GAO

Briefing Report to the Chairman and the Ranking Minority Member, Subcommittee on Transportation, House Committee on Appropriations

July 1986

AIR TRAFFIC CONTROL

Status of FAA's Host Computer Project and Related Software Enhancements

130525

GAO/IMTEC-86-25BR

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INFORMATION MANAGEMENT
& TECHNOLOGY DIVISION

B-206887

July 3, 1986

The Honorable William Lehman
Chairman, Subcommittee on
  Transportation
Committee on Appropriations
House of Representatives

The Honorable Lawrence Coughlin
Ranking Minority Member,
Subcommittee on Transportation
Committee on Appropriations
House of Representatives

    In your October 1, 1985, letter (appendix I) and subsequent
discussions with your office, you requested our observations on
the Federal Aviation Administration's (FAA) testing and
implementation of "Host" computers and related software
enhancements that FAA will install at 20 en route air traffic
control centers. These computers will replace older, less capable
computers and will use a modified version of current air traffic
control software. You expressed particular interest in learning
whether FAA was conducting performance testing before installing
the new computers, as promised to the Subcommittee by the
Secretary of Transportation.

    On July 26, 1985, FAA awarded a $197-million contract to the
International Business Machines (IBM) Corporation. The contract
called for (1) converting the existing National Airspace System
software and (2) installing new IBM 3083 computers at FAA's en
route centers. The agency justified this Host computer
acquisition on the basis of capacity limitations of existing
computers, as well as its inability to implement operational and
safety enhancements until such capacity was available. Before the
contract award, we reported[1] to the Subcommittee that FAA did not

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[1]Federal Aviation Administration's Host Computer: More Realistic
Performance Tests Needed Before Production Begins
(GAO/IMTEC-85-10, June 6, 1985).

conduct full performance testing on the competing Host computer
systems. Such testing, we stated, would provide FAA with better
information on whether these systems could meet projected workload
demands of the 1990s. Subsequently, citing a need to stay on
schedule, FAA assured the Subcommittee that it had conducted
adequate testing to make a production decision and that it would
conduct full performance testing before installing the Host
computers.

From April 1 to May 23, 1986, FAA planned to conduct
operational software testing, evaluate the results, and accept the
system. Performance tests were scheduled to be completed during
operational software testing. Performance testing results are
valuable because problems are often identified for the first time;
until then, hardware and software--as a complete system--have not
yet been subjected to the higher workloads of the 1990s. These
tests have been delayed 6 months and are now scheduled to begin in
August 1986. As a result, the first Host computer delivery to the
Seattle en route center has been delayed from May to November
1986. The last delivery--to the Salt Lake center--has been
delayed from June to December 1987.

According to officials from FAA's Host computer project
office, the 6-month delay occurred primarily because of
(1) unresolved software problems encountered in converting the
software and (2) the lagging development of system documentation.
FAA officials also told us that IBM had underestimated the effort
needed to convert certain portions of the software to operate on
the new system.

IBM originally estimated that about 81,000 lines of code
(software) would need to be written or modified to convert the
software to the Host computer. FAA told us that 130,899 lines
have already been changed--or about 62 percent more than the total
amount anticipated. Further, resolution of software problems
resulting from the conversion process has taken longer than
anticipated. For example, as of June 4, 1986, about 285 of the
critical software problems noted during conversion remained
unresolved. According to FAA, these problems affect the
performance of a crucial function of the air traffic control
system and must be corrected before performance testing can
begin. FAA officials also told us that performance testing could
not begin because thousands of pages of system documentation that
need to be reviewed and accepted prior to operational software
testing were still in various stages of preparation. FAA
officials told us they believed IBM has a 50-percent chance of
solving the software and documentation problems in time to start
testing in August.

In late May 1986, IBM informed FAA that a $5-million to
$6-million increase could be expected in the project. IBM agreed
to provide FAA with more definitive cost estimates in late June.
The 6-month delay will also postpone the implementation of

operational and safety enhancements designed to improve safety for aircraft flying close to one another and to provide benefits in terms of fuel savings. Implementation of these enhancements in all of the en route centers cannot occur until the higher capacity Host computers are installed.

While FAA intends to conduct performance testing, as promised to the Subcommittee, it is too early to tell if the testing will be completed within FAA's latest schedule. Because of (1) the number of unresolved software problems, (2) the possibility of additional problems that can only be identified during performance testing, and (3) FAA's own reservations about IBM's ability to meet the new schedule, we believe that additional delays and cost increases to the Host computer project could occur.

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We obtained the information for this report from reviews of pertinent management and contract reports and discussions with FAA officials at FAA's Advanced Automation Program Office in Washington, D.C., and Technical Center in Pomona, New Jersey. We also met with IBM representatives. We have updated the status of the Host computer project through June 4, 1986. Details on our scope and methodology can be found in appendix II. As you requested, we did not obtain official comments on a draft of this report. During our audit, we obtained the views of responsible FAA officials and IBM representatives.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this briefing report until 30 days after its issue date. We will then send copies of the report to the Secretary of Transportation, the FAA Administrator, IBM Corporation, and related House and Senate oversight and appropriations committees, and will make copies available to others upon request.

Should you desire additional information on our work, please contact Mr. Allen Li, Group Director, on 275-4649.

Carl R. Palmer
Associate Director

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C o n t e n t s

ABBREVIATIONS

FAA	Federal Aviation Administration
GAO	General Accounting Office
IBM	International Business Machines
NAS	National Airspace System

AIR TRAFFIC CONTROL:

STATUS OF FAA's HOST COMPUTER PROJECT

AND RELATED SOFTWARE ENHANCEMENTS

OVERVIEW OF FAA's
HOST COMPUTER PROJECT

Computers play a critical role in the Federal Aviation Administration's (FAA) mission of safely controlling air traffic. Computers process radar data, identification data from electronic transponders located in aircraft, and flight plan information filed by pilots. Air traffic controllers use computers to help track and monitor an aircraft's progress while it is located within the airspace of FAA's 20 en route centers--facilities controlling aircraft traveling between airports. To process the information, en route centers use one of two types of computers manufactured by the International Business Machines (IBM) Corporation--model 9020A or 9020D. FAA has stated that these computers, acquired between 1969 and 1977, will not be able to handle increased air traffic and planned software enhancements because of capacity limitations. In addition, FAA has stated that the two models are increasingly difficult to maintain because of their age and because their spare parts are no longer readily available. Thus, the agency is acquiring new computers to replace the IBM 9020s. Rather than rewrite the complex National Airspace System (NAS) software,[2] FAA is modifying it to operate on new IBM computers--a procedure known as "rehosting." Redesign of all the software is planned for the 1990s, when FAA plans to acquire and implement the Advanced Automation System, which will replace the Host computer, remaining hardware and software, and controller workstations.

Contracts for the Host computer's design
competition and acquisition phases

FAA has divided the Host computer project into two phases: the design competition phase and the acquisition phase. During the design competition phase, conducted from September 1983 through July 1985, the agency awarded contracts totalling about $92.4 million to two vendors, IBM Corporation and Sperry Corporation. These contracts called for each vendor to submit a design for rehosting the NAS software. According to FAA, the intent of the design competition phase was to (1) assess the capabilities of the competing contractors to convert the NAS operational and support software for operation on new off-the-shelf equipment and (2) reduce the risks involved in rehosting the software by allowing each contractor to become

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[2]Developed in the 1960s, the NAS software processed on FAA's IBM 9020 computers includes operational, support, and maintenance software. Several versions have been implemented since the software's inception.

knowledgeable about the NAS hardware, software, and system documentation before bidding on the acquisition phase contract.

On July 26, 1985, FAA awarded a $197-million contract to IBM for the acquisition phase of the Host computer project. The acquisition phase encompasses the production, installation, integration, and testing of Host computer system hardware at 24 locations: 20 en route control centers, the Aeronautical Center, the Technical Center, and two sites run by the competing contractors for the Advanced Automation System.[3] IBM's tasks are to convert the current version of the NAS software used at the en route centers, train FAA personnel on Host computer hardware and software, provide maintenance and logistics support for all delivered hardware, and provide associated contract support efforts. The first system delivery was scheduled for the Seattle en route center on May 23, 1986. The last delivery was scheduled for the Salt Lake City center, 14 months later.

Testing of the Host computer

Numerous categories and levels of testing are performed under the Host computer project. Testing began during the design competition phase and will continue through the acquisition phase. Testing is conducted at FAA's Technical Center and at each en route center. Software testing is included within the major category "developmental testing and evaluation" and is divided into two sub-categories--support/ maintenance software testing and operational software testing. Operational software testing was scheduled to begin on April 1, 1986. As a part of operational software testing, the Host computer will be required to pass a performance (capacity and response time) test. This test is intended to provide a valid prediction of the Host computer's ability to satisfy the projected workload of the 1990s.

Other aspects of testing are also conducted at each en route center. This culminates in an operational readiness demonstration and transition to operations. System delivery to operational readiness demonstration is expected to take about 6 months at each center. After the initial system is delivered, additional Host computers will be sent to the other en route centers at a rate of about two a month.

Previous GAO reports
on the Host computer

We have issued two reports addressing FAA's rehosting of the NAS software on new computer hardware. In May 1984,[4] we made observations concerning FAA's development and acquisition of the Host computer system and the Advanced Automation System. Regarding the Host system, we stated that it appeared that more

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[3] IBM and Hughes Aircraft are the design competition phase contractors for the Advanced Automation System.

[4] Interim Observations on FAA's Plans for Major Systems Acquisitions (GAO/IMTEC-84-14, May 4, 1984).

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extensive software changes would be necessary to transfer the software to the Host computer. We also noted that changes in any one part of the software could cause new problems in apparently unrelated parts because the existing software had reached such an advanced state of complexity. As a result, major changes to the software could adversely affect both software performance and reliability. We concluded that complete and thorough performance testing was needed to ensure that major performance problems did not go undiscovered.

In June 1985,[5] we reported that (1) testing during the design competition phase did not adequately simulate operational requirements of the present or the 1990s and (2) documentation of test plans and results and technical oversight of performance testing were inadequate to make a sound production decision. We recommended that the Secretary of Transportation consider the merits of deferring the production and vendor selection decision for the Host computers to complete more realistic performance tests.

Transportation's response to GAO's recommendation to defer production

In a July 18, 1985, letter to the Chairman, Subcommittee on Transportation, House Committee on Appropriations, the Transportation Secretary provided the Department's rationale for not delaying the award of the acquisition phase contract. According to the Secretary, the Department had determined that it was prudent to proceed with Host computer production and not to extend the development program to perform additional computer capacity testing. She also stated that the tests that we recommended would be performed as a part of the testing conducted under the acquisition phase contract. Finally, she assured the Subcommittee that the Host computer would not be delivered to FAA field locations until performance tests demonstrated that operational requirements had been met or exceeded.

FAA's August 1985 response[6] to our June 1985 report further stated that two conditions--the existing computer capacity shortfalls at some en route centers and the increasing failure of the aging IBM 9020 systems--indicated a pressing need for installing the Host computers. FAA believed that technical risks were low and that the Host computer needed to be implemented as scheduled.

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[5]Federal Aviation Administration's Host Computer: More Realistic Performance Tests Needed Before Production Begins (GAO/IMTEC-85-10, June 6, 1985).

[6]Response To Recommendations to the Secretary of Transportation Regarding the FAA's Host Computer Program for Air Traffic Control Contained in GAO Final Report GAO/IMTEC-85-10 (DOT/FAA/AAP-85-4, August 1985).

CURRENT STATUS OF THE HOST
COMPUTER PROJECT

Operational software testing (including performance testing), which was scheduled to begin in April 1986, will not start until August 1986. IBM currently projects a 6-month delay in the overall project schedule. The following table lists the order in which the Host computers will be installed and compares the original planned delivery date for each center with the latest estimated date resulting from the 6-month delay.

Center	Host delivery dates	
	Original	Current[a]
Seattle, Wash.	5/23/86	11/21/86
Houston, Tex.	7/25/86	1/21/87
Denver, Colo.	9/5/86	3/7/87
Boston, Mass.	9/26/86	3/21/87
Leesburg, Va.	10/10/86	4/7/87
Chicago, Ill.	10/24/86	4/21/87
Oakland, Calif.	11/21/86	5/21/87
Albuquerque, N. Mex.	12/5/86	6/7/87
Memphis, Tenn.	12/26/86	6/21/87
Cleveland, Ohio	1/9/87	7/7/87
Atlanta, Ga.	1/23/87	7/21/87
Miami, Fla.	2/6/87	8/7/87
Los Angeles, Calif.	2/20/87	8/21/87
New York, N.Y.	3/6/87	9/7/87
Kansas City, Kans.	3/20/87	9/21/87
Minneapolis, Minn.	4/10/87	10/7/87
Indianapolis, Ind.	4/24/87	10/21/87
Jacksonville, Fla.	5/8/87	11/7/87
Fort Worth, Tex.	5/22/87	11/21/87
Salt Lake City, Utah	6/5/87	12/7/87

[a]In a May 15, 1986, letter to FAA, the contractor presented the revised delivery dates in terms of "months after contract award." For comparison purposes with the original planned delivery dates, we show the projected delivery dates as calendar dates.

As of May 31, 1986, IBM had not provided the FAA contracting officer with the anticipated cost increase resulting from the 6-month delay. We found that Advanced Automation Program Office officials were told by IBM on May 27, 1986, an increased contract cost of $5 million to $6 million is expected. IBM agreed to provide FAA with more definitive cost estimates in late June. Our review of FAA's fiscal year 1986 budget and proposed fiscal year 1987 budget showed that Host computer project increases due to delays were not specifically identified.

Causes of delay

FAA attributes the delay in the Host computer project to a greater effort needed for software development and for resolution of software problems and the lagging development of system documentation.

Software development effort
greater than anticipated

IBM's software development plan--based on experience gained during the corporation's $41.1-million design competition effort--estimated that about 81,000 lines of code would be written or changed during the acquisition phase. However, figures provided by Technical Center representatives show that 130,899 lines of code have already been added or changed. The increase of 49,899 lines is about 62 percent greater than the total amount anticipated. The following table shows the number of lines of code, by major software category, that IBM had planned to modify versus the number of lines already modified as of May 16, 1986.

Type of software	Total no. planned for modification	Total no. modified as of May 1986	Percentage difference
Operational[a]	38,000	60,119	58.2
Support[b]	35,000	68,084	94.5
Maintenance[c]	8,000	2,696	(66.3)
Total	81,000	130,899	61.6

[a]The operational software includes the (1) NAS monitor, which allocates system resources, (2) the NAS applications software, which performs the air traffic control functions of the system, and (3) the COMPOOL and universal data set, which provides data base support.

[b]The support software provides the ability to modify, build, test, and verify all Host computer system software.

[c]The maintenance software provides diagnostic support for all Host computer system hardware elements and peripheral devices.

IBM representatives admitted that they underestimated portions of the software development effort. They also pointed out that almost 30,000 lines of the unanticipated additional code were written to modify commercially available software, which aids in software maintenance functions.

While software conversion is essentially complete, additional lines of code may still need modification depending on how IBM addresses unresolved software problems.

Unresolved software problems

Unresolved software problems that were noted during software conversion have prevented FAA from beginning operational software testing on April 1, 1986, as planned. FAA has characterized some of these problems as critical and has divided them into two categories: mission performance and support system performance related. Mission performance problems (Type I) affect the performance of a critical function of the operational air traffic control system or degrade the Host computer's reliability. Support system performance problems (Type II) do not preclude the primary mission of controlling aircraft, but they have an unsatisfactory impact on a key support function. The following table summarizes the critical operational and maintenance software problems that were unresolved as of April 25, 1986.

	Total	Resolved	Unresolved	Percent open
Type I	254	85	169	66.5
Type II	147	49	98	66.7
Total	401	134	267	66.6

As the table shows, 267 Type I and Type II, or over 66 percent of the critical problems, were unresolved at the end of April. A Technical Center representative told us that IBM will not be permitted to start operational software testing until all Type I and Type II problems are resolved. Both FAA officials and IBM representatives agree that the number of unresolved software problems was one of the principal reasons for the 6-month delay. Although software problems are being corrected, it is important to note that the total inventory of the critical Type I and Type II problems was still increasing at the time we completed our field work. For example, the number of unresolved Type I and Type II problems had increased from 267 on April 25 to 285 on June 4.

On June 9, 1986, IBM representatives told us that, considering the overall magnitude of the Host computer project, they were not alarmed about the current number of unresolved software problems. They told us they had developed a plan to address and resolve the problems by the time testing was scheduled to begin. They also stated that, on the basis of their internal records, the number of unresolved problems is starting to decline. On June 12, 1986, FAA project office managers told us that it was their assessment that IBM had about a 50-percent chance of solving the software problems in time to begin operational software testing on August 25, 1986.

Lagging development of
system documentation

IBM is required to modify the documentation that explains the operation and maintenance of the NAS hardware and software. The software documentation must be received and approved by FAA prior to starting operational software testing. Host computer project officials told us that IBM was behind schedule in providing this documentation. They also said that portions of the documentation were returned without review because their condition was unacceptable (for example, they contained numerous typographical errors). The following table shows the status of the system documentation, which includes information on all new, modified, or deleted software.

Delivery number	Date due	Projected page count	Pages accepted as of 4/21/86	Pages outstanding
1	11/26/85	1,043	1,043	0
2	12/26/85	4,918	442	4,476
3	1/26/86	4,595	970	3,625
4	2/26/86	17,175	2,099	15,076
	Subtotal[a]	27,731	4,554	23,177
5	3/26/86	3,339	0	3,339
Total		31,070	4,554	26,516

[a]Deliveries 1 through 4 are required to be received and approved by FAA before operational software testing begins.

As the table shows, FAA has accepted 4,554 pages, or 16.4 percent of the 27,731 pages of documentation that are required before operational software testing begins. FAA officials told us that IBM has a 50-percent chance of completing the documentation by the time operational software testing is scheduled to begin.

IBM representatives told us they were surprised by the poor quality of the documentation originally provided by FAA. They stated that they initially planned to use optical character readers to transcribe the existing documentation to an electronic medium. However, they experienced problems during the transcription process. As a result, the documentation required rekeying, which meant additional time and effort.

STATUS OF SOFTWARE ENHANCEMENTS

The increased capacity of the Host computers is needed for the implementation of the three software enhancements:

En Route Metering II, Conflict Resolution Advisory, and Conflict Alert Instrument Flight Rules/Visual Flight Rules. The Host computer project slippage will delay these enhancements because they cannot be implemented until the Host computers are installed and the later NAS software version is converted to operate on the Host computers.

En Route Metering II

This software enhancement is a planning tool that is designed to increase the efficiency of the air traffic system by reducing fuel-consumption delays and by providing data to controllers that would allow them to handle delays efficiently.

The design evaluation of this enhancement was completed in December 1984. However, changes have been made to the program since then. FAA now refers to the program as the En Route Spacing Program/Arrival Sequencing Program and considers it part of its overall Traffic Management System/Central Flow Control program.

FAA has included the functions of En Route Metering II that relate to Central Flow Control in a later version of the NAS software than IBM is currently converting. FAA plans to install this later software version solely on the IBM 9020 computer at the Dallas/Fort Worth en route center. According to a Technical Center representative, this is the only center that has enough capacity to accommodate the enhancement. This version of NAS software will be available at other centers after the Host computers are installed and after it is converted to operate on the Host computers. Plans for converting the new version of the NAS software to the Host computers have not been completed at the time of our review.

Conflict Resolution Advisory

This software enhancement is designed to provide automation-aided assistance to controllers in resolving potential conflicts when aircraft violate separation standards. Conflict Resolution Advisory will provide the controller with a display of alternatives when conflicts are detected, thereby reducing the number of operational errors.

Due to insufficient capacity, the function cannot be processed on existing IBM 9020s, including the computer at the Dallas/Fort Worth center. Conflict Resolution Advisory is not included in the NAS software version being converted by IBM. According to FAA, the enhancement will be incorporated in a future version of the NAS software, but it has not yet determined how this will be accomplished.

Conflict Alert Instrument Flight Rules/
Visual Flight Rules Mode C Intruder

This software enhancement will modify the existing conflict alert function. Currently, conflict alert provides information to the controller when two controlled aircraft flying under instrument flight rules, and equipped with a Mode C transponder[7], will violate minimal separation standards within the next 2 minutes. The enhancement will improve safety by alerting controllers when an uncontrolled aircraft flying under visual flight rules--but equipped with a Mode C transponder--and a controlled aircraft will violate separation standards within the next 2 minutes.

The enhancement has been included in the NAS software version scheduled to be implemented on the Dallas/Fort Worth IBM 9020. However, FAA will not install this enhancement at any other center until after the Host computers are installed and the later NAS software version is converted to operate on the Host computers.

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[7]Mode C transponders are electronic devices located within an aircraft that continually transmit certain information, including aircraft identification and altitude, to ground receiving stations.

Request Letter

Congress of the United States
House of Representatives
Committee on Appropriations
Washington, DC 20515

October 1, 1985

Honorable Charles A. Bowsher
Comptroller General of the United States
U.S. General Accounting Office
Washington, D.C.   20548

Dear Mr. Bowsher:

Recently, the General Accounting Office's Information Management
and Technology (IMTEC) Division responded to the Subcommittee's request
for a review of the Federal Aviation Administration's efforts to
modernize its automated air traffic control system. The two reports
issued by IMTEC on the acquisition of the "host" computer system and
the development of the Advanced Automated System (AAS) have greatly
aided the Subcommittee in this year's mark up.

The Subcommittee intends to continue to rely on GAO to provide
objective analyses of FAA's $12 billion national airspace program.
Based on concerns raised in both reports, we request that IMTEC
continue its review of FAA's AAS and related programs. Specifically,
the Subcommittee is interested in IMTEC's observations concerning the
soundness of FAA's AAS investment decision from a technical, economic
and managerial perspective, including the soundness of FAA's
benefit/cost analysis for the AAS. In that an effective implementation
of the "host" computer program is essential to any future transition to
the AAS, the Subcommittee is also interested in GAO's observations on
FAA's efforts to test and implement the "host" including an assessment
of whether performance testing is being conducted as promised to the
Subcommittee. The Subcommittee requests that GAO provide its
observations on the above issues by June 1, 1986. We may also request
the GAO to testify on these subjects during our fiscal year 1987 budget
hearings.

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The Subcommittee is also interested about how FAA plans to integrate recently identified user requirements for communications, navigation and surveillance (CNS) systems. Specifically, the Subcommittee is concerned as to what degree FAA's advanced system will be able to accommodate these requirements in a timely and cost-effective manner and what additional funding will be needed to satisfy these requirements. We request that GAO initiate a survey to begin exploring this issue including FAA's planned investment in CNS systems. Based on the results of the survey, the Subcommittee may request further review of FAA's investment in CNS technology.

We have been very pleased with the cooperation and quality of work provided by your staff on this important multi-year program and hope that your special efforts in this regard will continue.

Sincerely,

Lawrence Coughlin
Ranking Minority Member
Subcommittee on Transportation and
   Related Agencies Appropriations

William Lehman
Chairman, Subcommittee on
   Transportation and Related
   Agencies Appropriations

OBJECTIVE, SCOPE, AND METHODOLOGY

Our objective was to assess the status of FAA's efforts to test and implement the Host computers that will be installed nationwide at 20 en route centers. Our evaluation was limited to identifying hardware and operational software test results to date, the current implementation schedule for the 20 en route centers, and when software enhancements could be expected to be operational. Due to time constraints, we did not independently verify the causes for the schedule slippage, but relied on information provided to us by FAA and the contractor.

Our work covered the period between July 26, 1985--the date FAA awarded the Host acquisition phase contract--and April 30, 1986. Where possible, we updated information about the status of the project through June 4, 1986. Because FAA had not begun operational software testing when our field work was completed, we could not evaluate the results of performance testing. FAA plans to conduct this test starting in August 1986.

To obtain information on the overall status of the Host computer project, we met with FAA project representatives in the Advanced Automation Program Office and the contracting officer in the Acquisition and Materiel Service at FAA Headquarters in Washington, D.C. We also met with representatives of the IBM Corporation. Because we met after our field work was completed, we could not verify their claim that the number of unresolved software problems had started to decrease. For information on system testing, we met with representatives of FAA's Technical Center in Pomona, New Jersey. We also reviewed FAA contract and correspondence files and analyzed project management and cost reports prepared by FAA and IBM.

During our review, we obtained the views of responsible FAA officials and IBM representatives and have incorporated their comments in the report where appropriate. As requested by your office, we did not obtain official comments on a draft of this report from Transportation, FAA, or the IBM Corporation.

Except as noted above, we performed our work in accordance with generally accepted government auditing standards.

(510152)

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