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Report to the Honorable
Daniel K. Inouye, Chairman,
Subcommittee on Defense, Committee
on Appropriations, U.S. Senate

June 1993

DEPOT MAINTENANCE

Requirement to Update Maintenance Analyses Should Be Modified

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National Security and
International Affairs Division

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June 22, 1993

The Honorable Daniel K. Inouye
Chairman, Subcommittee on Defense
Committee on Appropriations
United States Senate

Dear Mr. Chairman:

A Department of Defense (DOD) directive and military service regulations require the services to perform reliability centered maintenance (RCM) analyses.[1] The Senate report on the fiscal year 1992 DOD Appropriations Act directed us to report on the Air Force's progress in implementing the RCM concept. We reviewed the status of the Air Force's implementation of RCM and discussed our findings with your office in July 1992. As a result of those discussions, we expanded our review to include determining (1) DOD and service policies relating to RCM, (2) the extent to which the services applied and updated RCM analyses on their aircraft and aircraft engines, and (3) what other programs the services use to ensure appropriate preventive maintenance is done.

Background

RCM is a method of developing preventive maintenance programs. In general, its purpose is to ensure that equipment lasts as long as it was designed to and to do so at the least cost. Under the RCM concept, the only maintenance performed is what is necessary to restore equipment to its design levels of safety and reliability. More specifically, RCM attempts to manage the amount of maintenance done on a system by (1) identifying those items whose failure will adversely impact the safety or mission capability of the system or that will cause more costly maintenance by failing and (2) determining the correct interval between maintenance actions. Applying RCM consists of (1) analyzing how structures, assemblies, and items can fail, and the effect those failures will have on the item being analyzed and the total system; (2) performing a decision logic process that determines what items need to be maintained; and (3) determining the best interval for maintenance and inspections.

[1]DOD defines reliability centered maintenance as a disciplined logic or methodology used to identify preventive maintenance tasks to realize the inherent reliability of equipment with the least expenditure of resources.

The concept of RCM originated in the late 1960s when the Air Transport Association[2] supported its development and the airline industry implemented it. In the mid-1970s, the Office of the Secretary of Defense established a requirement for the services to use the RCM concept to determine preventive maintenance on both new and operational systems. DOD Directive 4151.16, dated August 23, 1984, also required the services to use RCM to justify new or modified maintenance tasks and to continually evaluate existing tasks. DOD Directive 4151.18, dated August 12, 1992, replaced DOD Directive 4151.16 and deleted the requirement to update RCM analyses. According to Office of the Assistant Secretary of Defense (Production and Logistics) officials, the services are still required to perform RCM analyses during the weapon system development phase and for major modifications to aircraft systems. In addition, service regulations still require RCM analyses to be updated.

Results in Brief

The services have not completed or updated their RCM analyses on operational aircraft and aircraft engines. The Army did not do complete RCM analyses of its operational aircraft and has no plans to do so. The Navy completed initial analyses on most of its operational aircraft systems and is planning to perform or update its analyses over the next 5 years. The Air Force did RCM analyses on its major systems in the 1970s, but until recently had not updated them.

Service officials said performing or updating RCM analyses on operational systems with extensive maintenance experience is not cost effective because the analyses are expensive to perform and would not significantly reduce the maintenance requirements. Officials of the Air Transport Association, which sponsored development of the RCM concept, and the Federal Aviation Administration, which approves airlines' maintenance schedules, stated that their experience has been that RCM analyses of systems with many years of experience and actual maintenance data are not cost effective.

However, the services are in the process of making RCM analyses on major systems they have in development—for example, the Army's T800 engine, the Navy's F/A-18E/F aircraft, and the Air Force's F-22 aircraft. DOD and Air Transport Association officials said that applying such concepts as RCM during system development contributes to efficient preventive maintenance programs.

[2]The Air Transport Association represents the commercial airline industry, and the Federal Aviation Administration approves commercial airlines' maintenance plans. Both were instrumental in developing the RCM concept in the late 1960s and early 1970s.

Army RCM Program

In addition to the DOD directive on RCM, the Army has its own RCM regulations. They require RCM to be applied to all operational and developmental systems. They also require RCM analyses to be updated, but do not specify how frequently.

The Army is applying RCM to the Comanche helicopter and its T800 engine, which are currently in development. Although the Army indicated specific cost benefits from implementing RCM could not be determined, it expects the scheduled maintenance plan for this helicopter and engine to be cost effective and enhance system readiness.

The Army has not done a complete RCM analysis of its operational systems, although it has done portions on some systems. It has not done the decision logic process that determines the needed maintenance tasks based on the failure modes and effects analysis. According to Army officials responsible for determining maintenance requirements for Army systems, the estimated cost of doing complete RCM analyses for operational systems exceeds the expected benefits, that is, potential reduced maintenance costs.

Army maintenance officials said that the Army has other engineering programs to ensure that appropriate maintenance is being done on operational systems. These programs include (1) aircraft condition evaluation, which is used to determine candidates for depot maintenance; (2) pre-shop analysis, which is used to determine what types of maintenance are needed on an aircraft or engine once it is in the depot; and (3) engineering directives, which analyze and adjust the maintenance tasks on helicopters and engines. Although these programs are designed to minimize preventive maintenance, they do not include RCM formal decision logic procedures. In commenting on a draft of this report, DOD officials said they plan to assess whether these Army programs ensure appropriate maintenance is being done.

Navy RCM Program

Navy regulations require that RCM be applied to all developmental and operational aircraft to determine preventive maintenance tasks and intervals for all levels of maintenance. The RCM analysis is to be updated throughout the aircraft's life to refine tasks and intervals using operational maintenance data.

The Navy has applied RCM analyses to most of its operational aircraft systems. However, it has not updated these analyses. The Navy plans to

perform or update its RCM analyses on all its operational aircraft and engines in the next 5 years at an estimated cost of about $16.6 million. The Navy is also applying the RCM concept to its newer systems, such as the V-22 and F/A-18E/F.

The Navy RCM program manager said it would be cost effective to update RCM analyses if they are done to refine maintenance intervals and to group maintenance actions together so they can be done as a package. He said other Navy programs, which are a part of RCM, already ensure appropriate maintenance tasks are being done, such as (1) the age exploration program, which is a process to determine age-reliability relationships through controlled testing and analysis and (2) the aircraft service period adjustment program, which consists of evaluating the general material condition of an aircraft through an analysis of an aircraft's maintenance history and a physical examination. Based on data from these programs, the Navy decides whether to defer depot maintenance. Although these programs are designed to minimize preventive maintenance, they do not include RCM decision logic procedures. In commenting on a draft of this report, DOD officials said they plan to assess whether these Navy programs ensure appropriate maintenance is done.

Air Force RCM Program

Air Force regulations require RCM to be applied to all operational and developmental systems and to modifications that may result in new maintenance requirements. They also require RCM be used to justify other new maintenance tasks and to evaluate existing tasks. These regulations require the system manager to reassess the maintenance requirements every 2 years.

The Air Force did RCM analyses on many of its major systems from 1976 to 1980. The Air Force is currently doing RCM analyses on developmental aircraft, including the C-17, F-22, and B-2. Air Force officials said the benefits of RCM analyses during the developmental phase include (1) reducing maintenance support costs, (2) increasing aircraft mission availability, (3) reducing parts costs, and (4) allowing early identification of high-cost items requiring maintenance at short intervals.

In response to a DOD Inspector General report and at the urging of the Senate Committee on Appropriations, the Air Force is updating the depot maintenance analyses for 8 aircraft and 10 engines. As of December 31, 1992, as a result of the updates, the Air Force has identified estimated savings totaling about $190,000 annually on the F-111 aircraft. However, no

additional savings on other aircraft or engines had been identified. The estimated cost to perform the updates is about $8 million.

Air Force officials stated that RCM updates were not done previously for operational systems because the updates would cost more than the expected benefits. Moreover, they said other programs are in place to ensure appropriate maintenance is done. Among these other programs are the (1) controlled interval extension program, which sets up controlled conditions for extending maintenance and inspection intervals; (2) aircraft structural integrity program, which improves design, diagnoses possible structural failures, provides a basis for corrective action, and predicts the expected life of the aircraft; and (3) analytical condition inspection, which systematically disassembles and inspects a sample of aircraft to find hidden defects, deteriorating conditions, corrosion, fatigue, overstress, and other deficiencies in the aircraft structure or systems. This inspection goes into greater detail than normal inspections and is used as support for adjusting preventive maintenance intervals. Although these programs are designed to minimize preventive maintenance, they do not include RCM decision logic procedures. In commenting on a draft of this report, DOD officials said they plan to assess whether these Air Force programs ensure appropriate maintenance is done.

Other Organizations See Little Value in RCM Updates

Air Transport Association and Federal Aviation Administration officials said the value of doing an RCM analysis is derived early in the aircraft or aircraft engine program. An Association official said within commercial practice it is not cost effective to do an RCM analysis of an aircraft after it is in service. According to this official, commercial aviation uses a different program to assess maintenance intervals for aircraft already in service.

Association and Administration officials said they do not believe that it is cost effective to do an RCM analysis on an aircraft for which there are many years of maintenance experience available. They stated that once actual maintenance data are available and are used to update maintenance tasks and maintenance intervals, reassessing the RCM analysis will not reduce the programmed maintenance.

Recommendations

The services have applied RCM to systems they have recently developed or are developing because they recognize the benefits of the early application of RCM. They had not, as required by service regulations, performed or updated the RCM analyses to determine preventive maintenance for

existing systems. The cost-effectiveness of updating RCM analyses for systems with extensive maintenance histories and for which a structured program exists to adjust maintenance task requirements and intervals is questionable. Therefore, we recommend that the Secretaries of the Army, the Navy, and the Air Force revise their regulations to remove the requirement to update RCM analyses on operational systems with both extensive maintenance histories and structured programs to adjust maintenance tasks and intervals.

Further, we recommend that the Navy not expend resources to update RCM analyses on any system with extensive maintenance histories and for which a structured program exists to adjust maintenance task requirements and intervals.

Agency Comments and Our Evaluation

DOD officials were given an opportunity to comment on a draft of this report but did not provide written comments. We received official oral comments and have incorporated them as appropriate in this report. DOD officials generally agreed that if a structured program exists to adjust maintenance task requirements and intervals, updated RCM analyses on systems with extensive maintenance experience are not necessary.

In an earlier draft of this report, we recommended that the Secretary of Defense modify the requirement for the services to update RCM analyses on operational systems. DOD replaced DOD Directive 4151.16 in August 1992 and eliminated the requirement. The service regulations, however, still require RCM analyses to be updated. Therefore, we have directed our recommendation to the service secretaries. DOD officials also noted that since we did not evaluate how the maintenance data from existing programs are being used to update maintenance tasks and extend intervals, they will need further study to ensure that proper maintenance is being performed and the intent of reliability centered maintenance analyses is being met.

Appendix I presents the objectives, scope, and methodology of this review. Appendix II lists the aircraft and aircraft engines to which the services have applied the RCM concept. Appendix III lists those aircraft and aircraft engines to which the services have not applied RCM.

We are sending copies of this report to the Secretaries of Defense, the Army, the Air Force, and the Navy; the Chairmen, House and Senate

Committees on Appropriations and on Armed Services; and the Director of the Office of Management and Budget. We will also make copies available to others on request.

Please contact me at (202) 512-5140 if you or your staff have any questions concerning this report. Major contributors to this report are listed in appendix IV.

Sincerely yours,

Mark E. Gebicke
Director
Military Operations and Capabilities Issues

Contents

Abbreviations

DOD	Department of Defense
RCM	reliability centered maintenance

Objectives, Scope, and Methodology

The Senate report on the fiscal year 1992 Department of Defense (DOD) Appropriations Act urged the Air Force to implement reliability centered maintenance (RCM) and to report the resultant cost savings in its fiscal year 1993 budget request. It also directed us to report on the progress the Air Force made to implement RCM and to analyze the savings reported by the Air Force.

We briefed your office in July 1992 that the Air Force was updating its RCM analyses on aircraft but had not identified any significant savings. As a result of discussions with your office, we expanded our review to include all three services. Our objectives were to answer the following questions:

- How have the services implemented and updated RCM on their developmental and operational aircraft and aircraft engines?
- On which aircraft and aircraft engines have the services applied and not applied RCM?
- What other programs do the services use to meet the intent of RCM to ensure appropriate maintenance is done?

To accomplish these objectives, we reviewed the DOD directive and the services' regulations and guidance related to applying RCM to operational and developmental aircraft and engines. To understand the elements of an RCM analysis, we reviewed various studies, reports, and portions of RCM analyses on selected aircraft and aircraft engines and discussed them with system engineers and program managers. To gain independent opinions, we contacted officials from the aircraft industry and academia and discussed the benefits and limitations of RCM.

To find out what other engineering and analytical programs the services use to determine maintenance requirements, we interviewed program managers, logisticians, maintenance engineers, and maintenance management specialists to ascertain how these programs relate to RCM. We also reviewed regulations and other documents pertaining to these programs.

We did not evaluate the accuracy or completeness of the services' RCM analyses. In addition, we did not determine whether the services' maintenance tasks or maintenance intervals were appropriate. We also did not verify that RCM analyses were done on the aircraft and aircraft engines listed in appendix II. The list was based on interviews with service officials and documents provided by them.

To determine how the services use RCM and other programs to decide on maintenance tasks and schedules and to determine which aircraft and aircraft engines the services applied RCM to, we contacted officials from the

- Office of the Assistant Secretary of Defense (Production and Logistics), Washington, D.C.;
- Department of Defense Office of the Inspector General, Washington, D.C.;
- Army Headquarters, Washington, D.C.;
- Army Materiel Command, Alexandria, Virginia;
- Aviation and Troop Command, St. Louis, Missouri;
- Materiel Readiness Support Activity, Lexington, Kentucky;
- Corpus Christi Army Depot, Corpus Christi, Texas;
- Navy Headquarters, Washington, D.C.;
- Naval Air Systems Command, Washington, D.C.;
- Naval Aviation Depots, Norfolk, Virginia, and Cherry Point, North Carolina;
- Naval Aviation Maintenance Office, Patuxent River, Maryland;
- Air Force Headquarters, Washington, D.C.;
- Air Force Materiel Command, Wright-Patterson Air Force Base, Ohio;
- Warner-Robins Air Logistics Center, Georgia;
- Oklahoma City Air Logistics Center, Oklahoma;
- Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio;
- Aeronautical Systems Center, Wright-Patterson Air Force Base, Ohio;
- Federal Aviation Administration, Washington, D.C.; and
- Air Transport Association, Washington, D.C.

We performed our work between May 1992 and March 1993 in accordance with generally accepted auditing standards.

DOD Aircraft and Aircraft Engines With RCM Analyses

Military service	Aircraft (Aircraft and Engines on the same line are not related)	Engine
Army		
	RAH-66[a]	T800[a]
Navy		
	A-6	F110
	AV-8	F404[b]
	E-2	J-52[b]
	F-14	J-56[b]
	F-18	TF-30
	F/A-18E/F[a]	TF-34[b]
	H-53	
	H-60	
	P-3	
	S-3	
	V-22	
Air Force		
	A-7	F-100-100/200
	A-10	F-100-220
	A/T-37	F-101-102
	OA-37	F-110-110
	B-1B	F-117
	B-2[a]	F-119[a]
	B-52	J-85-5
	C-5	TF-30-100
	C-17[a]	TF-30-109
	C-130	TF-30-111
	C-141	TF-33-100
	F-15	TF-33-102
	F-16	TF-33-3/103
	F-22[a]	TF-33-5
	F-106	TF-33-7
	EF/F/FB-111	TF-33-9
	F-117A	TF-34
	H-1	TF-39
	H-3	T-56-A7/15[a]
	H-53	T-58

(continued)

Military service	Aircraft (Aircraft and Engines on the same line are not related)	Engine
	C/KC-135	T-64-7A/100
	OV-10	
	T-38	
	CT/T-39	

[a]RCM analyses were being developed as of February 1993.

[b]According to the Navy RCM manager, partial RCM analyses were done on these engines.

DOD Aircraft and Aircraft Engines Not Having RCM Analyses

Service	Aircraft	Engine	Reason for waiver
Army[a]			
	AH-1		No waiver issued
	AH-64		No waiver issued
	CH-47		No waiver issued
	CH-54		No waiver issued
	OH-6		No waiver issued
	OH-58		No waiver issued
	UH-1		No waiver issued
	UH-60		No waiver issued
		T53	No waiver issued
		T55	No waiver issued
		T63	No waiver issued
		T73	No waiver issued
		T700	No waiver issued
Navy			
	AH-1W		No waiver issued
	C-2		No waiver issued
	C-130		No waiver issued
	E-6A		No waiver issued
	H-46		No waiver issued
	T-45		No waiver issued
		F402	No waiver issued
		T-76	No waiver issued
		T400	No waiver issued
		T700	No waiver issued
Air Force			
	C-9		Contractor maintained
	C-12		Contractor maintained
	C-18		Contractor maintained
	C-20		Contractor maintained
	C-21		Contractor maintained
	C-22		Contractor maintained
	C-23		Contractor maintained
	C-26		Contractor maintained
	C-27		Contractor maintained
	C-29		Contractor maintained
	C-131		Small inventory
	C-137		Contractor maintained

(continued)

Service	Aircraft	Engine	Reason for waiver
	E-3A		Using commercial maintenance practices
	E-4B		Contractor maintained
	E-9		Contractor maintained
	H-60		Using commercial maintenance practices
	KC-10		Contractor maintained
	T-41		Contractor maintained
	T-43		Contractor maintained
	UV-18B		Contractor maintained
		F103-100	Contractor maintained
		F103-101	Contractor maintained
		F108-100	Using commercial maintenance practices
		F113	Contractor maintained

[a]The Army has performed partial RCM analyses on these systems, but it has not done the decision logic process on them.

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