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United States Government Accountability Office  
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November 9, 2006

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Chairman  
The Honorable Patty Murray  
Ranking Minority Member  
Subcommittee on Transportation, Treasury,  
the Judiciary, Housing and Urban Development,  
and Related Agencies  
Committee on Appropriations  
United States Senate

The Honorable Joe Knollenberg  
Chairman  
The Honorable John W. Olver  
Ranking Minority Member  
Subcommittee on Transportation, Treasury,  
and Housing and Urban Development, the Judiciary,  
District of Columbia and Independent Agencies  
Committee on Appropriations  
House of Representatives

Subject: *FAA's Proposed Plan for Implementing a Reliability Centered  
Maintenance Process for Air Traffic Control Equipment*

The Federal Aviation Administration's (FAA) Air Traffic Organization (ATO) is responsible for maintaining approximately 40,000 pieces of air traffic control equipment, such as radars, navigation beacons, communication systems, and instrument landing systems that are essential to the safe operation of the national airspace system (NAS). Currently, ATO engineers and technicians conduct routine maintenance, periodic inspections, and performance checks on air traffic control equipment to ensure that it functions properly. Recently, ATO identified another process called reliability centered maintenance (RCM) that it plans to add to the other methods it uses to maintain the equipment. RCM is a data-driven, analytical process used to determine the most value-added maintenance requirements that are needed to keep equipment functioning properly. RCM processes are used by federal and private organizations because they reduce unnecessary maintenance. ATO believes that RCM's data-driven analyses for identifying maintenance needs,

combined with the equipment manufacturers' maintenance recommendations and engineers' knowledge of the air traffic control equipment, will enhance the ways that ATO maintains the equipment. Senate Report 109-109, which accompanied the Fiscal Year 2006 Appropriations Act for the Department of Transportation,<sup>1</sup> asked us to analyze FAA's plans to develop an RCM process and the impact of these plans. Since FAA is just beginning to define its approach to RCM, we could not address the specific request. However, as agreed with your offices, we are reporting on (1) what RCM is and where it is being used and (2) the status of ATO's plan for developing and implementing an RCM process for maintaining air traffic control equipment.

To address these questions, we interviewed ATO officials assigned to FAA offices in Washington, D.C., and in Oklahoma City, Oklahoma,<sup>2</sup> and reviewed their operating procedures and maintenance documents. We also interviewed, and obtained documents from, officials of the FAA employee unions that represent ATO technicians and engineers, the Professional Airways Systems Specialists (PASS), and the National Air Traffic Controllers Association (NATCA), respectively. In addition, we interviewed officials of the National Aeronautics and Space Administration (NASA) and the Department of Defense (DOD) about their agencies' RCM initiatives. Finally, we reviewed pertinent documents, books, and our prior reports on FAA maintenance procedures for air traffic control equipment, RCM, and planning strategies of leading organizations. (See encl. I for additional information on our methodology.) We conducted our work from May 2006 through October 2006 in accordance with generally accepted government auditing standards.

## Summary

RCM is a data-driven, analytical process used to determine the most value-added maintenance requirements that are needed to keep equipment functioning properly. It requires that data be collected and analyzed on the causes and consequences of failures, in order to determine the maintenance needed to prevent future failures. For example, performance data can be analyzed to determine whether a particular component wears out with age or fails randomly—key information for deciding the maintenance approach most appropriate for that item. Generally, RCM analyses are used to identify which of three approaches is most appropriate for preventing equipment failures: (1) periodic maintenance, meaning procedures are performed at regular intervals (for example, monthly); (2) condition-based maintenance, meaning equipment is monitored but only serviced when potential problems warrant it; and (3) run-to-fault maintenance, meaning equipment is allowed to fail because maintenance would have no effect on whether (and when) equipment fails. Both federal agencies and private industry utilize RCM for their equipment maintenance. Leading organizations that introduce new processes, like RCM, develop strategic

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<sup>1</sup>Transportation, Treasury, Housing and Urban Development, The Judiciary, The District of Columbia, and Independent Agencies Appropriations Act, 2006, P.L. 109-115, 119 Stat. 2396.

<sup>2</sup>ATO's National Airway Systems Engineering Group in Oklahoma City, Oklahoma, is responsible for exploring RCM and pilot-testing the development of RCM-based maintenance procedures.

implementation plans that articulate program objectives and timetables, and commit resources for training, data collection and analysis, and other costs.

ATO has announced that it intends to add an RCM process to its current methods of maintaining air traffic control equipment, which rely on recommendations made by equipment manufacturers and ATO's own expertise. Currently, ATO is in the early planning phase. At the time of our review, ATO had not yet developed a plan or identified resources for implementing an RCM process for maintaining air traffic control equipment. ATO officials told us that they hope to complete a number of steps within the next year, such as designating the ATO offices to be responsible for implementing RCM maintenance policy and procedures, providing appropriate RCM training to ATO engineers and technicians, and having ATO engineers begin using RCM to update equipment maintenance handbooks. ATO officials estimate that it will take at least 10 years before RCM can be fully implemented as part of ATO's maintenance process because more than 300 system maintenance handbooks will have to be updated. ATO officials are aware that the unions representing the agency's engineers and technicians are concerned that an RCM process will lead to unsafe air traffic control equipment. This concern has arisen, in part, because FAA experimented several years ago with a different maintenance process that union officials have criticized as unsafe, and because ATO has not explained its vision of an RCM process. ATO officials told us that they intend to work with the unions as they implement an RCM process.

The Department of Transportation provided technical comments on a draft of this report, which we incorporated as appropriate.

## **Background**

A complex array of primarily ground-based navigation and communication equipment facilitates the safe and efficient movement of aircraft throughout the NAS. The NAS infrastructure includes information technology systems and equipment, including radar installations, signal beacons, and communication towers. Maintaining this equipment is the responsibility of the FAA's Technical Operation Services unit, within the agency's ATO. With an annual budget of over \$1.86 billion, Technical Operations Services has about 6,300 systems specialists and engineers to maintain approximately 40,000 pieces of NAS equipment. ATO engineering offices responsible for developing ATO equipment maintenance approaches and procedures are located in Oklahoma City, Oklahoma, and Atlantic City, New Jersey.

FAA's interest in improving maintenance of air traffic control equipment is part of a broader agency initiative to improve the way it provides air traffic services. As early as 1997, the National Civil Aviation Review Commission recommended that FAA's air

traffic control operations be consolidated under a performance-based organization.<sup>3</sup> By 2004, FAA reorganized all areas of its air traffic control program under the Air Traffic Organization, and established an office goal of providing customer service at lower cost by incorporating leading industry practices and procedures, where applicable, in a way that would ensure safety equal to or better than before.

The RCM approach to maintenance began to develop in the late 1960s, when a joint FAA and commercial airline industry task force investigated the periodic-maintenance approach then widely used to ensure aircraft safety. In 1968, the task force created a handbook that was applied to the Boeing 747. The handbook called for a reduction in the requirements established for maintenance and overhauls of equipment, while increasing reliability and safety.<sup>4</sup> Subsequently, in the 1970s, DOD hired United Airlines to study the relationship between maintenance, reliability, and safety. In 1978, United Airlines staff produced a document entitled “Reliability-Centered Maintenance.” This document differed from the 1968 handbook in that it expanded certain points and called for a more rigorous analysis of scheduled maintenance programs. Different versions of RCM have evolved from the original 1978 process. RCM processes are highly regarded by several different industries and are used worldwide.

Currently, engineers in ATO’s Technical Operation Services unit rely on instructions provided by equipment manufacturers and their own expertise to write handbooks detailing the procedures that technicians should use to maintain about 40,000 pieces of air traffic control equipment. In October 2004, ATO officials formed a committee to examine new practices that could improve their maintenance of air traffic control equipment. Committee members included representatives of FAA’s PASS and NATCA unions, as well as additional engineers and maintenance office managers. The committee generally favored incorporating an RCM process into ATO’s maintenance process, although the union representatives opposed it. PASS and NATCA believed that RCM resembled another maintenance approach that FAA had previously pilot-tested—a process that deferred maintenance and led the unions to question the safety of air traffic control equipment. PASS withdrew from the committee in March 2005. ATO planned to proceed with development of an RCM process, as announced by a formal vision document issued in September 2005.

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<sup>3</sup>A performance-based organization is a discrete management unit with incentives to manage for results. In the 1990s, federal law established performance-based organizations as a way of restructuring federal agencies and holding them accountable for program results. The pay and tenure of the head of a performance-based organization is tied to achievement of the unit’s clearly defined performance goals.

<sup>4</sup>Although the 1968 maintenance approach had many features of a reliability-centered maintenance process, it was not referred to by that name.

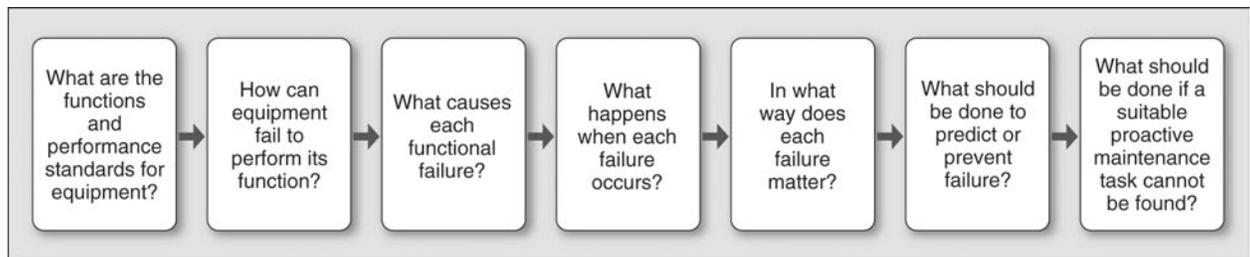
## RCM Is a Data-Driven, Analytical Process That Is Used to Determine Appropriate Maintenance Approaches

The RCM process requires an analysis of equipment function and performance data to determine the most appropriate method and timing for conducting maintenance activities. It requires data on the function and performance of specific equipment to be collected and analyzed, including data on the causes and consequences of failure, in order to determine the maintenance needed to prevent future failures. For example, analysis of performance data can determine whether a particular component wears out with age or fails randomly—key information for deciding the maintenance approach most appropriate for that item. The goals of an RCM process are to reduce equipment-caused delays, eliminate ineffective maintenance, keep maintenance costs to a minimum, and preserve the functioning of an entire system rather than its individual components. RCM does not guarantee that a system will not fail; instead, it seeks to mitigate the impact of a failure on safety through the selection of an appropriate maintenance approach indicated by an analysis of the relevant data.

### Steps in the RCM Process

No single RCM process is recognized throughout government and private industry. However, a widely recognized set of RCM standards or steps was developed in 1999 by the Society of Automotive Engineers<sup>5</sup> (SAE), and updated in 2002,<sup>6</sup> for use by organizations that have, or make use of, physical assets or systems. The SAE steps shown in figure 1 below contain the minimum questions that a maintenance process must answer in order to be an RCM process.

**Figure 1: Basic Steps for Developing an RCM Equipment Maintenance Procedure**



Source: GAO.

The first steps in a typical RCM process involve collecting and analyzing data on the function and performance of each piece of equipment. Performance information is found in databases that record how long equipment operates and under what

<sup>5</sup>The Society of Automotive Engineers has more than 90,000 members—engineers, business executives, educators, and students from more than 97 countries—who share information and exchange ideas for advancing the engineering of mobility systems.

<sup>6</sup>SAE JA1011, “Evaluation Criteria for RCM Processes,” August 1999, and SAE JA1012, “A Guide to the RCM Standard,” January 2002.

conditions it fails. In addition, staff use their knowledge of the equipment's operation to supplement performance data. The data are then analyzed according to the steps shown in figure 1 for each piece of equipment.

Using the results of the analysis, staff then decide what maintenance approaches will best ensure that equipment will perform properly without undergoing unnecessary maintenance. Generally, RCM approaches to preventing equipment failures include performing (1) periodic maintenance, such as inspections, repairs, and performance checks (which are performed at specific intervals); (2) condition-based maintenance, which is performed to prevent or predict equipment failures; and (3) run-to-fault maintenance, under which equipment is allowed to fail because it is not possible or prudent to avoid failures or extend the life of the equipment through maintenance. Changing the battery in a smoke detector every 6 months illustrates a typical household example of periodic maintenance. Checking tire treads for excessive wear illustrates a condition-based maintenance procedure. Run-to-fault maintenance could be illustrated, for example, by light fixtures in halls, cafeterias, and lounges, where bulbs are only replaced as they burn out because an outage would not generally disrupt use of the facility or pose a safety hazard. A hypothetical RCM-based analysis of the performance data for a radar system might show that a particular component causes outages most often after 2 years of use. Engineering analysis could show that monthly maintenance procedures for that component are excessive to protect equipment against a biennial outage and that quarterly procedures would be more effective. (See encl. II for a flowchart showing the types of questions that can identify the most appropriate approaches.)

### RCM Is Used in the Federal Government and Private Industry

Both federal agencies and private industry utilize RCM for their equipment maintenance. For example, the Naval Air Systems Command (NAVAIR) under the DOD has been using RCM approaches on its systems since 1972, and NASA started using RCM in 1995 at its laboratory facilities. Organizations such as commercial airlines, electric power companies,<sup>7</sup> and chemical processors also use RCM-based approaches to maintain equipment that is essential for their industries. RCM is considered such an effective way for organizations to maintain their physical assets that many professional maintenance training and certification programs have incorporated it in their curriculums. For example, the Society for Maintenance and Reliability Professionals requires candidates for professional certification to become familiar with RCM, and several universities operate maintenance management certificate programs that introduce RCM to participants.

### RCM Requires Organizations to Plan and Commit Resources

Implementing an RCM process demands a certain level of commitment for most organizations. We reported in an earlier study that leading organizations rarely make

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<sup>7</sup>According to the Electric Power Research Institute, electric utilities need maintenance practices to ensure reliability while controlling and possibly lowering costs. The institute offers RCM program support tailored to individual utility company needs.

major changes to their processes without first developing strategic plans to guide their implementation.<sup>8</sup> Strategic planning can be defined as a structured process through which an organization translates a vision and makes fundamental decisions that shape and guide what the organization is and what it does. Since RCM is a data-driven process, an organization planning to adopt it must usually dedicate resources to pay for items necessary to support it. Costs could include items such as acquiring a computerized maintenance management system to collect performance data on equipment, training staff in RCM, and covering higher labor costs during the initial analyses to identify maintenance approaches and specific maintenance procedures. However, these costs may be mitigated by savings after organizations implement an RCM process, according to literature on the subject.

### **ATO Has Not Developed Plans for Implementing RCM**

ATO is in the early planning phase of developing an RCM process for maintaining air traffic control equipment. At the time of our review, ATO had developed a draft order that calls for using RCM as part of its maintenance process because ATO engineers believe that the newer technology of air traffic control equipment requires less maintenance than what is currently being performed, and because RCM will make maintenance decisions more transparent. However, ATO has not yet developed a plan for implementing an RCM process. ATO officials told us that they envision using RCM in conjunction with the maintenance recommendations supplied by equipment manufacturers, and the expertise of its engineers and technicians to form a complete maintenance program for air traffic control equipment. ATO officials estimated that, for RCM to be implemented, over 300 system maintenance handbooks would have to be updated over a period of at least 10 years. However, basic issues about the RCM process that ATO wants to develop remain undecided. For instance, ATO has not decided whether the data now collected will be sufficient for RCM analysis, or what RCM training will be provided for its staff.

ATO officials have identified certain decisions they need to make before an RCM plan can be established. These officials told us that they plan to complete several steps within the next year that will signal their commitment to eventually using an RCM approach for maintenance, including (1) designating the ATO offices that will be responsible for implementing RCM policy and procedures, (2) providing appropriate RCM training to ATO engineers and technicians, and (3) having ATO engineers use RCM to update equipment maintenance handbooks. However, as discussed, implementing an RCM process usually requires an organization to plan its development and commit resources for training, equipment, and labor costs—steps that ATO has not yet taken.

Currently, ATO oversees the functioning of NAS equipment by using a maintenance process, primarily based on periodic maintenance activities, including preventative maintenance inspections, performance checks, and routine maintenance. For

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<sup>8</sup>GAO, *Executive Guide: Leading Practices in Capital Decision-Making*, [GAO/AIMD-99-32](#) (Washington, D.C.: December 1998).

example, ATO currently maintains its instrument landing system (ILS) equipment against failure through periodic maintenance that includes monthly, quarterly, semiannual, and annual service for the system’s components. However, an RCM process would generally indicate the appropriateness of using one or more of three approaches for preventing equipment failures: (1) periodic maintenance, (2) condition-based maintenance, and (3) run-to-fault maintenance. Therefore, under RCM, some periodic tasks for maintaining the ILS might remain unchanged while other tasks might be rescheduled for new intervals, replaced by monitoring tasks, or dropped altogether, depending on the results of engineering analyses. For example, an ILS component that currently receives quarterly maintenance could be found, through an engineering analysis, to need only annual maintenance. Furthermore, a study of a different ILS component could show that it needs no planned maintenance, so the run-to-fault maintenance approach should apply. Display monitors in air traffic control towers illustrate a different type of equipment that could qualify for run-to-fault maintenance, according to ATO officials. In one failure mode, these monitors gradually develop alignment problems over time, but are still useable. When a monitor finally becomes unusable, towers use backup monitors while the unusable monitor is repaired. ATO officials told us that, for this type of failure, they could allow a monitor to run-to-fault because a failed monitor would pose no operational issues and repairing the monitor after a failure would not be costly. An ATO official told us that once an RCM process is implemented, staff will be able to expand the selection of maintenance approaches by incorporating those shown in table 1.

**Table 1: FAA’s Potential RCM Maintenance Approaches**

Maintenance approach	Description
Periodic maintenance	Scheduled maintenance performed at set time intervals, regardless of equipment condition. Maintenance can include inspection, adjustments, cleaning, lubrication, parts replacement, calibration, and repair. If failures are unrelated to equipment age, periodic maintenance can be unnecessary. <i>Possible application:</i> radar antenna drive motors.
Condition-based maintenance	Condition-based monitoring forecasts time when maintenance should be performed. Predictive testing and inspections eliminate unnecessary maintenance and extend equipment life. Also includes cycle-based and performance-hour procedures. <i>Possible applications:</i> replacement of digital audio tapes after a certain number of recording cycles; maintenance of emergency power generators after a certain number of hours of operation.
Run-to-fault maintenance	No maintenance is planned for equipment because it would not reduce the probability of failure or extend equipment life. Backup equipment may be needed to reduce the risk and cost of failure. <i>Possible application:</i> flat panel displays.

Source: FAA.

ATO pilot-tested the development of RCM procedures in 2006 when it assigned a team of engineers to update maintenance procedures for ILSs. The team drafted new procedures that combined the use of periodic, condition-based, and run-to-fault maintenance for various components of the systems. However, ATO did not consider these to be true RCM procedures because the team arrived at its results without systematically examining the function and performance information essential to the RCM process. As a result, the team provided no RCM analytical documentation when the pilot ended, and ATO officials concluded that staff needed more training in the RCM process than the RCM familiarization course that ATO had supplied. During our review, we were told that ATO was contacting NAVAIR about the possibility of using its RCM training as a model for future ATO training. Despite the challenge shown by ATO's initial attempt to develop a procedure, an ATO official told us that the first RCM system maintenance handbook for certain aircraft navigation beacons, known as very high frequency omnidirectional range systems, would be developed by 2007.

### Concerns about RCM Are Based on Failed Alaskan Pilot Maintenance Program

Union officials told us that RCM appears to be no different from an Alaskan pilot program that limited the use of periodic maintenance. Even before ATO's 2005 planning document announced its intention to implement RCM, officials from the two FAA unions that represent ATO's technicians (PASS) and engineers (NATCA) testified before Congress that RCM is unsafe, inefficient, and a threat to the reliability of NAS equipment. For example, the President of PASS stated that RCM would significantly reduce periodic maintenance and substitute a "fix-on-fail" method that would increase disruptive unplanned downtime, thereby threatening flight safety and wasting agency resources. NATCA's Alaskan Regional Vice President stated that RCM would lead to equipment outages disrupting air traffic routes important to Alaskan communities. Both officials testified that RCM resembles a maintenance pilot program that FAA had tested in its Alaska region with less-than-favorable results.

FAA conducted a maintenance pilot program, called the Corporate Maintenance Philosophy (CMP), in its Alaska region from 1997 to 2000. The goal of this pilot was to test a more "business-like" approach to air traffic control maintenance. Under CMP, the intervals between servicing much of the region's equipment, including some of its critical safety equipment, increased. In addition, the CMP pilot relied extensively on run-to-fault maintenance and led to operational problems that staff were unable to correct. A NATCA official told us that under CMP, servicing intervals were longer, equipment outages increased, and repairs at each facility were more substantial. Because of the unions' complaints and a resulting Federal Labor Relations Authority ruling, the CMP pilot was discontinued, and the Alaska region reverted to using the national periodic maintenance and certification standards.

Furthermore, our report<sup>9</sup> on the CMP pilot and its aftermath described safety concerns arising from the lack of quality control checks being performed by FAA staff responsible for ensuring that maintenance information was properly entered in FAA's computerized maintenance management system. In addition, we found that, at all 12 Alaska region offices, the staff were behind schedule in performing their periodic maintenance activities.

ATO officials acknowledge that safety issues resulting from the CMP pilot have given staff and unions reason for concern about the proposed RCM maintenance process. According to an internal ATO briefing paper, RCM is often mistakenly viewed as an approach that abandons periodic maintenance. However, ATO officials told us that, unlike the CMP pilot program in Alaska, RCM will not abandon periodic maintenance. According to ATO officials, RCM will be a data-driven process that differs distinctly from the CMP pilot. ATO officials explained that equipment under CMP was allowed to run-to-fault because of a lack of money for repairs and the remote nature of the equipment in Alaska. RCM, however, will preserve periodic maintenance and incorporate condition-based maintenance, except where run-to-fault maintenance is appropriate. Furthermore, an ATO official told us that his office plans to do more to point out the differences between RCM and the CMP pilot program to secure buy-in from ATO staff and unions.

## Agency Comments

We provided copies of a draft of this report to the Department of Transportation for its review and comment. The agency provided technical comments, which we incorporated into the report as appropriate.

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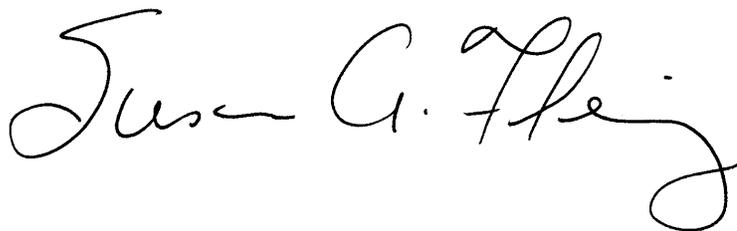
We are sending copies of this report to the Chairmen and Ranking Minority Members of the Senate and House Subcommittees with jurisdiction over FAA matters. We will also send copies to the Secretary of Transportation and the Administrator of the Federal Aviation Administration, and other interested parties. In addition, the report will be available on the GAO Web site at <http://www.gao.gov>.

If you or your staff have any questions about this report, please contact me at [Flemings@gao.gov](mailto:Flemings@gao.gov) or at (202) 512-2834. Contact points for our offices of

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<sup>9</sup>GAO, *National Airspace System: Incomplete Transition Back to National Maintenance and Certification Standards in the Federal Aviation Administration's Alaskan Region*, GAO-02-127R (Washington, D.C.: Nov. 30, 2001).

Congressional Relations and Public Affairs may be found on the last page of this report. Individuals making key contributions to this report are listed in enclosure III.

A handwritten signature in black ink, reading "Susan A. Fleming". The signature is written in a cursive style with a large initial 'S' and a long, sweeping tail on the 'g'.

Susan A. Fleming  
Director, Physical Infrastructure Issues

## **Scope and Methodology**

For information about Reliability Centered Maintenance (RCM), we reviewed professional and academic literature on its background, purpose, development, and standards, and obtained information on the RCM programs at the National Aeronautics and Space Administration and the Department of Defense, Naval Air Systems Command.

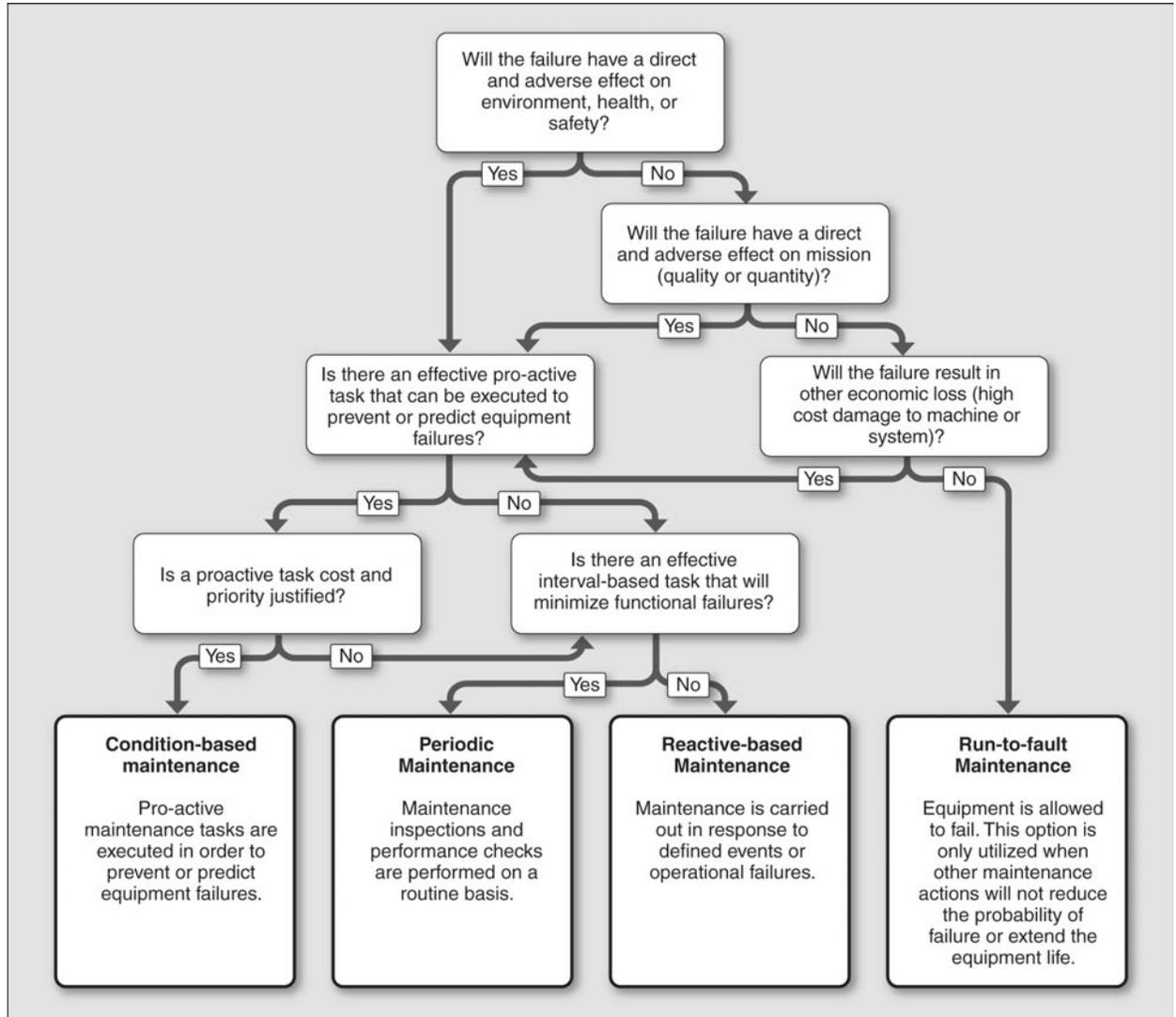
To provide information on the Air Traffic Organization's (ATO) plan for developing and implementing RCM, we interviewed officials at the Federal Aviation Administration's (FAA) headquarters in Washington, D.C., and FAA's National Airway Systems Engineering office in Oklahoma City, Oklahoma. During these visits, we interviewed ATO's Director of Safety and Operations Support, the Manager of Safety and Operations Support, the Manager of National Airway Systems Engineering Group, program analysts, and engineers responsible for maintenance procedures for two types of air traffic control equipment—instrument landing systems (ILS) and navigation beacons called very high frequency omnidirectional range (VOR). We also reviewed a September 2005 ATO Technical Operations vision paper, minutes of internal ATO planning meetings, and a draft maintenance order outlining proposed RCM requirements for air traffic control equipment maintenance. Additionally, we reviewed early draft RCM maintenance procedures for ILSs and compared them with ATO's current procedures.

To provide information on concerns about ATO's RCM initiative, we interviewed union representatives from the Professional Airways Systems Specialists (PASS) and the National Air Traffic Controllers Association (NATCA), representing technicians and engineers, respectively. We also reviewed GAO and FAA reports on the FAA's maintenance pilot program in its Alaska Region and planning strategies of leading organizations. We performed our work from May 2006 through October 2006 in accordance with generally accepted government auditing standards.

**Example of a NASA Decision Process for Selecting an RCM Maintenance Approach**

Generally, RCM programs use flow charts called logic trees, like the one below, to guide staff in identifying the appropriate maintenance approaches.

**Figure 2: Reliability Centered Maintenance (RCM) Decision Logic Tree**



Source: NASA Facilities RCM Guide.

Enclosure III

**Contact and Staff Acknowledgments**

**GAO Contact** Susan Fleming, (202) 512-2834 or [Flemings@gao.gov](mailto:Flemings@gao.gov)

**Staff  
Acknowledgments**

In addition to the contact named above, Nabajyoti Barkakati, Richard Calhoon, Virginia Chanley, Bess Eisenstadt, David Hooper, Amanda Krause, Joshua Ormond, Nitin Rao, Taylor Reeves, and Phillis Riley made key contributions to this report.

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