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Report to the Chair, Government Activities and Transportation Subcommittee, Committee on Government Operations, House of Representatives

September 1992

AIR TRAFFIC CONTROL

FAA Needs to Justify Further Investment in Its Oceanic Display System

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Information Management and
Technology Division

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September 30, 1992

The Honorable Barbara Boxer
Chair, Government Activities
and Transportation Subcommittee
Committee on Government Operations
House of Representatives

Dear Madam Chair:

We are addressing this report to you in accordance with your August 21, 1992, request. The report, entitled Air Traffic Control: FAA Needs to Justify Further Investment in Its Oceanic Display System (GAO/IMTEC-92-80), cites serious problems with the Federal Aviation Administration's (FAA) Oceanic Display and Planning System (ODAPS) and concludes that until FAA thoroughly assesses alternative system solutions to its oceanic air traffic control mission requirements using credible and verifiable life cycle cost data, FAA is not justified in its development of ODAPS, and could be wasting time and money by continuing to do so.

As agreed with your office, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the date of this letter. We will then send copies to the appropriate House and Senate committees, the Secretary of Transportation, the FAA Administrator, and other interested parties. Copies will also be made available to others upon request.

This report was prepared under the direction of JayEtta Z. Hecker, Director, Resources, Community, and Economic Development Information Systems, who can be reached at (202) 512-6416. Other major contributors are listed in appendix II.

Sincerely yours,

Ralph V. Carlone

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Assistant Comptoller General

Executive Summary

Purpose

The Federal Aviation Administration's (FAA) manually intensive process for controlling aircraft over our nation's oceanic airspace cannot keep pace with growing traffic volumes. Without some relief, air traffic controllers will be asked to maintain mentally taxing work loads, and aircraft will have to continue flying less-than-efficient routes. As a first step in a long-term effort to address this situation, FAA is acquiring the Oceanic Display and Planning System (ODAPS). In January 1991, GAO issued a report that described FAA's present system for controlling air traffic over oceans and its acquisition of ODAPS, and recommended that FAA examine alternatives to ODAPS. [1] GAO's objectives for this follow-on review were to (1) identify key risks facing FAA on ODAPS and (2) determine whether FAA was effectively addressing these risks and justified in its continued development of ODAPS.

Background

FAA's air traffic control mission is to promote the safe, orderly, and expeditious flow of civilian and military aircraft over both the United States and most of the Atlantic and Pacific oceans. Unlike flights over land, which are under direct radar control and involve a high degree of automation, transoceanic flights are indirectly and manually controlled using radio communications. That is, air traffic controllers use paper flight strips containing aircraft identification, route, and location information, and update them manually on the basis of indirect and periodic reports from pilots via radio. This process is inefficient, cumbersome, and time-consuming.

ODAPS provides controllers with a computer-generated display of oceanic air traffic and an automatic update and display of flight plan information. FAA's plans are to have a fully functional ODAPS at its two key oceanic air traffic control facilities—the New York Air Route Traffic Control Center (ARTCC) and the Oakland ARTCC—and at the FAA Technical Center for testing and operational support. The heart of ODAPS will be the "conflict probe" function, which will allow controllers to extrapolate the effect of proposed route and altitude changes on aircraft separation. In 1984 FAA estimated the cost of developing ODAPS to be $22 million and the completion date to be August 1987. In contrast, the latest project cost estimate is about $51 million, over $49 million has already been spent, and there is no projected completion date.

Since its inception, ODAPS has experienced significant problems. According to FAA officials and internal FAA reports, the problems include inadequate

[1] Air Traffic Control: Efforts to Modernize Oceanic System Delayed (GAO/IMTEC-91-2, Jan. 16, 1991).

program office staffing for ODAPS development, poorly defined requirements, and inadequate coordination between the program office and the users.

ODAPS was installed at the Oakland ARTCC in December 1989 and at the New York ARTCC in May 1992. Neither of the systems is operating with a conflict probe.

Results in Brief

ODAPS has a long history of problems and more system deficiencies continue to surface. Despite investing over $49 million over 11 years, ODAPS is still missing a key element—an operational conflict probe function that can determine the impact of flight changes on aircraft separation. Moreover, delivering this important function, according to a recent independent study, will require extensive time and effort because the current ODAPS software fails to meet certain conflict probe requirements and is poorly written. Further, FAA is not performing basic capacity management activities on ODAPS, which increases the risk of system performance shortfalls in processing air traffic.

Although FAA claims that the cost to complete ODAPS is only about $1.5 million, this estimate is highly suspect because it is not based on any formal estimating tools or techniques, and it does not include the resources to correct known conflict probe problems. Further, FAA does not know when ODAPS will be completed. Until FAA uses credible and verifiable life cycle cost data and thoroughly assesses alternative system solutions to its oceanic air traffic control mission requirements, FAA is not justified in its development of ODAPS and could be wasting time and money by continuing to do so.

Principal Findings

FAA Is Moving Slowly to Address Serious ODAPS Problems

In November 1991, independent verification and validation (IV&V) findings were presented on the latest available version of the conflict probe software. Verification and validation involves the analysis and testing of software throughout its life cycle to ensure that it meets specified requirements and provides required functions. Modern software engineering standards advocate verification and validation activities.

The ODAPS IV&V effort compared the existing software to the system's specifications and found 22 deficiencies. Moreover, 19 of these were described by the IV&V agents as requiring extensive to moderate time and resources to correct. The deficiencies include failure to meet specified requirements for ensuring minimum separation of aircraft, lack of design documentation, inconsistencies between the conflict probe software and air traffic control operational standards, and poor coding practices, among others. The impact of these deficiencies ranges from the system's inability to perform critical mission needs, such as accurately projecting aircrafts' future violation of separation standards, to more difficult, costly system maintenance.

In response to GAO's inquiries, FAA formed a disposition team to analyze and track the findings. However, this team has yet to issue its conclusions, further delaying resolution of the findings, as well as the delivery of a fully operational ODAPS.

FAA Failing to Perform Capacity Management Activities on ODAPS

Capacity management helps ensure that computer systems (1) are properly designed and configured to give efficient performance and (2) have sufficient resources to support operational work loads. Capacity management activities are encouraged by federal guidance and are a generally accepted practice in the private sector.

FAA is not performing basic capacity monitoring and planning activities for ODAPS. According to ODAPS program management officials, capacity was viewed from the outset of the program as a "nonissue," and has thus been ignored. Although FAA officials claim that neither the Oakland nor New York center is experiencing capacity shortfalls, this assessment is based on limited data—neither center is operating with conflict probe, New York is running only a fraction of its normal work loads, and ODAPS has never been tested at peak work loads (i.e., stress tested). Without an active capacity management program in which (1) existing system resources are stressed; (2) future work loads and required service levels (e.g., system availability) are forecast; and (3) system configurations to meet the demands are proposed, modeled, and tested, FAA runs the risk of experiencing performance problems.

ODAPS Completion Date Is Unknown and Its Cost Estimate Is Highly Questionable

Reliable estimates of the cost and time needed to complete large software development projects require careful analysis and the use of formal estimating tools and techniques. FAA does not know when ODAPS will be completed. Additionally, although it estimates that an additional $1.5 million is needed to complete ODAPS, the cost estimate is not based on formal estimating models. In fact, senior program management officials told us that ODAPS cost and schedule estimates have never been based on such tools. Moreover, neither FAA nor the ODAPS contractor could provide GAO with the information necessary for GAO to independently generate these estimates. According to the program management officials, ODAPS cost and schedule estimates represent a consensus of opinion among experienced program officials of the time and effort necessary to complete identified tasks. In the absence of any disciplined analysis, use of formal estimating tools, or the development of basic information needed to systematically derive such estimates, GAO views FAA's latest estimates as highly questionable.

Moreover, FAA's cost estimate does not include correcting serious problems found by the IV&V team. When GAO asked one senior program official about the cost and time to correct these deficiencies, the official responded that what remains to be done on ODAPS is not difficult; he based his position on his professional judgment and experience.

FAA Continues to Develop ODAPS Without Adequately Analyzing System Alternatives

In response to an earlier GAO recommendation on ODAPS, FAA assessed ODAPS and made recommendations on actions necessary to implement an operational system. FAA also assessed selected alternatives to ODAPS. However, FAA's assessment fell short of a credible analysis of alternatives. In particular, all viable alternatives were not considered, such as (1) initiating a new system development effort; (2) adapting the Japanese system, which has had a conflict alert function for the past 10 years; or (3) incorporating the basic oceanic requirements into the existing en route air traffic control system, known as the Host computer system. In addition, FAA's assessment did not include data on the relative life cycle cost and schedule implications of the alternatives it did consider, including ODAPS. In the absence of such a credible analysis of alternatives, and in view of the problems now surrounding the system, ODAPS may not be the most cost-effective option available.

Recommendations

Because of the problems and uncertainties FAA faces on ODAPS, GAO recommends that the Administrator, FAA, certify to the Secretary of

Transportation that a thorough analysis of all feasible alternatives to ODAPS has been performed. At a minimum, this analysis should include life cycle cost data for each alternative that is credible and verifiable. It should consider not only FAA's short-term oceanic communications, processing, and display requirements, but also its long-term requirements. Should ODAPS emerge from this analysis as the most cost-effective alternative, GAO also recommends that the Administrator certify to the Secretary that:

- All ODAPS IV&V findings are thoroughly and expeditiously assessed and appropriately resolved.
- An ODAPS capacity management program is established.
- ODAPS cost and schedule are systematically estimated using contemporary estimating tools and techniques, and that these estimates are kept current to reflect changes in the program.
- ODAPS is continually monitored relative to other feasible alternatives in light of any changes to the estimates.

Agency Comments

As requested, GAO did not provide a draft of this report to FAA for its review and comment. However, GAO discussed the report's facts with responsible FAA officials, including the Deputy Program Manager for Enroute/Oceanic Automation and Traffic Management System, who generally agreed with the facts. GAO has incorporated FAA's views in the report as appropriate.

Contents

Abbreviations

ADS	Automatic Dependent Surveillance
ANSI	American National Standards Institute
ARINC	Aeronautical Radio Incorporated
ARTCC	Air Route Traffic Control Center
CRT	cathode ray tube
FAA	Federal Aviation Administration
FDIO	Flight Data Input/Output
GAO	General Accounting Office
HF	high frequency
IEEE	Institute of Electrical and Electronics Engineers
IMTEC	Information Management and Technology Division
IV&V	independent verification and validation
NORAD	North American Aerospace Defense Command
ODAPS	Oceanic Display and Planning System
PVD	plan view display

Introduction

Background

FAA's air traffic control mission is to promote the safe, orderly, and expeditious flow of civilian and military aircraft. To accomplish this mission, air traffic controllers direct aircraft departures and approaches; maintain safe distances between aircraft; and communicate weather information, instructions, and clearances to pilots and other personnel.

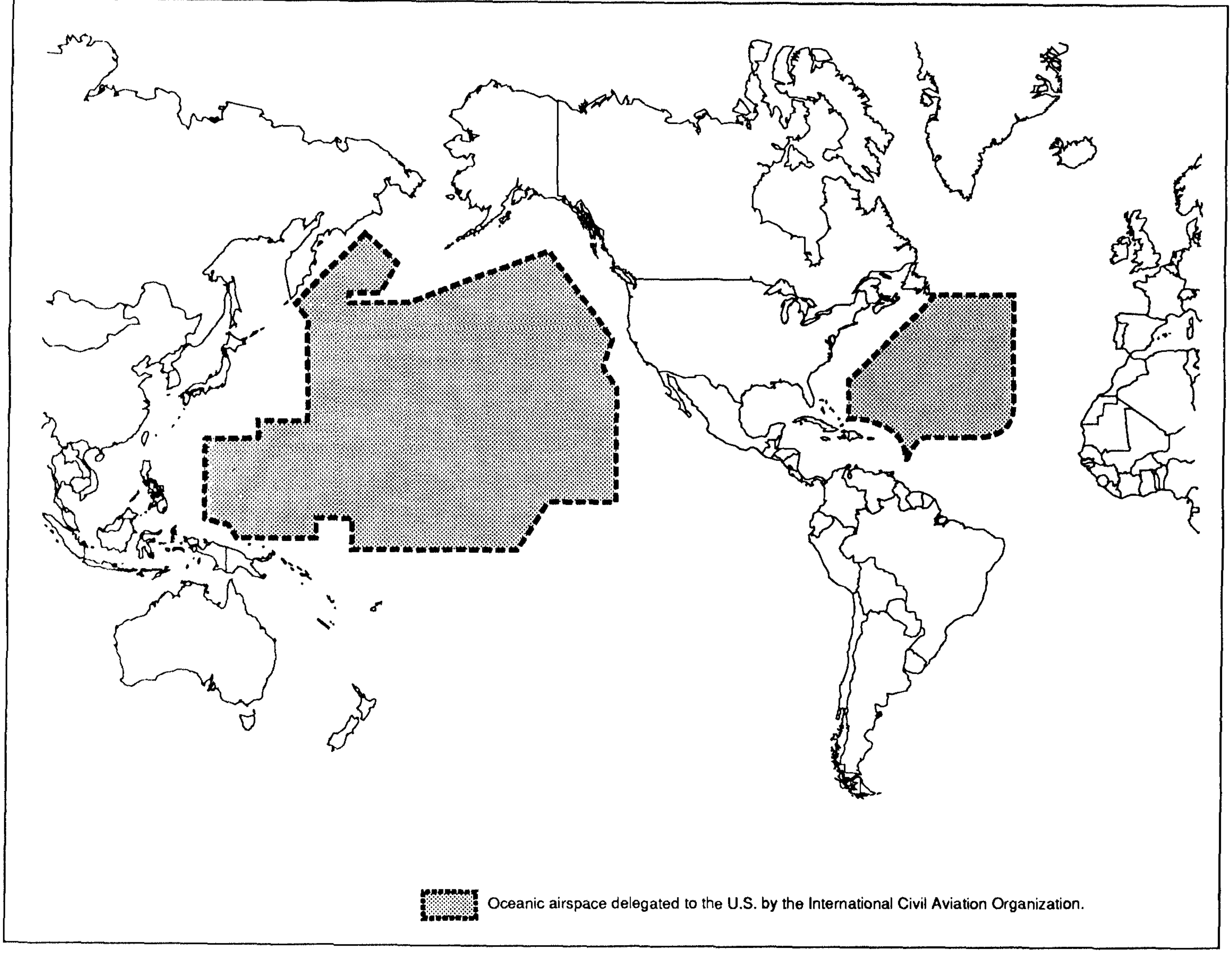
For the continental United States and its coasts, FAA has 20 domestic air route traffic control centers to control aircraft en route between airports, and about 182 terminal radar approach control facilities to control aircraft in terminal airspace. At each of these facilities, controllers rely on radar to provide aircraft location information. These radar data, along with other appropriate information, such as filed flight plans, are then processed by computers and displayed on video screens at controllers' workstations. This information may include airplanes' identity, position, altitude, speed, and direction. In addition, controllers and pilots can communicate directly via very high frequency radio channels.

Due to technological limitations, these surveillance and communications systems are not available for use in all types of airspace. Specifically, both radar coverage and very high frequency communications are "line-of-sight" systems that are limited by distance and the earth's curvature. For example, land-based radar is only able to identify aircraft up to about 175 to 225 miles from the radar's location. Thus, these systems cannot be used to support air traffic services in certain areas such as oceanic airspace, high latitude airspace, and areas with rugged terrain.

An Overview of Oceanic Air Traffic Control

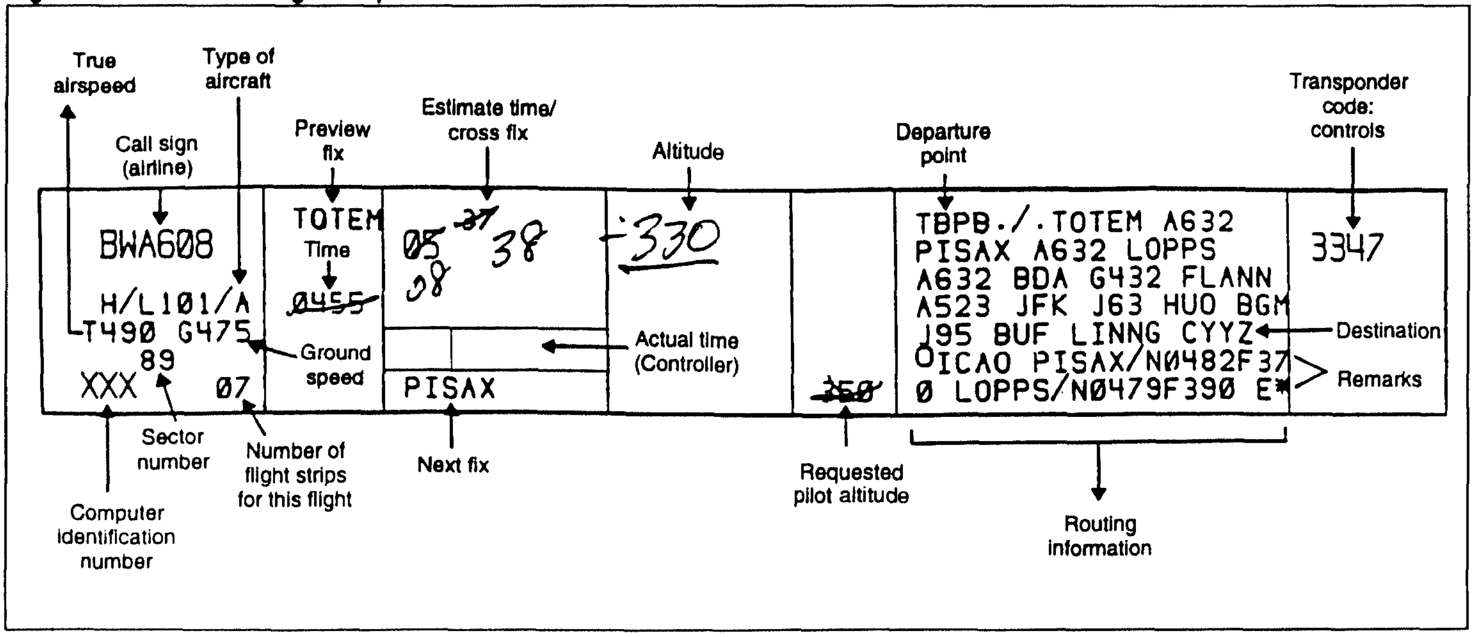
The International Civil Aviation Organization—an agency of the United Nations—has delegated responsibility to the United States for providing air traffic services in most of the Atlantic and Pacific Oceans (see fig. 1.1). FAA's New York Air Route Traffic Control Center (ARTCC) handles traffic over large areas of the Atlantic Ocean; its Oakland, California, ARTCC is responsible for much of the Pacific Ocean. New York ARTCC's oceanic airspace consists of approximately 3.25 million square miles, and Oakland ARTCC's oceanic airspace totals approximately 18 million square miles. In comparison, all domestic airspace regions in the contiguous United States combined are about the same size as New York's oceanic airspace.

Figure 1.1: FAA-Controlled Airspace Over the Pacific and Atlantic Oceans



Except for the recent introduction of some ODAPS functions, FAA's approach to controlling aircraft in nonradar oceanic areas has not changed significantly since the 1950s. Basically, controllers use paper flight progress strips, which contain aircraft identification, destination, and other information about planned flights (see fig. 1.2).

Figure 1.2: Annotated Flight Strip



Note: A fix is the estimated time of arrival at the coordination fix or destination airport.

The flight strips, which are delivered to controllers prior to aircrafts' entry into oceanic airspace, are manually updated by a controller as an aircraft progresses through the airspace. The updates are based on the aircraft's last reported position and its cleared flight plan. Updating of flight progress strips occurs as follows:

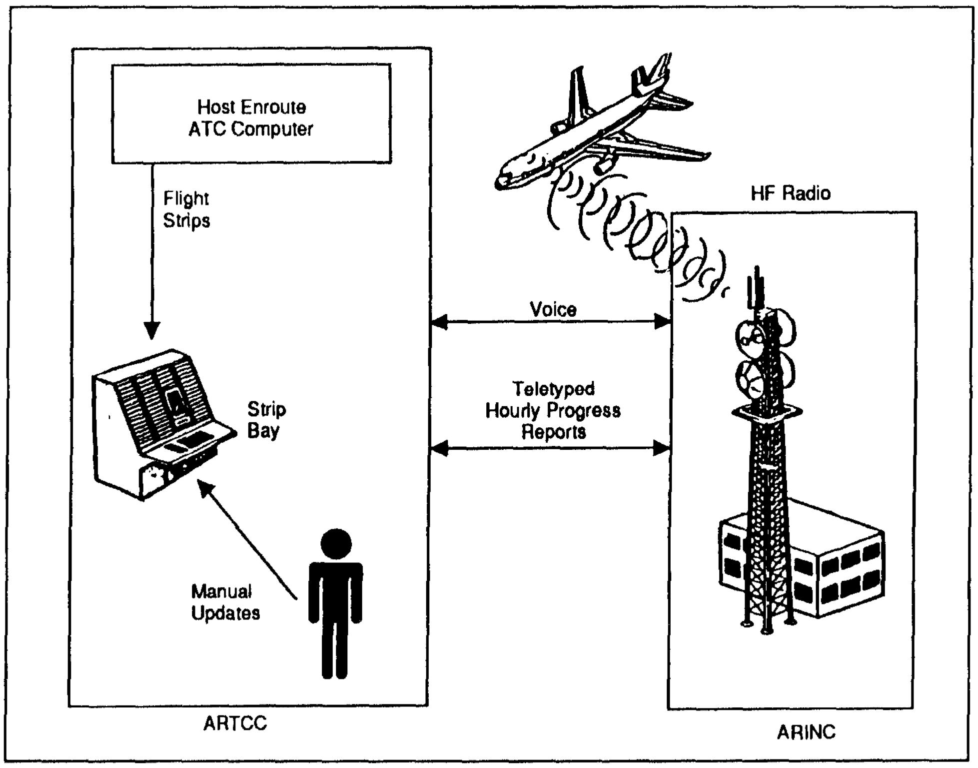
- Pilots report their positions at least once an hour to one of four ground-based radio stations via high frequency (HF) voice radio. Aeronautical Radio Incorporated (ARINC), a private organization funded by the airlines and the federal government, operates these radio stations.
- The communications operator at the radio station then teletypes the contents of the voice report to the appropriate FAA facility. [1]
- The message is printed and delivered to the controller.
- The controller uses the information to manually update the flight progress strips.

[1]Teletyped messages can also be sent from the FAA facility to ARINC.

Current Oceanic Air Traffic Control Process Is Inefficient

FAA's process for controlling aircraft in nonradar oceanic areas imposes restrictions and limitations on FAA's abilities to provide effective and efficient air traffic services. Specifically, unlike their counterparts who handle domestic air traffic, the oceanic controllers do not have a display that accurately depicts real-time aircraft location. Also, the oceanic controllers rarely have direct communication with pilots; they must communicate indirectly through ARINC, except in emergencies when controllers are patched through directly to pilots. This is a cumbersome and time-consuming process that, in a few rare cases, has resulted in inaccurate location information being provided to the controllers due to human errors that occur during the exchange of data. In addition, the quality of HF radio transmissions is affected by atmospheric conditions and electrical storms. Severe degradations in service occur periodically under such conditions. Figure 1.3 depicts FAA's current oceanic air traffic control environment.

Figure 1.3: Oceanic Air Traffic Control Environment Without Automation



Source: Federal Aviation Administration

Because this manually intensive process does not provide real-time data, controllers must maintain large horizontal distances, ranging from approximately 60 to 160 miles, between planes. By contrast, in the domestic environment, where frequent radar surveillance is available, controllers are required to maintain only about 3 to 5 miles of horizontal distance between controlled aircraft.

The process also requires aircraft to generally adhere to rigid route structures that offer limited flexibility for change. Controllers are often unable to provide timely responses to pilot requests for more fuel-efficient routes, due to the lengthy communications process and the absence of real-time data on aircraft location. As a result, planes cannot always take the most efficient routes to their destinations, resulting in flights that take longer than necessary and lost opportunities for saving fuel.

Although the current oceanic air traffic control system has an excellent safety record, its capacity to absorb anticipated increases in air traffic is severely limited. To address this concern, in the late 1970s FAA explored the feasibility of providing automation support for oceanic air traffic control. This effort, now known as the Oceanic Display and Planning System (ODAPS), has resulted in the deployment of some automation capability at the New York and Oakland ARTCCs.

A Description of ODAPS

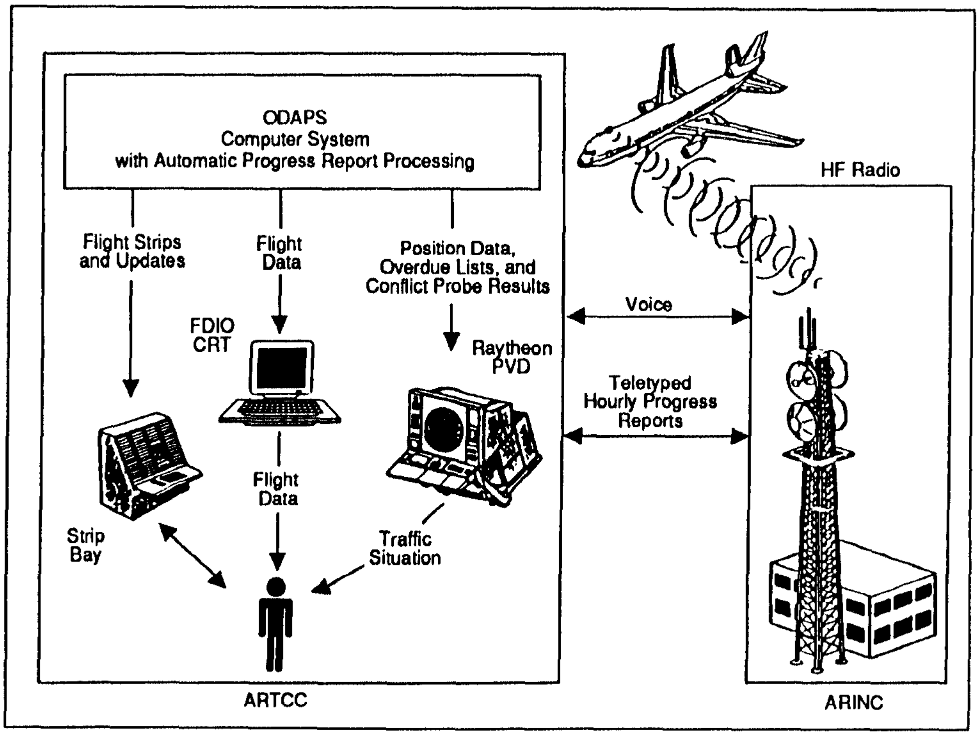
ODAPS is FAA's first step in enhancing and automating oceanic air traffic control. It currently provides controllers with a computer-generated display of aircraft position based on an extrapolation of periodic voice position, heading, and wind reports from pilots, coupled with filed flight plans. ODAPS is also intended to provide a conflict probe capability. This capability, which is considered crucial to the success of the system, is to notify the controller when any flight plan or pilot-requested aircraft route change will cause loss of separation with other aircraft. In effect, conflict probe will perform the same analysis that controllers now mentally perform when determining the impact of altitude and route changes. Controllers enter and retrieve ODAPS data through the Flight Data Input/Output (FDIO) equipment, which includes keyboards, cathode ray tube (CRT) displays, and flight strip printers.

ODAPS is not intended to permit a reduction in separation standards. Further, the display is not to be used for separating aircraft; the display is to be used for planning purposes only. Also, ODAPS is not intended to change the present method of pilot-to-controller communications. ODAPS air traffic control automated functions include:

- Automated Processing of Progress Reports: Currently, ODAPS software automatically processes ARINC progress report messages and, where necessary, updates the estimated times of arrival at future fixes and prints new strips indicating the changed time-of-arrival estimates.
- Traffic Situation on Plan View Display (PVD): The ODAPS situation display on the PVDs now provides the oceanic controller with a graphic representation of all aircraft positions and a list of overdue progress reports. In the future, it is to provide tabular list displays of predicted conflicts.
- Conflict Probe and Trial Plan: The ODAPS conflict probe is to provide the controller with advanced notification of any predicted loss of separation between aircraft. The probe is to operate periodically, as well as on flight plan activation, flight plan amendment, or controller request. The controller is also to be able to enter a trial plan, generating a conflict probe on a proposed flight plan change.
- Automated North American Aerospace Defense Command (NORAD) Interface: ODAPS transmits aircraft movement messages to the appropriate NORAD Regional Operations Control Centers.
- Paper Flight Strip Generation: ODAPS software generates flight strips that oceanic controllers use to separate aircraft. Data for the strips are derived from filed flight plans, progress report messages, and controller-entered amendments.

Figure 1.4 depicts FAA's oceanic air traffic control environment with ODAPS.

Figure 1.4: Oceanic Air Traffic Control Environment With ODAPS



Source: Federal Aviation Administration

A Brief History of ODAPS

In October 1984, FAA awarded a $12.2 million contract for the design, development, installation, and testing of ODAPS. The contract was originally scheduled to be completed in August 1987, 34 months after contract award. FAA planned to deploy ODAPS to the FAA Technical Center in Pomona, New Jersey, for testing and software support and then to its two key oceanic air traffic control operational facilities in Oakland and New York. In December 1989, over 2 years behind schedule, a less than fully functional system was deployed at the Oakland ARTCC, and in May 1992 this same system was deployed at the New York ARTCC. Neither of the systems has the key conflict probe capability operational. Moreover, because of a lack of personnel trained on ODAPS, the New York system serves only three of the facility's seven oceanic sectors. The FAA Technical Center received its system in the spring of 1990.

Since the program's inception, ODAPS has experienced significant problems. According to FAA officials and internal reports, the development of ODAPS has suffered from (1) inadequate project office staffing, (2) poorly defined requirements, and (3) inadequate coordination between the program office and users. Other problems cited include ODAPS' reliance on poor-quality, government-furnished equipment.

In response to these problems, FAA has taken some steps to strengthen overall program management and contractor monitoring. In particular, the program office now documents and tracks issues raised during progress review and technical interchange meetings with the ODAPS contractor. Also, additional staff, with strong automation backgrounds, have been added to FAA's ODAPS program management team. At the New York center alone, up to six full-time staff members have been assisting with ODAPS implementation and refinement.

ODAPS' Current Status and Future Plans

FAA is currently developing and testing the conflict probe capability, as well as key corrections and enhancements identified in early 1991 by both the New York and Oakland centers during limited operational use. Several of these address reliability problems with the flight progress strip time calculations, problems that in turn affect flight plan position extrapolation, visual display, and the conflict probe. Another enhancement alleviates some controller-to-controller communication work load and sets the stage for eventual elimination of flight strip printers. Still another enhancement simplifies the display of conflict probe outputs and automates associated housekeeping functions currently performed manually by controllers. These enhancements are scheduled for testing at the FAA Technical Center in late September 1992. FAA does not have an estimate of when Oakland and New York will have a fully functional system.

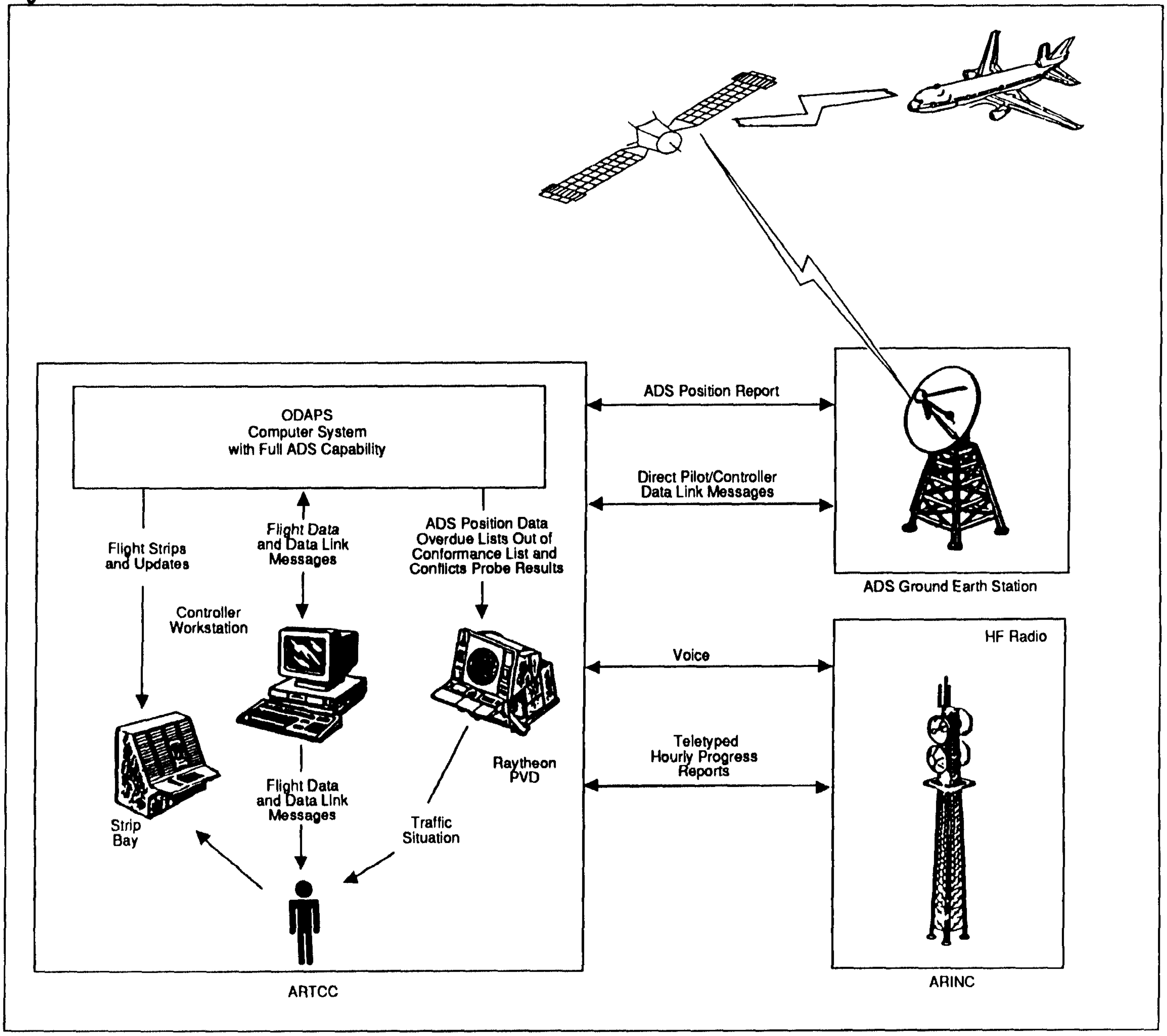
As of April 1992, FAA had spent $49.5 million on ODAPS. This includes about $40 million for the basic development, $1.7 million for contractor-provided training, $3.7 million for contractor-supplied maintenance, $1.6 million for the aforementioned system enhancements, and the remainder for FAA administrative support costs. Its latest estimate for completing a fully operational system is about $51 million.

Once a fully operational ODAPS has been deployed to the Oakland and New York centers, FAA's plans call for improving the human-machine interface by acquiring a modern color display. Also, prototyping is underway to improve flight data input-output processing. Additionally, to eliminate the labor-intensive process of manually entering National Weather Service wind data into ODAPS, FAA has developed the software and is obtaining the hardware to automate this operation. These later improvements are not part of FAA's $51-million estimate to complete ODAPS.

ODAPS' Role in FAA's Long-Term Goal of Satellite-Based Oceanic Air Traffic Control

ODAPS represents FAA's first step in a long-term plan for improving oceanic air traffic control. This plan calls for using communications satellites to provide position information on a near real-time basis (i.e., every 5 minutes) rather than continuing to receive hourly position information via high frequency radio. To accomplish this, FAA has recently begun a separate contractual effort to extend or modify ODAPS, adding software and hardware to receive, process, and display data received from satellite transmissions. This effort, referred to as the Automatic Dependent Surveillance (ADS) project, is designed to use commercially available communications satellites to relay aircraft position data from navigation equipment on-board aircraft to ground-based air traffic control facilities, as well as to eventually provide two-way data communications between pilots and controllers. The availability of near real-time position information on aircrafts' locations and two-way data communications is expected to permit a reduction in aircraft separation standards. Figure 1.5 depicts FAA's planned oceanic air traffic control environment with ADS, showing the current communications system retained as a backup.

Figure 1.5: Oceanic Air Traffic Control Environment With ADS



Source: Federal Aviation Administration

Objectives, Scope, and Methodology

In January 1991, we issued a report describing FAA's present system for controlling oceanic air traffic and the status of ODAPS. We also recommended that FAA assess alternatives to ODAPS. Our objectives for this follow-on review were to (1) identify key risks facing FAA on ODAPS and (2) determine whether FAA was effectively addressing these risks and whether it was justified in its continued development of ODAPS.

To address our objectives, we interviewed program and contractor officials and reviewed ODAPS progress reports and related program management documentation. We also witnessed the operation of ODAPS in the New York and Oakland ARTCCS. Additionally, we reviewed FAA's recent report examining alternatives to ODAPS and discussed its contents with officials from FAA's air traffic and oceanic program management staffs. We then compared the report's contents and analysis to relevant federal regulations governing alternatives analyses for systems development projects. We also observed the operation of the Japanese Oceanic Air Traffic Control Data Processing System at the Tokyo Area Control Center, and discussed with Japanese air traffic control officials the capabilities of the system and their operational experience with it. Additionally, we analyzed key ODAPS software development processes, comparing these to federal standards and regulations, as well as to commercial standards and general industry practice. The key process areas we focused on were software cost and schedule estimating; capacity management; system testing; and various quality assurance activities, such as IV&V and coding inspections. In analyzing these areas, we reviewed agency and contractor progress reports, cost and schedule analyses, system trouble reports, test plans, test results, capacity management activities, and sample source code for ODAPS. We also reviewed the IV&V report, including its methodology, and discussed its findings with cognizant FAA and contractor personnel. We also discussed these reports and documentation with various FAA headquarters officials, the ODAPS contractor, and various FAA support contractors.

We reviewed records and interviewed FAA officials at FAA Headquarters in Washington, D.C.; FAA Technical Center in Pomona, New Jersey; FAA Eastern Regional Office in Jamaica, New York; Oakland ARTCC in Fremont, California; and the New York ARTCC in Ronkonkoma, New York. We also interviewed executives at Hughes-STX Corp. in Lanham, Maryland, the ODAPS contractor; and Martin Marietta Corp. in Washington, D.C., FAA's systems engineering and integration contractor.

Our review was conducted from September 1991 to August 1992, in accordance with generally accepted government auditing standards. As requested, we did not provide a draft of this report to FAA for its review and comment. However, we discussed the report's facts with responsible FAA officials, including the Deputy Program Manager for Enroute/Oceanic Automation and Traffic Management System, who generally agreed with the facts. We have incorporated their views in the report as appropriate.

FAA Slow in Addressing Serious Problems With ODAPS

In mid-1991 FAA commissioned an independent review of whether ODAPS' operational software meets all applicable requirements and standards. The purpose of the review was to identify any deficiencies in the latest version of the software and thereby "determine the appropriate actions to produce an operationally acceptable conflict probe." The review disclosed a variety of software deficiencies that the reviewers described as significant and/or requiring extensive software rework to correct. We found that FAA has moved slowly to address the deficiencies. Until each of these deficiencies is resolved, FAA will be without a fully functional ODAPS, and the system that it has will be difficult, and thus costly, to maintain.

Independent Verification and Validation Is Critical to Effective Software Development

The ODAPS software development process must produce high-quality, error-free software that FAA can depend on to perform as expected. Software quality assurance, a planned and systematic set of activities to ensure that software processes and products conform to requirements, standards, and procedures, is critical to systems like ODAPS, whose failure could cause loss of life. Two of the supporting software quality assurance disciplines—verification and validation—involve the analysis and testing of software throughout its life cycle to ensure that it meets requirements and functions as specified. Its purpose is to ensure the final product's performance, integrity, reliability, safety, and quality.

Software verification is the process of determining whether or not the products of a given phase of the software development cycle fulfill the requirements established during the previous phase. [1] It usually involves reviewing, testing, and documenting that system specifications, designs, code, and documentation conform to requirements. Verification leads to improvements in overall software quality and reduced operational costs by allowing early detection of errors and performance problems. Validation is "the process of evaluating software at the end of the software development process to ensure compliance with software requirements." [2] It ensures that systems perform intended functions correctly and perform no unintended functions. A primary benefit of performing independent verification and validation (IV&V) is increased confidence in the quality of the software.

[1]IEEE Standard Glossary of Software Engineering Terminology, Institute of Electrical and Electronics Engineers (IEEE), Inc., American National Standards Institute (ANSI), ANSI/IEEE Standard 729-1983, August 1983, p.37.

[2]IEEE Standard Glossary of Software Engineering Terminology, p. 37.

Requirements for planning, specifying, performing, and monitoring validation and verification activities are delineated by industry software standards and federal guidelines for software management. For example, the Institute for Electrical and Electronics Engineers (IEEE) has issued a specific standard on software verification and validation.[3] For federal application, the National Institute of Standards and Technology has issued guidance on verification and validation.[4]

IV&V Review Cited Serious ODAPS Software Deficiencies

An ODAPS IV&V review was completed in November 1991 by an FAA systems engineering and integration contractor, with the assistance of FAA personnel and support contractors. They evaluated whether ODAPS satisfied its requirements and the extent to which sound, industry-accepted software engineering standards were being followed. To accomplish the former, source code is normally compared to software design documentation, which in turn is compared to system requirements. However, the contractors found the system design documents to be neither complete nor up-to-date. As a result, their approach was to compare the source code directly to the system specifications.

The IV&V report detailed 22 problems with the conflict probe software. Of the 22 problems, 5 were categorized as mission-critical and 4 were described as potentially causing frequent incorrect results. The report also described 9 of the problems as requiring extensive software modifications to correct and another 10 that would entail moderate modifications. According to the IV&V report, extensive software modifications require redesign of algorithms and/or redesign of software. Redesign of software can include complete replacement of software modules with new modules, subdivision of software modules, or repartitioning of functionality within multiple software modules, thereby requiring new interfaces within modules. They can also include modifications of existing data structures or new data structures. Moderate modifications require additional algorithm functionality and/or software. No redesign of software structure is necessary, although modifications of existing software modules or new software modules may be necessary. They can also require modification of existing data structures or new data structures. (See app. II for a complete listing of the 22 problems and their

[3]IEEE Standard for Software Verification and Validation Plans, IEEE, New York, N.Y., ANSI/IEEE Standard 1012-1986, Nov. 14, 1986.

[4]Guideline for Lifecycle Validation, Verification, and Testing of Computer Software (Federal Information Processing Standard Publication 101, June 6, 1983).

estimated severity, and the estimated level of effort to address each. Currently, all 22 are under review by FAA.)

The IV&V findings include the following:

- the inability of the conflict probe to function in areas with multiple separation standards, such as the airspace over the Caribbean Ocean;
- software coding practices inconsistent with contemporary standards (e.g., modules in excess of 200 executable source statements and modules that do not contain important programmer comments), which make the code difficult to understand and maintain; and
- algorithms that, as implemented in the software, incorrectly predict an aircraft's flight path.

FAA Slow in Addressing IV&V Deficiencies

In April 1992, we questioned the FAA Manager of the Automation Engineering Division, who is responsible for managing ODAPS, on actions to address the IV&V findings and found that FAA had not developed an effective strategy for resolving them. Following our encouragement, FAA developed a tool for tracking the status and disposition of the findings, and it established an IV&V disposition team to review the basic assumptions from which the IV&V report was developed, examine alternatives for addressing the IV&V findings, and offer recommendations on each. At a minimum, the team's findings are to consider each recommendation's cost and schedule impact and its relative priority, and to identify the party to be responsible for implementing the recommendation. The disposition team was to present its findings in July 1992; however, it did not hold its first meeting until August 1992 and as of September 1992 had yet to issue its findings. These delays only serve to fuel the uncertainty about both FAA's commitment to resolving these problems and the eventual cost and delivery date of a fully functional ODAPS. Given the seriousness of the IV&V findings, immediate action by this team is warranted.

FAA Lacks a Capacity Management Program for ODAPS

Capacity management is the process by which the components of a computerized system are configured, utilized, and maintained to effectively and efficiently process work loads. Its purpose is to permit efficient operations and to correct and prevent processing shortfalls. FAA is not performing basic capacity management activities on ODAPS. Without a capacity management program, FAA has no systematic approach for ensuring that ODAPS effectively processes air traffic, either now or in the future.

Capacity Management Is a Critical Activity for Computer Systems

Computer capacity management at FAA is critical to the safe and efficient use of the nation's airspace. It provides the analytical basis for predicting when hardware and software will need to be upgraded to meet projected work-load growth. Federal guidance highlights the need for government agencies to conduct capacity management activities in planning, acquiring, and using computer resources.

Capacity management has two key components: (1) performance management, which measures and evaluates system performance to prevent or correct problems; and (2) capacity planning, in which required resources are projected based on estimated work loads and reserve capacity. Performance management activities include (1) establishing performance objectives, (2) measuring overall system performance and individual component utilization, and (3) analyzing and reporting performance data. Performance measurement should focus on both the system as a whole and on individual system components. The components of a system include the central processor, memory, input/output channels, peripheral devices, communications, processors, and the associated software and data files. Performance management ensures that services are provided efficiently and effectively. The capacity planning process includes (1) projecting future work loads and required user service levels, (2) proposing resources to meet these demands, and (3) planning to obtain the required resources. Capacity plans help agencies ensure that equipment is available to meet actual need, thereby preventing capacity shortfalls.

Capacity Management on ODAPS Has Been Neglected

According to FAA Technical Center and ODAPS program officials, ODAPS has never had a capacity management program or a capacity management plan. In fact, some of these officials stated that from ODAPS' inception, capacity was assumed to be a nonissue and thus was not systematically addressed. However, testing of ODAPS at the Oakland ARTCC in 1989 revealed that the central processing unit was overutilized. Subsequent testing in 1991 and 1992 at the New York ARTCC revealed similar capacity shortfalls. We witnessed central processing unit monitoring at the FAA Technical Center in November 1991, and found the central processing unit, with conflict probe enabled, was running at more than 90-percent utilization while processing only about one-third of its peak work load. At that time, a center official told us that the utilization of all other system resources was not being monitored.

According to FAA officials, this capacity problem has been corrected. On the basis of capacity testing performed recently at the FAA Technical Center, FAA found that every time the conflict probe was enabled while ODAPS was running, central processor utilization would soar to 90 percent or more. To correct this, the officials told us they made a procedural change requiring that the conflict probe not be enabled while the system is running. Instead, the probe is to be enabled at the same time ODAPS is initiated. They stated that this change produces a single peak in processor utilization in the 90-percent range which then drops and stabilizes.

Despite these test results, we remain concerned. Specifically, the test results that FAA provided to us to support their claim that the problem has been corrected state that "analysis of ODAPS central processing unit performance was beyond the scope of this task [test]." Moreover, FAA Technical Center officials told us that data on the utilization of ODAPS resources (e.g., central processing unit, input/output channels), although routinely collected at the Oakland and New York ARTCCs and the Technical Center, were not being analyzed for two reasons. First, they stated that neither Oakland nor New York has reported any shortfalls and until they do, capacity is not a concern. We do not agree. Specifically, the New York system is not processing even normal work loads, much less peak work loads (only three of New York's seven oceanic sectors have been activated on ODAPS). Moreover, neither the Oakland nor the New York system is running the very demanding conflict probe function. Second, FAA officials stated that it would be premature to focus on capacity monitoring and planning now because the conflict probe software has yet to be optimized. Thus, they characterized capacity management as currently "not a problem yet." We again do not agree. Capacity management activities are integral to all stages of a system's life cycle, including planning, design, development, and operation and maintenance. To postpone these activities until a system has been optimized is not prudent management.

FAA has also yet to "stress test" the system and to use the results in defining future resource requirements. For example, FAA Technical Center testing to date has been based on Oakland ARTCC data. It has yet to use New York ARTCC data, which will involve more complex calculations because of the more complex nature of the center's airspace. Moreover, FAA has yet to use the resource utilization data it is collecting to perform work-load analyses or conduct configuration modeling to define future resource requirements.

ODAPS Schedule Is Uncertain and Cost Estimate Is Questionable

To reliably estimate the cost and time necessary to implement large software development projects, careful analysis and formal estimating techniques and tools are used. In the case of ODAPS, we found that FAA does not have an estimate of when the system will be fully operational. Moreover, we found that the latest cost estimate is not based on any formal estimating tools, but rather represents the judgment of program and contractor officials. Additionally, this latest judgment does not include the time and money necessary to address the IV&V findings discussed in chapter 2. As a result, ODAPS cost and schedule estimates do not provide a sound basis for deciding whether continued investment in the system is warranted.

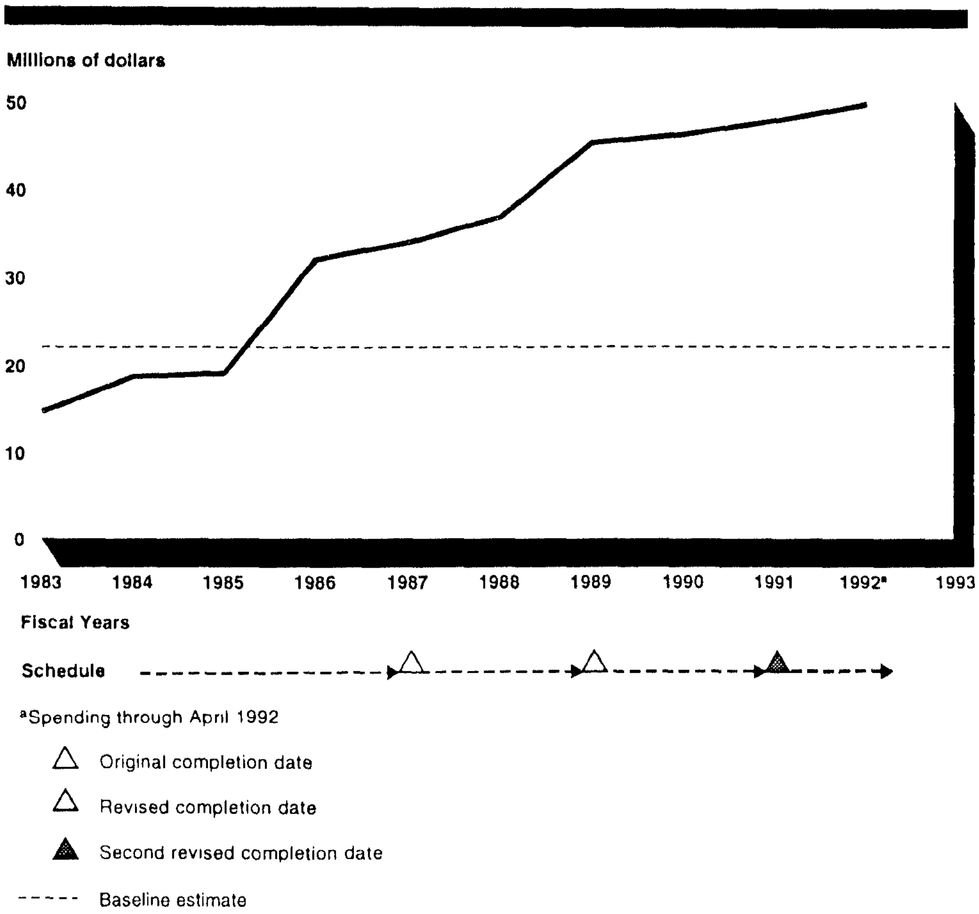
ODAPS Has a History of Unreliable Cost and Schedule Estimates

ODAPS has experienced considerable cost growth and schedule delays over its life (see fig. 4.1). In 1984 FAA estimated ODAPS' project cost to be $22 million and awarded a $12.2 million contract for the design, development, installation, and testing of ODAPS. Work under the contract was to be performed in two phases. During phase I, the contractor was responsible for establishing functional specifications and a preliminary design. The cost of phase I was estimated at $7.2 million. Phase II called for the contractor to develop, install, and test the system. At the time of contract award, $5 million was allocated to phase II, although the actual cost could not be determined until after phase I was completed and phase II was defined. Both phases were to be completed by August 1987.

By 1987 approximately $33.8 million had been spent on the program, and not one system had been delivered to FAA. In fact, several months earlier, the contractor estimated that it would take an additional $13 million to complete the contract. Faced with this cost growth, FAA decided to reduce costs by eliminating the ODAPS support system slated for the FAA Technical Center (a decision that was later reversed). On the basis of this decision, the contractor submitted a revised estimate of about $7 million to complete ODAPS by 1988.

As of September 1990, FAA had spent approximately $46 million on ODAPS, had not yet received a fully operational system, and did not have a revised cost estimate for completing the system. However, it did revise its completion date at this time to May 1991. As of April 1992, the amount spent on ODAPS had climbed to approximately $49.5 million, including training, operation and maintenance, and software corrections and enhancements. (See ch. 1 for a breakdown of this cost). The latest cost estimate is $51 million. FAA is currently attempting to establish a project completion date.

Figure 4.1: Growth in ODAPS' Cost and Schedule



ODAPS' Latest Cost Estimate Lacks a Firm Basis and Cannot Be Independently Validated

FAA's latest estimates of the additional money needed to complete ODAPS is about $1.5 million. However, this estimate is not based on formal estimating tools, techniques, or models. In fact, senior program officials told us that ODAPS' cost and schedule estimates have never been based on analytical tools, and no analysis is available to support their latest cost estimate. According to the program officials, the cost and schedule estimates have been derived informally and are based on the best judgments of those parties familiar with the system. In effect, they are a consensus of opinion among experienced program officials of the time and effort necessary to complete remaining ODAPS tasks.

In contrast, formally derived cost and schedule estimates are based on sophisticated models that use certain basic inputs about a system's size and complexity. Examples of such inputs include the number of lines of code to be developed or modified or the software's algorithmic complexity. Using these inputs, analytically based estimates can be made and tracked. There is little analytical underpinning to estimates based on the best judgment of officials relying on vague and unspecified assumptions and predictions.

In an attempt to evaluate FAA's latest cost estimate for ODAPS, we requested that FAA and the ODAPS contractor provide some basic inputs, such as the number of new lines of code to be written, so that we could develop our own estimates using a commercially available model. However, neither FAA nor the contractor was able to provide all the data necessary.

Impact of IV&V Findings on Cost Estimate Yet to Be Considered

FAA's latest cost estimate is also incomplete. It does not include the resources (time and money) needed to correct the deficiencies identified by the IV&V team (see ch. 2). According to the IV&V team, correcting many of these findings will require extensive revisions to ODAPS software. The program office has recently formed a group to review and analyze these deficiencies and make recommendations that consider the cost and schedule impacts, but the latest ODAPS cost estimate does not reflect the potentially significant resources that may be required to correct identified system deficiencies.

FAA Has Yet to Adequately Analyze Alternatives to ODAPS

In January 1991 we reported that FAA needed to evaluate the feasibility of successfully developing and deploying ODAPS, including assessing whether other automation alternatives could better provide automated support to the oceanic environment.[1] Such assessments are mandated by federal regulations.[2] More importantly, however, they make good managerial sense, especially when projects experience unexpected problems, delays, or cost growth. In response to the findings in our report, FAA studied whether there were timely and cost-effective alternatives to ODAPS, but FAA's study was neither complete nor thorough. As a result, FAA's decision to continue development of ODAPS is without sound justification and may be unwise.

Periodic Analysis of Alternatives Is Vital to Cost Effectively Meeting Oceanic Requirements

The Federal Information Resources Management Regulation states that when acquiring information systems, agencies should conduct an analysis of alternative system solutions, commensurate with the size and complexity of the system, to identify the government's most advantageous alternative. The regulation further states that in conducting an analysis of alternatives, agencies should take the following actions, among others:

- Conduct market research to determine the availability of technology to meet agency requirements and to assist in identifying feasible alternatives.
- Calculate the total estimated cost for each alternative. This cost is to include the system life cycle cost for each alternative.
- Study the benefits, costs, and risks of using existing systems, both from within the agency and from other agencies, to satisfy requirements.

While this regulation does not expressly state when such analyses are to be performed, it is generally recognized that they are not one-time exercises performed at the beginning of a project. Instead, the analyses are done throughout a system's life whenever estimates of expected benefits and costs change significantly. In fact, Department of Defense policy expressly requires analyses of ongoing system acquisition programs to ensure that expected benefits are being attained and specified requirements are being met in the most cost-effective manner.[3] The value of such an approach to system investment decisions is clear. While one alternative may be the better solution to an automation problem early in a

[1] Air Traffic Control: Efforts to Modernize Oceanic System Delayed (GAO/IMTEC-91-2, Jan. 16, 1991).

[2] Federal Information Resources Management Regulation, Analysis of Alternatives, Subpart 201-20.2, Oct. 1, 1990.

[3] Defense Instruction 7041.3, Economic Analysis and Program Evaluation for Resource Management.

system development project, given its expected costs and benefits, this does not guarantee that it will continue to be the optimal solution should its estimated costs climb or its expected benefits or operational capability shrink. Without periodic evaluation of alternatives, poor investment decisions can result.

FAA's Analysis of Alternatives to ODAPS Was Inadequate

In response to our earlier findings on ODAPS, FAA issued an "ODAPS Review Team Report" that, among other things, examined alternatives to ODAPS. However, this report was inadequate in that it did not address all feasible alternatives for providing automation support in the oceanic environment, and it did not include credible cost estimates for the alternatives that were examined.

Several Viable Alternatives Not Considered

Although FAA's 1990 analysis of alternatives discussed six alternatives to meeting its requirements, all of them focus on either ODAPS/ADS or the Dynamic Ocean Track System (a research and development system currently used to support oceanic traffic planning activities). The analysis did not consider other feasible alternatives. For example, it did not discuss the feasibility of (1) initiating a completely new system development effort, (2) incorporating the ODAPS' functionality into the Host computer system (FAA's domestic en route air traffic control system), or (3) adapting oceanic automation systems used by Japan.

The first option, starting afresh in developing ODAPS, appears attractive when viewed in the context of ODAPS' existing foundation. Specifically, ODAPS is a modification and extension of 20-year-old code written in two languages, assembly and JOVIAL; the assembly language portion is substantial and difficult to maintain. [4] Further, this code is heavily patched, [5] making it even more difficult to maintain, and as of December 1991, it had hundreds of unresolved trouble reports associated with it. [6]

[4] An assembly language, in which each statement usually corresponds to one machine language statement, is much more cumbersome to use and maintain than a higher-level programming language, such as JOVIAL, in which each statement generally corresponds to more than one machine language statement.

[5] A patch is a temporary solution to a software problem. In the case of the Host, patching involves identifying a problem, writing corrective code in assembly or JOVIAL language, and testing and implementing the additional code. This testing is less comprehensive than that done to incorporate changes into a new version of software. While patching provides a quick remedy, patched code is more difficult to test and maintain.

[6] Air Traffic Control: Software Problems at Control Centers Need Immediate Attention (GAO/IMTEC-92-1, Dec. 11, 1991).

According to federal standards, [7] code such as this should generally not be used as the basis for a new system.

With respect to satisfying its requirements through the Host computer system, FAA's Eastern Region, which oversees operations at the New York center, recommended in March 1989 that a feasibility study be initiated to "analyze the potential benefits to be derived by a functional inclusion of ODAPS into the [Host]." The region believed that a stand-alone ODAPS would create unnecessary operational and technical problems as FAA moved away from the Host environment and toward implementation of the Advanced Automation System, the centerpiece of FAA's overall air traffic control modernization program. [8]

In August 1989, senior FAA officials responded that while such an effort was technically feasible, the massive software changes involved did not make it a viable option. However, FAA could not provide us any data or analysis quantifying the level of effort required. Moreover, since this response, but before FAA's December 1990 analysis of alternatives to ODAPS, new problems with ODAPS surfaced. For example, an April 1990 FAA memorandum pointed out at least 57 open problems with ODAPS, including 6 critical problems that were preventing system testing. In addition, an August 1990 report by an FAA-sponsored review team found that ODAPS suffered from serious computer program errors. Last, August and September 1990 FAA/contractor technical interchange meetings surfaced a myriad of concerns, such as inadequate system documentation and testing and vague and inconsistent requirements, and it concluded that ODAPS was "a long way from a deliverable product which meets the basic air traffic requirements." Collectively, these circumstances argue for having considered writing ODAPS functionality into the Host system in the 1990 analysis of feasible alternatives. While this alternative suffers from one of the limitations of ODAPS (i.e., using old, "brittle" code as the foundation for a new system), it also offers the potential advantage espoused by FAA's Eastern Region of facilitating transition to the Advanced Automation System.

Using or modifying existing oceanic automation systems in other countries was also not considered. In particular, the system that has been operating

[7]Federal Information Processing Standard 106, Guideline on Software Maintenance, Section 5, pages 14-17.

[8]The Advanced Automation System is to provide a new automated air traffic control system that includes improved controller workstations, software, and other hardware. According to FAA, the system will make possible the full consolidation of en route and terminal operations into area control facilities. Oceanic air traffic control operations are part of these consolidation plans.

since the early 1980s in Japan was not part of FAA's analysis. During our review, we observed the Japanese system at the Tokyo Area Control Center. This system, called the Oceanic Air Traffic Control Data Processing System, performs functions similar to that of ODAPS and has been operating since 1980 with conflict alert—a capability similar to ODAPS conflict probe. The conflict alert function was demonstrated to us by creating a false alert through manual keyboard entries. Additionally, we observed the system's ability to automatically process and display flight data changes (e.g., aircraft position, direction, speed) due to periodic pilot reports and controller-directed movements. Japanese officials told us that because of traditional conservatism, controllers still manually control oceanic traffic using flight strips, and depend on the Oceanic Air Traffic Control Data Processing System only for confirmation of their judgments.

Credible Cost Data Not Used

FAA's analysis of alternatives did not include the basic cost data necessary to thoroughly compare and contrast competing investment options. In addition to the limitations in the ODAPS cost estimates discussed in chapter 4, the analysis provided cost estimates for only one of its alternatives—modifying the Dynamic Ocean Track System—and this estimate lacked any real foundation. [9] Specifically, the analysis states that "based on past experience developing and certifying flight data processing systems, this [alternative] has the potential to be a very costly approach in the $25 [million] to $50 [million] range." No supporting analysis for FAA's derivation of this estimate was either included in the analysis of alternatives or otherwise prepared.

The cost data used in the analysis were also incomplete, thereby failing to meet Federal Information Resources Management Regulation requirements. According to the regulation, life cycle costs [10] are to be used in assessing alternatives. However, FAA's analysis included only project development and deployment estimates. Such an incomplete analysis is invalid. In particular, there are fundamental tradeoffs between investing time and effort in the development/deployment of a system versus the operation/maintenance of it. That is, short-cutting certain development activities or building on an old, existing system may save time and money in the short term, but it can also be very costly in the long term.

[9] The Dynamic Ocean Track System is used by oceanic air traffic control facilities' Traffic Management Units for oceanic traffic route and flow planning and management.

[10] Life cycle cost refers to the cost to not only develop and deploy a system, but also the cost to operate and maintain the system over its expected useful life.

This point could be especially true for ODAPS. As stated earlier, FAA's approach to developing ODAPS was to use software from the Host computer system as a starting point and extend it to provide ODAPS with unique functions. Federal software standards discourage such practices because it makes system maintenance more difficult. In particular, the standard states that any system is a good candidate for redesign and starting anew if any of the following are true: (1) the system experiences frequent failures, (2) the code is over 7 years old, (3) the code has an overly complex program structure and logic flow, (4) the code was written for previous generation hardware, (5) the code has very large modules or unit subroutines, (6) the system has "hard-coded" parameters that are subject to change, (7) it is difficult to retain people to maintain the code, or (8) the system does not have complete design specifications. In the case of the Host computer system, several of these conditions are met. For example, the code is well over 7 years old and written in 1960s-vintage, second-generation languages (JOVIAL and assembly) for which new maintenance personnel are difficult to find. In addition, the code is not well-structured and the modules are very large, some having thousands of lines of code. Further, the software was originally written for hardware that is more than 20 years old (i.e., for the International Business Machines 9020 mainframe).

Conclusions and Recommendations

ODAPS has a long history of technical and management problems that have stretched completion milestones and expanded cost estimates. More importantly, new problems continue to surface, problems that may require substantial investments of time and resources to correct, and problems that FAA is moving slowly to address. In light of these problems and the uncertainty of their impact, as well as the uncertainty of FAA's cost and schedule estimates for completing ODAPS and the fact that all feasible alternatives to ODAPS have never been thoroughly thought through, FAA has not justified continuing its development of ODAPS, and could be wasting time and taxpayer dollars in doing so.

FAA needs to move swiftly in justifying ODAPS' continuation by determining the cost and schedule impact of known ODAPS deficiencies, developing credible and verifiable cost and schedule estimates for ODAPS and other viable alternatives, and systematically weighing the pros and cons of each. The more FAA delays, the greater the risk that taxpayer dollars will be wasted on the wrong system solution, the longer inefficient use of oceanic airspace will continue, and the longer controllers will be required to assume the mental burden for visualizing current and projected traffic situations.

Recommendations to the FAA Administrator

Because of the uncertainties surrounding FAA's cost and schedule estimates for ODAPS and the significant software problems still surfacing about the system, we recommend that the FAA Administrator certify to the Secretary of Transportation that a thorough and complete analysis of feasible alternatives to ODAPS has been performed. At a minimum, this analysis should include life cycle cost data for each alternative that is credible and verifiable. Additionally, it should consider not only FAA's short-term oceanic processing, display, and communications requirements, but also its long-term requirements for satellite-based oceanic air traffic control and integration with the Advanced Automation System. Should ODAPS emerge from this analysis as the more cost-effective alternative, we also recommend that the Administrator certify to the Secretary that:

- All ODAPS IV&V findings have been thoroughly and expeditiously assessed and fully resolved.
- A capacity management program for ODAPS has been established.
- ODAPS' cost and schedule are systematically estimated using contemporary estimating tools and techniques, and that these estimates are kept current to reflect changes to the program.

- ODAPS is continually monitored relative to other feasible alternatives in light of any changes to the estimates.

Summary of 22 ODAPS IV&V Findings

Problem Statement	Estimated Severity	Level of Effort Required for Fix
Algorithms for route conversion processing, flight position processing, and other functions are inadequate for the ODAPS conflict probe system requirements.	2	Extensive
Requirement for identical operational software at all sites is insufficient for the implementation of Organized North Atlantic Track utilization at the New York ARTCC.	1	Extensive
Approximate equations in route conversion and posting algorithms.	3	Minimal
Approximate values used in calculations for fix postings.	4	Minimal
Inappropriate use of embedded constants in conflict probe purposes.	2	Minimal
Algorithms for flight plan position extrapolation mix various coordinate systems, resulting in inaccurate calculations.	2	Extensive
Algorithms for winds aloft calculations and other functions mix multiple coordinate systems, resulting in inaccurate calculations for conflict probe analysis.	3	Moderate
Algorithms for calculating distances incorrectly mix various coordinate systems, resulting in less than required accuracy.	3	Extensive
Poor software coding practices encountered (e.g. software modules containing more than 200 lines of executable source code, module comments and revision dates that were incomplete, and the same arguments used as input and output to procedures).	4	Extensive to minimal
Improper application of the 15-degree divergence aircraft separation rules.	3	Moderate
The "width" of an air traffic route may not be constant over the length of a route segment. The conflict probe feature was not designed to handle these variable widths.	3	Moderate
Conflict probe cannot be applied to route segments containing fixes defined with respect to navigational aids.	3	Moderate
Conflict probe does not contain special processing for tracks with respect to onboard navigational aids.	3	Moderate
Conflict probe does not handle separation criteria for aircraft transitioning from offshore to oceanic airspace.	1	Extensive

(continued)

Problem Statement	Estimated Severity	Level of Effort Required for Fix
Improper handling of separation near temporary airspace reservations.	3	Moderate
ODAPS does not have data structures for defining moving airspaces.	4	Extensive
Conflict probe does not properly handle longitudinal separation for Minimum Navigation Performance Specification aircraft in North Atlantic, International Civil Aviation Organization Region on diverging tracks.	3	Moderate
Conflict probe algorithms do not differentiate between published and random routes. Application of separation standards is on a route segment basis with no consideration of origin and destination of flight.	1	Moderate
Conflict probe does not properly handle longitudinal and lateral separation on published routes in the Caribbean International Civil Aviation Organization Region.	1	Extensive
Conflict probe does not properly handle aircraft leaving the composite route system.	2	Moderate
Conflict probe does not properly handle lateral aircraft separation in the Arctic control area.	4	Extensive
Conflict probe makes no distinction between random and published routes (in Pacific)	1	Moderate

The estimated severity levels are as follows:

Level of Significance

Level 1—The requirement is for a significant function. Without meeting the requirements, the ODAPS function cannot perform its mission in New York and/or Oakland oceanic airspace.

Level 2—The functional design, including the mathematical algorithms and software implementation, is inaccurate. The function specified by this requirement is commonly used and, as a result, could cause frequent incorrect results for conflict probe (or other commonly used ODAPS functions).

Level 3—Either the set of cases that this requirement addresses is expected to be small in comparison to total traffic, or the margin for error in the requirement is large so that the current design deficiency will not create an unsafe situation.

Level 4—Either the requirement is applicable to a very small subset of all flight plans, or the requirement is not necessary for near-term implementation at either New York and/or Oakland oceanic airspace.

Estimated Level of Effort to Meet Requirement

Extensive: Requires redesign of algorithms and/or redesign of software. Redesign of software can encompass complete replacement of software modules with new modules, subdivision of software modules, or repartitioning of functionality within multiple software modules, thereby requiring new interfaces within modules. Modifications of existing data structures or new data structures may be required.

Moderate: Requires additional algorithm functionality and/or software. No redesign of software structure is necessary although modifications of existing software modules or new software modules may be necessary. Modifications of existing data structures or new data structures may be required.

Minimal: Requires no new functionality, but minor changes to existing software and/or data structures are necessary. An example would be the replacement of an approximate algorithm by an exact algorithm affecting only a few lines of code.

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