the Army and the Navy collect, process, record, and effectively use data generated from the system to detect and predict engine, component, and structural failures before they occur.

- DUSD(L) RESPONSE: Concur. The Joint Advanced Health and Usage Monitoring System (JAHUMS) is an Advanced Concept Technology Demonstration (ACTD). It will involve joint Navy and Army participation. The Deputy Under Secretary of Defense (Advanced Technology) manages and maintains oversight of all the Department of Defense ACTDs. In the case of the JAHUMS ACTD, the Deputy Under Secretary of Defense (Logistics) will provide management oversight in coordination with the Deputy Under Secretary of Defense (Advanced Technology). The JAHUMS ACTD is scheduled for initiation in Fiscal Year 1997. Specific plans are dependent upon the Fiscal Year 1997 budget level for general ACTD funding. Presently, $16M is programmed to demonstrate the JAHUMS capability in a number of test aircraft. General JAHUMS ACTD goals will be to demonstrate the following:

  - 30% reduction in Class A material mishaps
  - 90% probability of detecting incipient mechanical component failures
  - <1% false alarm rate
  - 25% reduction in maintenance costs/flight hour
  - 40% reduction in airframe vibration
  - 95% accuracy in structural loads prediction

The goals satisfy the Joint Technology Development Approach (TDA) Objectives. Specific aircraft model goals will be based upon available maintenance baseline performance.

Department of the Army Comments

DEPARTMENT OF THE ARMY
OFFICE OF THE DEPUTY CHIEF OF STAFF FOR LOGISTICS
500 ARMY PENTAGON
WASHINGTON, DC 20310-0500

03 JUN 1996

DALO-SMV

MEMORANDUM THRU

DEPUTY CHIEF OF STAFF FOR LOGISTICS

~~DIRECTOR OF THE ARMY STAFF~~ GREGORY P. GUILLIE, LTC, GS, ADECC

ASSISTANT SECRETARY OF THE ARMY (INSTALLATIONS, LOGISTICS & ENVIRONMENT)
Deputy Assistant Secretary of the Army (Logistics) OASA (I&L)

FOR INSPECTOR GENERAL, DEPARTMENT OF DEFENSE (AUDITING)

SUBJECT: Audit Report on Engine Monitoring Systems for Jet Aircraft Engines (Project No. 5LB-0046)--INFORMATION MEMORANDUM

1. This is in response to USAAA memorandum of 8 April 1996 (Tab A), which asked ODCSLOG to respond to your memorandum of 8 April 1996 (Encl to Tab A). Your memorandum requested that ODCSLOG review the findings, recommendations, or estimated monetary benefits of subject report.

2. The Army's response to the subject draft audit is at Tab B.

2 Encls

WIMPY D. PYBUS
Director of Maintenance Management

CF:
VCSA
CDR, AMC
DALO-ZXA

AMC (AMCIR-A) - Concur, Mr. Kurzer/617-9025 (by phone)
ATCOM (AMSAT-B-L)- Concur, Mr. Huseman/693-3777 (by phone)

Army response to Audit Report on Engine Monitoring Systems for Jet Aircraft Engines (Project No. 5LB-0046)

The following paragraphs list the Army portions of the DODIG recommendations followed by the response, as applicable:

a. Recommendation 2. The Commander, Aviation and Troop Command (ATCOM) issue guidance requiring that performance specifications be developed for all engine monitoring system (EMS) under development. The specifications should ensure that the systems generate the data needed to monitor, diagnose, and trend the condition of engines.

b. Army Response. Concur. An EMS, as a part of the T800 engine development program, and the Built-in-Test subsystems for the Subsystem Power Unit are currently being developed. Both are for the RAH-66 Comanche and both are being developed to performance specifications that we believe will ensure that the appropriate data are generated to monitor engine condition, diagnose faults, and trend engine performance.

c. Recommendation 3. The Commander, ATCOM selectively test the consistency and timeliness of EMS data being reported by maintenance organizations. Where determined necessary, additional training should be provided to maintenance personnel on timely reporting of EMS data.

d. Army Comment. Concur. Action has been initiated to improve data reporting for the T-700 engine. DA Form 2408-19-3 data were compared to DA Form 2410 installed data and discrepancies noted. On 29 Feb 96, 156 letters, with 1024 aircraft/aircraft serial number combinations, were sent out. To date, 42 percent of the organizations have responded with clarifications and/or data corrections. This process will be repeated to continually monitor and improve the timeliness and accuracy of data reporting. In addition, we are supporting the development and fielding of Unit Level Logistics System-Aviation (ULLS-A). We have submitted requirements to the Program Manager, ULLS-A, for the automated electronic transmission of DA Form 2408-19-3 data to ATCOM. When implemented, this will lessen the burden on the units and improve accuracy and timeliness of data input. ULLS-A is currently being fielded and the transmission of data to ATCOM should begin in FY 98.

e. Recommendation 4. The Commander, ATCOM develop guidance to establish useful performance measures to determine the cost and operational effectiveness of the engine monitoring system programs already in existence and those under development. Special emphasis should be placed on criteria for determining

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whether the EMS reduces unscheduled engine removals, maintenance man-hours, or air and ground aborts.

f. Army Response. Partially concur.

Concur with regards to the system under development. The ATCOM Directorate for Maintenance will perform an analysis of field maintenance performance data on the T800 EMS in order to assess value added by the diagnostic system. The analysis will require the engines to be fielded for some period of time to develop failure diagnostic history and will be contingent upon funding support from the Aviation Program Executive Office/Comanche Program Manager.

Nonconcur with regard to the system in existence. The T700 engine series history recorder/counter is not an EMS and thus an analysis to determine whether it reduces unscheduled engine removals, maintenance man-hours, or air and ground aborts is not feasible. As mentioned in the report, the history recorder was not designed to provide diagnostic and trending capabilities.

3. Additional comments.

a. The DODIG states that existing EMS did not provide all the information needed to diagnose, monitor, and trend the condition of the engines. It should be noted that the T700 engine series history recorder/counter was not designed, nor was there a mission need statement, for that purpose.

b. Reference page 10, second paragraph. The Army at ATCOM does not use the history recorder data to control the maximum allowable operating time between overhaul of the Apache and Blackhawk helicopters. Both the aircraft and engine are "on-condition" and the responsibility for component removal on life limited components lies solely with owning units. Only in special cases, such as Safety-of-Flight, does ATCOM direct removal of components.

c. Reference page 10, second paragraph, last sentence. DODIG states "...the data were furnished to General Electric to determine useful life of engine components." This statement is incorrect. Useful life is not based on historical data.

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