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UNITED STATES GENERAL ACCOUNTING OFFICE

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WASHINGTON, D.C. 20548

INFORMATION MANAGEMENT & TECHNOLOGY DIVISION

MAY 4, 1984

B-206887

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

Dear Mr. Chairman:

Subject: Interim Observations on FAA's Plans for Major Systems Acquisitions (GAO/IMTEC-84-14)

This is in response to your April 3, 1984, letter (see encl. I), asking for our observations with respect to the Federal Aviation Administration's (FAA's) development and acquisition of the Host Computer System, the Mode S System, and the Advanced Automation System (AAS). Since your earlier request in June 1983, we have been working to identify and develop issues related to FAA's development and acquisition of the Host Computer System. We have also begun a planning effort to identify potential strategic issues associated with FAA's long term modernization of the air traffic management system. Based on discussions with Subcommittee staff subsequent to that request, we have expanded our planning efforts to include FAA's design, development, and acquisition of the major data processing, communications, and surveillance systems for air traffic management.

OBJECTIVES, SCOPE, AND METHODOLOGY

In response to your letter, this report contains our preliminary observations regarding (1) Host computer technical risks and their potential impact on program performance and milestones, (2) the desirability of a full-scale Mode S acquisition at this time, and (3) the adequacy of the overall design and acquisition strategy for the AAS.

We conducted our work primarily at the Department of Transportation and FAA headquarters in Washington, D.C.; and the FAA Technical Center in Atlantic City, New Jersey. We interviewed staff members at Transportation and FAA, and technically qualified people from private industry, and aviation users. We reviewed Transportation and FAA documents related to FAA's planning, management, and operation of the National Airspace System. Although the work has been conducted in accordance with generally accepted government audit standards, it is still in its early stages; therefore the

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observations in this report are preliminary and tentative, and subject to revision in the normal course of completing our review.

The following two sections should provide the necessary background about the existing air traffic control (ATC) system and functions, and the roles that the Host computer, Mode S, and AAS are intended to satisfy in evolving to the future ATC system and functions. Following those sections are our preliminary observations addressing the Subcommittee's request. Enclosure II discusses our preliminary observations in more detail.

EXISTING AIR TRAFFIC CONTROL (ATC) SYSTEM AND FUNCTIONS

Today, IBM 9020 computers are used at FAA's 20 en route air traffic control (ATC) centers to assist ATC controllers in managing air traffic -- primarily aircraft separation. Ten of the centers have 9020A computers and the other ten have 9020D computers. The 9020A computers were installed between 1969 and 1972 and have less computer processing capacity than the 9020D models which were installed between 1971 and 1977. The 9020 computers are used primarily to process radar surveillance data and flight plan data to assist the controllers in managing air traffic.

With respect to radar data processing, the 9020 computer takes inputs from many surveillance radars, performs tracking on targets, associates the tracks with flight plans, and presents a visual display of aircraft data to the controller at a work station. Secondary surveillance radars provide the 9020 system with aircraft surveillance and identification data by interrogating beacon transponders installed in the aircraft. The current secondary surveillance radar system is called the air traffic control radar beacon system (ATCRBS). With respect to flight plan data processing, the 9020 computers accept flight plan data filed prior to the flight, and as the aircraft flies through a center's airspace, update this information and print flight progress strips which are used by the controllers to keep track of aircraft which are under their control.

The 9020 system also uses the radar and flight plan data to perform two other functions -- conflict alert for aircraft flying under instrument flight rules (IFR) and minimum safe altitude warning. The conflict alert function warns the controller when two aircraft are predicted to have less than standard separation within the next two minutes. The minimum safe altitude warning function determines whether an aircraft is predicted to be below a predetermined safe altitude in the next several minutes.

According to FAA, while the above functions are currently sufficient to provide safe and efficient air traffic control, there is a need for higher levels of automation to perform additional functions. In a report to the Senate and House Appropriations

Committees in 1982, FAA identified the following four functional improvements that it planned to implement in the 1980s: conflict alert for visual flight rules (VFR) intruders, conflict resolution advisories, en route metering, and electronic tabular display.

The conflict alert for VFR intruders function would provide to controllers warnings of potential aircraft-to-aircraft conflicts between IFR aircraft and those visual flight rules aircraft which are equipped with transponders that report data via ATCRBS. The conflict resolution advisories function would provide to controllers potential solutions to the conflict identified by the conflict alert function. The en route metering function would provide to controllers metering advisories to assist them in managing the flow of traffic into congested terminals in a fuel-efficient manner. The electronic tabular display function would provide to the controller flight plan information on a graphic display, thus automating the controller's flight strip handling and manipulation task. New controller work stations, called sector suites,[1] will also be needed to accomplish this improvement.

In its 1982 report, FAA explained that the lack of 9020 computer capacity, particularly the 9020As, was the principal constraint to implementing the first four functional improvements. Given its traffic load projections, FAA explained that implementing these four functions would bring on capacity problems at from 5 to 8 9020A centers beginning in the mid 1980s.

FAA is developing and acquiring a new Host computer system to provide the computer capacity to accommodate the first three additional functional improvements (conflict alert, conflict resolution advisories, and en route metering) and the higher traffic loads of the 1980s and early to mid 1990s. This project is a five year effort which will transfer the existing software from the older 9020 computers at all 20 en route centers to modern computers. This process is commonly known as re-hosting software to a host computer.

FUTURE ATC SYSTEM AND FUNCTIONS

To provide better services to users, further improve controller productivity, and enhance safety, FAA is developing additional long-term functional improvements that would implement even higher levels of automation such as the ability to provide a conflict detection function having greater look ahead time capability than the two minutes provided in the current conflict alert function.

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[1]The sector suite will be a controller workstation which will display information related to surveillance, weather, flight information, and traffic planning.

Another new functional improvement would be the ability to provide clearances for user preferred routing. These new functions are part of FAA's program to define an advanced air traffic management operational concept called automated en route ATC or AERA. According to FAA these functions could yield multi-billion dollar benefits.

FAA believes that it may need 1) an ADP capability greater than the Host computer; 2) a surveillance capability greater than ATCRBS; and 3) a computer-to-cockpit communications data link capability which the current system doesn't have at all, to implement the additional functional improvements eventually leading to AERA. FAA plans to begin, sometime in the fall of 1984, a concept design of a totally new ADP system called the Advanced Automation System (AAS)to provide the greater ADP capability. To replace ATCRBS and provide the greater surveillance and data link communications capabilities, FAA plans to begin procuring, sometime during the summer of 1984, Mode S -- a secondary surveillance radar and computer-to-cockpit data link.

FAA MAY HAVE UNDERESTIMATED THE TECHNICAL COMPLEXITY OF RE-HOSTING

Although technically feasible, re-hosting software can be a difficult and complex undertaking. As substantiated by other technical analyses, we are concerned that FAA may have underestimated the complexity of the technical problems associated with re-hosting its existing software. Consequently, FAA's planned test and evaluation of the vendors' systems may not be rigorous enough to adequately explore the operational performance which the Host computer is expected to provide. Specifically, it appears that FAA may not explore in sufficient depth potential software performance problems and their impact on overall system performance and reliability, particularly under the heavy traffic loads expected for the 9020D sites in the 1990s. Neither is FAA planning to test and evaluate the three new functions (conflict alert for VFR intruders, conflict resolution, and en route metering) which will be added to the Host computer as soon as it becomes operational and which were a primary justification for acquiring the Host computer.

It appears that more extensive software changes than originally anticipated by FAA will be necessary to transfer the software to the Host computer. According to FAA, its existing software has reached such an advanced state of complexity that a change in one part of the software can cause new problems in apparently unrelated parts. Consequently, as pointed out in several studies and technical symposiums, major changes to this type of software could adversely affect both software performance and reliability and make the already difficult re-hosting even more complex. Thus a complete and thorough testing is needed to assure that major software performance problems do not go undiscovered.

COMPUTER CAPACITY SHORTFALLS MAY NOT MATERIALIZE AS INITIALLY PROJECTED

In its 1982 report to the House and Senate Appropriations Committees, FAA projected that from five to eight 9020A centers may experience substantial capacity problems during the mid and late 1980s. FAA has stated that the Host computer acquisition decision should be made in the summer of 1985 in order to have the Host computer operating at all 20 centers by November, 1987 and thus avoid potential computer capacity problems. It appears that FAA believes the risk of not meeting the acquisition decision milestone is greater than the technical problems discussed earlier. This assumption may be contributing to an optimistic test and evaluation effort.

Our analysis of FAA's 1982 report and a March, 1983 FAA survey of 9020 computer system capacity indicates that only three 9020A sites may experience substantial computer system capacity problems by 1989. Recently, FAA testified before the Subcommittee that the 9020Ds could provide ample capacity until the mid 1990s. We believe this additional time may provide FAA the opportunity to fully explore the potential system performance and reliability risks discussed above, prior to making an acquisition decision. The additional information gained from a more thorough test and evaluation phase would likely improve the basis for the acquisition decision.

USER CONCERNS INDICATE FULL-SCALE ACQUISITION AND IMPLEMENTATION OF MODE S MAY BE QUESTIONABLE

It appears that most users recognize the potential benefits (e.g., more fuel-efficient routing) that could result from AERA and the importance of improved surveillance and data link communications. However, several users pointed out that several promising alternatives (primarily space-based systems) to Mode S are currently under development and evaluation by both private and international groups and that these systems could be available in the late 1980s to early 1990s. As currently planned, it appears that the full Mode S service may not begin becoming available until the early 1990s. These users believe such alternatives may offer significantly better coverage, accuracy and capacity than Mode S and at a lower total cost to FAA and users.

These observations appear to be consistent with an earlier Department of Transportation (DOT) study which pointed out that a space-based network offered higher benefits. At a March, 1982 Office of Technology Assessment symposium, numerous technically qualified participants expressed similar concerns and questioned whether FAA had given adequate consideration to such alternatives.

Recently, the prior FAA administrator testified that FAA had begun work to evaluate these alternatives and the potential to use them beginning in the mid to late 1990s. Consequently, some users are concerned that Mode S may be an unnecessary interim system and that just as users have installed Mode S, FAA will implement a space-based alternative which could require another multi-billion dollar transition for users.

Even if alternatives weren't available, several users explained that it was still unclear as to exactly how much improved capability Mode S will provide and whether this justifies the investment in Mode S. Mode S, like the existing ATCRBS, remains a system based on scanning beam radar technology which has some basic accuracy and capacity limitations. The Department of Defense (DOD) also appears concerned that equipping DOD aircraft with Mode S transponders could cause a significant increase in military expenditures with no appreciable increase in benefits. DOD is currently performing an analysis as to their needs for Mode S.

Given the above concerns, FAA may wish to re-evaluate its data communications and surveillance requirements, particularly those associated with the potentially stringent demands of AERA. These requirements could then serve as the baseline for evaluating and identifying the most promising system concepts.

PREMATURE AAS DESIGN COULD HAMPER THE EVOLUTION TO AERA

With respect to the AAS, we are concerned that FAA may be proceeding with its system concept design efforts before it more fully defines the functional requirements and design oriented specifications associated with the higher levels of automation leading to AERA. For example, in its solicitation for potential system design contractors, it appears that FAA has defined the requirements related to the functions provided by the existing system and those additional functions to be implemented on the Host computer. However, it does not appear that FAA has fully defined the requirements related to the higher levels of automation leading to AERA. Neither does it appear that FAA is requiring that the AAS have the capability and flexibility to accommodate potential major advances in surveillance technologies, such as space-based systems, which may be necessary to accomplish the higher levels of automation leading to AERA. Such flexibility was a very important part of FAA's July, 1981 Mission Need Statement for the advanced automation system.

Also, somewhat contrary to general policy guidance in OMB Circular A-109, FAA, in its guidance to potential system contractors, placed considerable emphasis on the existing system as a basis for defining needs for the AAS. FAA explained that this was done only for the ease and clarity of specifying requirements and that there was no intent or desire to restrict the AAS design to the existing system capabilities.

It is unclear how the above factors may have affected the number and type of contractors who may have bid for the concept design phase. However, based on our discussion with knowledgeable and technically qualified staff, these factors could restrict the range of system concepts and architectures likely to be proposed and evaluated. This presents the risk that the completed AAS design may not provide sufficient or cost-effective capability or flexibility to achieve the higher levels of automation and services of AERA. We have not reviewed any proposals which have been submitted by potential vendors.

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As requested in your letter and discussed with your staff, we did not obtain agency comments on this report. Unless you release its contents earlier, we plan no further distribution of the report until 30 days from its date.

Sincerely yours,

Warren G. Reed

Warren G. Reed
Director

Enclosures - 2

Congress of the United States
House of Representatives
Committee on Appropriations
Washington, D.C. 20515

April 3, 1984

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

Dear Mr. Bowsher:

Recently, staff from the General Accounting Office's (GAO's) Information Management and Technology (IMTEC) Division briefed our Subcommittee staff on the status of several Federal Aviation Administration major system acquisitions being pursued as part of the National Airspace System modernization program. This Subcommittee considers oversight of this program to be one of our top priorities and we have been very pleased with GAO's cooperation in helping us to meet our responsibilities.

We think the work of IMTEC shows promise, particularly with respect to FAA's host computer system, advanced automation system, and the Mode-S system. Although this work is still in its early stages, the Subcommittee believes an interim report summarizing GAO's observations on these system acquisitions would be helpful to our mark-up of FAA's fiscal year 1985 budget request.

More specifically, the Subcommittee would like an interim report submitted no later than May 1, 1984, providing GAO's observations thus far on the adequacy of FAA's assessment of potential host computer technical risks and whether such risks should be more fully evaluated prior to production. We also are interested in your observations of how these risks may affect the production award milestone given current system capacity. Also, any observations regarding (1) the overall acquisition strategy for the advanced automation system including the adequacy of FAA's concept design efforts to date, and (2) the desirability of proceeding into the full-scale acquisition of Mode-S at this time would be greatly appreciated.

Given the short reporting timeframe of this request, we are asking GAO not to solicit agency comments on the report. Thank you for your continuing cooperation.

Sincerely,

William Lehman
Chairman
Subcommittee on Transportation
Appropriations

PRELIMINARY OBSERVATIONS REGARDING FAA'S HOST COMPUTER SYSTEM, MODE S SYSTEM, AND ADVANCED AUTOMATION SYSTEM

THE HOST COMPUTER SYSTEM

Host Computer Will Change Current System Configuration

The 9020 computer system at each en route center is actually a combination of 2 to 3 processors which work together in a multiprocessing environment. In effect, these processors are configured so that they share memory. Special instructions are used to synchronize software execution in this multiprocessing environment.

The configuration of the Host Computer System will consist of dual processors (a primary and a standby) at each center which will not share memory. When both processors are in operation, the primary will process the on-line, real-time operational software while the standby processor will be available to take over primary processing.

Independent Analyses Identified Potential Technical Risks

Prior to approving the Host compute-off phase in March 1983, the Transportation Systems Acquisition Review Council (TSARC) [1] requested the Bell Telephone Laboratories (BTL) and the Transportation Systems Center (TSC) to conduct independent technical analyses of the Host computer acquisition. Both studies concluded that while transferring the existing software into a new Host computer should be technically feasible, major undiscovered problems with the existing software and certain key risks, such as the effect of using a virtual machine (VM) monitor should be fully examined during test and evaluation. The BTL study in particular, appeared concerned that FAA may be underestimating the complexity and difficulty of transferring existing software to a new Host computer. A similar concern was widely expressed at a technical symposium conducted by the Office of Technology Assessment in March, 1982. BTL has transitioned over 450 processors and is considered an expert on host projects.

A (VM) monitor is an operating system technique which manages and allocates the computer resources among multiple simultaneous tasks. To the user, the computer appears to have greater processor and memory capability than it actually does. For FAA the VM concept offered the advantage of being able to re-host the entire existing 9020 software into a host virtual machine; minimize the

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[1] A Department of Transportation committee established to review and approve the development and acquisition of major transportation systems.

software changes necessary to make the existing 9020 software compatible with the virtual machine; and perform more tasks on the Host computer in a more economical manner. The VM monitor, itself a complex element of software, serves as an interface between the machine and the re-hosted software. In effect, the VM monitor tailors the computer to the re-hosted software.

The primary disadvantage of VM is that it introduces delays in the software execution which can be unacceptable for real-time [2] applications. With VM, the execution of any input-output functions executed by the re-hosted software requires attention from the VM monitor thereby adding overhead to the execution requirements. The effect of this VM overhead is to increase the number of instructions required to execute the re-hosted software. VM monitors have been used extensively to rehost software for on line applications. The 9020 system however is a real-time system. According to both the TSC and BTL studies, there are no known applications of VM for real-time systems. In non real-time applications, the effect of execessive VM overhead results in, at worse, a degradation of performance. However, for real-time applications such as the air traffic management system, excessive VM overhead can impact seriously time-critical computations.

BTL, in its January 1983 study, pointed out that the achievement and cost of capacity increases from the Host will depend critically upon the overhead caused by the introduction of VM. BTL concluded that because they could not find any application of VM in a real-time, high availability environment using the type of architecture requested by FAA, there was no way to assess the impact of introducing VM. BTL did explain that depending upon the type of application, software overhead increases from VM could run as high as several hundred percent. In sizing the system FAA had used a software overhead figure of 70%. Again, because of no known similar applications, BTL could not validate this estimate. BTL explained that VM could have a significant impact on the existing software's performance--particularly under heavy traffic loads.

BTL also concluded that because the Host will retain the display subsystems, and existing software, while introducing directly coupled processors and memory elements, there would not likely be significant improvements in overall system reliability. In fact, the initial downtime experience would likely be worse until most software, hardware and procedural problems induced by the conversion are discovered and removed from the system. In addition, BTL pointed out that the new Host system, as configured at that time, could take up to several minutes to recover. Obviously system

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[2]Real-time applications, as opposed to on-line, refer to those systems that control an on-going process and deliver its outputs or inputs not later than the time when these are needed for effective control.

recovery time is crucial to a real-time air traffic control environment and FAA agreed with BTL that this area should be given top priority during the compute-off.

With regard to both the system performance and reliability issues above, BTL recommended that FAA should develop and apply system performance and reliability models to fully examine these issues. Finally, BTL concluded that while the Host's hardware maintenance should be superior, software maintenance could be more difficult because of the increased complexity of the transferred software due to modifications necessary to adapt the existing software to VM.

Similarly the TSC, in its December, 1982 study, concluded that transferring the existing software to a new Host was technically feasible but required thorough testing. In particular, TSC was aware of the potential system performance problems under heavy traffic load conditions and was concerned that FAA's Technical Center did not have an adequate capability to evaluate today's, let alone the 1990's heavy traffic loads. TSC also concluded that FAA should develop an improved methodology for estimating the costs and benefits of the Host prior to the acquisition decision in the summer of 1985.

On September 8, 1983 FAA responded to the TSARC regarding the BTL and TSC studies. FAA informed the TSARC that after negotiating with both Host vendors, it had decided to drop the requirement that both the primary and stand-by Host computers in each center employ VM monitoring. Only the stand-by processor will employ VM. The primary reasons for this change included potential certification problems and the fact that VM fault recovery mechanisms were not designed for a real-time environment. FAA believes that this change negates BTL's primary concerns over system performance and reliability and does not plan to develop and apply the system performance model. FAA does see some merit in a system reliability model and will pursue this after cutover to the Host.

With regard to TSC's concerns, FAA agreed that existing facilities and tools at the Technical Center are inadequate to evaluate system performance under those heavy traffic loads which are projected to occur during the timeframe when the Host will be operational. FAA explained it has initiated the development of a more representative test but that the development and validation of such a test is difficult, costly and time consuming. Consequently, the test may not be ready for the Host compute-off. With regard to cost/benefit analyses, FAA stated that it is updating these and results should be ready prior to the Host acquisition decision in the summer of 1985.

Notwithstanding FAA's recent changes to the Host computer acquisition, we remain concerned that as currently planned, FAA's test and evaluation requirements and timetable may not allow for a full exploration of potential system performance and reliability issues prior to the acquisition decision. Based on our discussions with agency, private industry, and other technically qualified staff, we believe that dropping the use of VM in the primary processor does not necessarily resolve all system performance and reliability issues. In fact, dropping VM may create different problems not envisioned which must now be addressed. For example, the primary reason FAA chose to originally require VM was to minimize the amount and complexity of changes to the existing operational software to make it compatible with the Host hardware; particularly since it is moving from a multiprocessing environment to a uniprocessing environment. The potential software performance problem, especially under high traffic loads, remains a significant concern. Also, whenever the primary computer should become inoperable, the ability of the standby computer to discontinue VM control and assume primary operational status in a timely fashion is unclear.

Also, we are concerned that FAA does not plan to test and evaluate during the compute-off the three functional improvements which FAA plans to implement on the Host after it is operational and which were a primary reason for acquiring the Host. This action may be inconsistent with that guidance provided by the Subcommittee in House Report No. 98-246 on FAA's appropriation for fiscal year 1984.

Host Acquisition Decision Milestone Could Slip

Currently FAA plans to request TSARC's approval (TSARC milestone #4) to make a Host acquisition decision in the summer of 1985. FAA has stated that not meeting this milestone is the largest risk in the Host project. We have discussed this schedule with agency, private industry, and other technically qualified staff, and believe it to be highly optimistic, particularly if system performance and reliability problems surface as a result of the test. Obviously, if FAA were to incorporate additional testing elements such as system performance modeling and high traffic load test scenarios described earlier the testing would likely take longer to complete and would push the acquisition decision further out.

However, the potential benefits associated with a more informed acquisition decision that could result from a thorough and exhaustive test phase may outweigh the increased time needed to accomplish the test--particularly given the importance of the Host to aviation safety. The one risk that may contradict this observation would be if the current 9020 system began to experience serious capacity problems prior to the cutover to the Host. Under the current schedule, after making the acquisition in the summer of 1985, FAA plans to cutover to the Host beginning in October 1986; completing the cutover for all en route centers by November 1987. This schedule is driven by FAA's original expectation that 5 to 8 9020A systems would begin to experience serious capacity problems beginning in the mid 1980s. However, based on an FAA analysis provided to Congress in January 1982, and a March, 1983 survey of 9020 system capacity, it appears that only three 9020A systems may incur serious capacity problems by 1989. Obviously, this date could vary if FAA has changed its air traffic growth projections.

MODE S AND AAS
FAA Plans To Soon Begin Procuring Mode-S and Designing AAS

Sometime in the summer of 1984, FAA plans to award the initial production contract for Mode S. Sometime in the fall of 1984, FAA plans to award a 35 month contract to design the Advanced Automation System (AAS). FAA anticipates that these two systems will play major roles in implementing higher levels of automation leading to AERA and its potentially significant benefits. For example, preliminary estimates by FAA indicated that AAS and Mode S together could be responsible for up to $8.8 billion of the $9.7 billion net benefits expected from the NAS plan. FAA has stated that it is difficult to separate and allocate these benefits to either Mode S or AAS since AERA requires the cooperative operation of the ADP, communication, and surveillance systems to achieve the benefits. FAA is working on a plan for conducting cost/benefit analysis of these programs.

AERA -- an advanced operational concept for air traffic management

Beginning in the 1990's, FAA plans to begin implementing AERA--an advanced operational concept for air traffic management (both en route and terminal) whose primary goals are to provide better services to users, improve controller productivity, and enhance safety -- primarily through higher levels of automation and ground/air telecommunications.

For example under AERA, additional functions are expected which will allow the system to accomodate user perferred routes that take advantage of the winds aloft to increase speed or reduce fuel consumption and other functions to provide fuel-efficient ways to absorb delay. It is clear that the current air traffic management ADP, surveillance, and communication systems do not and can not provide the capabilities necessary for AERA. FAA is currently performing a top-down mission analysis which will define AERA's mission goals, sub-goals, required capabilities, functional requirements, and finally, design-oriented specifications for system level specifications. Figure 1 illustrates how FAA may potentially refine AERA. While this approach appears to be sound and logical and FAA has made progress, much work remains before design-oriented specifications with sufficient detail are available as the basis for system design efforts.

MODE S acquisition and implementation

The purpose of the Mode S secondary surveillance radar is to provide the computer more accurate aircraft surveillance information and to eliminate the beacon transponder interference of the

ENCLOSURE II

- NAS PLAN
  - BETTER SERVICE TO USERS
    - MORE USER-PREFERRED ROUTES AND ALTITUDES
      - -More Flexible Specification of Route and Altitude — o Functional Requirements
      - -Flexible Application of Pref Routes — o "
      - -Improved Problem Monitoring, Detection, Resolution — o "
    - REDUCED FLIGHT DELAYS AND MORE FUEL-EFFICIENT DELAY ABSORPTION
      - -Improve Flight Plan and Amendment Processing — o "
      - -Reduce Route and Altitude Restrictions — o "
      - -Provide Efficient Conflict Resolution — o "
      - -Improve System Throughput — o "
      - -Provide Fuel-Efficient Delay Absorption — o "
    - REDUCED WORKLOAD IMPOSED ON THE PILOT BY THE ATC SYSTEM
      - -Reduce Need for Some Voice Communications — o "
      - -Improve Remaining Voice Communications — o "
      - -Eliminate Some Voice Communications — o "
    - IMPROVED INFORMATION AND INFORMATION FLOW TO AND FROM THE PILOT
      - -Have More Accurate Information — o "
      - -Improve Information Transmission — o "
      - -Prevent New Operational Limitations — o "
  - IMPROVED CONTROLLER PRODUCTIVITY
    - REDUCED CONTROLLER WORKLOAD/FLIGHT
      - -Improve Conflict Detection — o "
      - -Assist in Generation and Evaluation of Solutions to Control Problems — o "
      - -Reduce and Facilitate Communications and Coordination — o "
      - -Improve I/O Capabilities and Interactions — o "
      - -Provide Aids for Multi-Task Environment — o "
    - IMPROVED UTILIZATION OF CONTROLLERS
      - -Improve Estimate of Current and Future Sector Workload — o "
      - -Improve Input and Output Capabilities — o "
      - -Improve Board Management and Position Relief Briefings — o "
      - -Improve Ground-to-Ground Coordination and Communication — o "
  - ENHANCED SAFETY
    - REDUCED OCCURRENCE OF OPERATIONAL ERRORS
      - -Detect Conflicts — o "
      - -Provide Suggested Resolutions — o "
      - -Reduce Communication Errors — o "
      - -Detect and Resolve Imminent Violations — o "
    - OTHER SAFETY FACTORS IMPROVED
      - -Provide Backup Capability — o "
      - -Support System-Related Functional Hierarchy — o "
      - -Assist in Monitoring Air Traffic — o Functional Requirements

GOALS | SUB-GOALS | REQUIRED SYSTEM CAPABILITIES | REQUIRED FUNCTION-LEVEL CAPABILITIES

Figure 1

FAA's Methodology for Developing AERA's Functional Requirements current air traffic control radar beacon system (ATCRBS). In addition, Mode S will represent a significant and expensive departure from the use of ATCRBS as a radar surveillance system in that the Mode S secondary surveillance radar will also provide the computer-to-cockpit data link capability for weather, air traffic control clearances, and other information needed to implement the higher levels of automation under AERA.

Because of uncertainty regarding the costs to equip aircraft with Mode S transceivers, the total cost to acquire and implement Mode S is unclear. Through fiscal year 1982, FAA spent approximately $65 million on Mode S research and development. Based on a February 16, 1983 GAO report, FAA plans to spend an additional $54 million on Mode S development through fiscal year 1991. Through fiscal year 1992, FAA plans to spend approximately $500 million to acquire the MODE-S beacon sensor and $890 million to acquire the accompanying airport surveillance radar. Finally, according to GAO's February 1983 report, the costs to equip commercial and general aviation aircraft with transceivers could run as much as $2.9 billion. DOD expects its costs to be at least $1 billion and potentially higher than the civil sector.

FAA has already begun procurement of the airport surveillance radars and will begin procurement of the Mode S beacons in the summer of 1984. Also as a step towards phasing in Mode S, in October 1983, FAA issued an Advanced Notice of Proposed Rulemaking to terminate its authorization for manufacture of ATCRBS transponders in 1986.

Overall AAS design and acquisition strategy

FAA plans to develop and aquire the AAS in a two-phase procurement. The first phase is the Design Competition Phase (DCP). FAA has requested, received, and is currently evaluating proposals for this phase and plans to award a 35 month DCP contract in the fall of 1984. The DCP will be followed by an acquisition phase in which the chosen contractor will produce, install and test the hardware and software comprising the AAS.

FAA has specified that the AAS will consist of two operational elements. The Area Control Computer Complexes (ACCC) will be installed at about 20 consolidated air traffic control facilities, called Area Control Facilities (ACF) while the Tower Control Computer Complexes (TCCC) will be installed at approximately 300 Air Traffic Control Towers. Both of these computer complexes will consist of four architectural elements: new sector suites; processing elements; local area data networks tying the sector suites to the processing elements; and new, modular software.

In order to achieve anticipated controller productivity increases as early as possible, the sector suites (which replace the old controller display and work stations) will be deployed at the ACFs two years in advance of the remaining architectural elements of the ACCC. According to FAA, these new sector suites will achieve controller productivity increases via state-of-the-art display and input technologies, improved man/machine interfaces, and the automated display of flight information. These sector suites will be driven by the Host Computer System containing the re-hosted software. The resulting system is referred to as the Initial Sector Suite System (ISSS).

The specific nature of the processing elements in the overall AAS architecture is uncertain at this time. The number, type, and distribution of processors will be determined by the contractors as part of the design effort. It is unclear at this time as to whether the Host Computer will remain an integral part of the distributed processing network. FAA expects that within each ACF there will be central processors and separate distributed processors associated with each sector suite. However, the exact distribution of computing functions among the central processors and sector suite processors and the required performance of these processors have not been determined. These types of tradeoffs will be addressed by the contractors during the DCP.

Local area networks will be employed to provide communication among the sector suite processors, the central processors, and other systems within the ACFs. Again many of the details of these networks will be addressed by the contractors during the DCP.

With regard to new software, FAA desires a common higher order language for both the central processors and sector suite processors. The software is to be modularly structured so that new functions can be easily added or existing functions deleted.

Transitioning from the Host Computer System to the full AAS will require two steps. From the late 1980s to the early 1990s, the Initial Sector Suite System will be installed at the existing en route centers. From the early 1990s to the mid 1990s the ISSSs will be joined by new software, additional processors, and an expanded communications network to complete the ACCC configuration. Specific configuration and transition details for the 300 Tower Control Computer Complexes (TCCC) is unclear at this time. The exact distribution of computing functions among the ACCC's and TCCC's has not been determined.

Concerns Exist Regarding Mode S Capability And Cost-Effectiveness

Based on our preliminary evaluation thus far, it appears that technically, Mode S could offer some improved surveillance and data link communications capability over the existing ATCRBS. It also appears that to achieve the full safety and efficiency benefits from higher levels of automation, it may be desirable for most aircraft to be equipped with some type of surveillance/communications transceivers. In addition, it appears that most aviation users endorse FAA's goals for improved surveillance and communications.

However, there appears to be considerable uncertainty that Mode S is the most cost-effective alternative. Specifically given the anticipated stringent surveillance and communications demands resulting from higher levels of automation and given rapidly evolving alternative surveillance and communicatons technologies, the long-term capability and cost-effectiveness of Mode S may be questionable. Finally, based on an earlier DOT study, it appears that if a large additional investment is made to deploy a distributed ground-based surveillance system, it may reduce the cost-effectiveness of future alternative space-based technologies and hamper the consideration of such technologies.

Recent discussions with users indicate that because of the age and limitations of the Mode S technology, the capability offered by Mode S is marginal when compared to its costs. Several users pointed out that Mode S was formerly known as the Discreet Address Beacon System (DABS) and has been in development for over a decade. Several users pointed out that the use of a scanning beam radar system, like Mode S, as a ground-to-air communications data link is severely limited by the amount of time available for communicating during each sweep scan as the beam passes the aircraft. Increasing the beam width allows more time on target but can reduce surveillance accuracy and for longer messages and weather data more than a few sweep scans would be required to complete a transmission to one particular aircraft. Mode S is also limited because it is a single frequency system and has limited capacity for expansion when its frequency band becomes saturated. Saturation could also seriously degrade the surveillance function, particularly when the saturation is caused by airborne transmitters. Several users have pointed out that until the number of aircraft equipped with transponders compatible with ATCRBS is significantly reduced, Mode S ground beacons could experience many of the same interference problems as ATCRBS.

Our February 16, 1983 report explained that the prototype Mode S was unable to satisfy a basic performance requirement for future traffic projections during testing because it failed to interrogate a sufficient number of aircraft in a given area and transmit and receive longer messages. FAA has since responded that it has conducted further testing indicating Mode S can meet specified capacity requirements. We have not yet evaluated the additional testing.

The above concerns have led some users to conclude that as FAA further defines the surveillance and communication requirements associated with higher levels of automation and AERA, it will become clear that Mode S may not be either capable or cost-effective. Thus, perhaps FAA might usefully consider alternative approaches and technologies. Several users pointed out that promising space-based systems which may be more capable and cost-effective than Mode S, are currently under development and evaluation by both private and international groups and that these systems could be available in the 1990s. Indeed the former FAA administrator testified that FAA could be using space-based systems by 1995. The first 50-75 Mode S ground sensors are currently scheduled for delivery in the field between 1989 and 1990. Beginning in 1991 full AAS installation and integration will begin at the en route centers. Thus, it appears that the capabilities and benefits that are offered by Mode S may not begin becoming available until the early 1990's.

Most users appeared to understand and support the potential benefits offered by space-based systems. Consequently, unless either ATCRBS is unavailable or Mode S is mandatory, they believe very few users would equip with Mode S transponders; thus negating many of the benefits FAA anticipates. FAA's original version of the NAS plan anticipated widespread Mode S use by 1990. FAA's April 1983 update of the NAS plan indicates limited use of Mode S by 1990 with widespread use by the year 2000.

Several users appeared concerned that if Mode S usage was mandated either directly or indirectly (i.e., potentially FAA's proposed rulemaking), that by the time most aircraft will have equipped with the Mode S transponder, FAA may have decided to implement an alternative, probably a space-based system. However, Mode S transponders may not compatible with such an alternative system. Consequently, Mode S may turn out to be an interim system and users would face another costly transition in the late 1990s.

The Department of Defense (DOD) also appears to be very concerned regarding FAA's intent to acquire and implement Mode S. The primary concern is that equipping DOD aircraft with Mode S transponders could cause a significant increase in military expenditures with no appreciable increase in benefits. In addition the Mode S avionics could also have an adverse impact on certain military aircraft's aerodynamic performance. DOD is currently making a detailed analysis as to their needs for Mode S, particularly the data link portion.

Finally, given recent FAA congressional testimony that it intends to do a "clean-sheet" design for the AAS, several users suggested a similar "clean-sheet" approach for the surveillance and communication systems. This approach could use FAA's currently on-going, top-down AERA analysis to identify the minimum essential communications and surveillance requirements. These requirements could than serve as a basis for evaluating and identifying the most cost-effective system concepts. Several users pointed to a 1975 DOT study as an example of a "clean sheet" approach to air traffic management. That study pointed out that a distributed ground-based surveillance system did not seem to promise the equivalent benefits that a centralized (space-based) surveillance network could achieve. The study cautioned against further deployment of and prolonged reliance on ground-based systems in that their sunk costs and increased investment could decrease the cost-effectiveness of space-based systems and hamper their consideration and implementation.

Adequacy of AAS Design Efforts Is Uncertain

Recent FAA testimony explained that FAA intends to do a "clean-sheet" design for a totally new ADP system--the AAS--which is intended to satisfy the higher levels of services and automation leading to AERA. To accomplish this "clean-sheet" design, FAA plans basically to define general requirements and leave the detailed design considerations to the successful bidder. In support of this "clean-sheet" approach, FAA has explained it will not require that the Host Computer necessarily remain an integral part of the final AAS. We believe that if adequately planned and managed, a "clean-sheet" design approach could provide a strong foundation for future improvements to air traffic management. Given the time likely required to develop and implement a "clean-sheet" design, and FAA's predicted life of the Host Computer, FAA's intent to not let the Host necessarily restrict the "clean-sheet" AAS may also be a sound decision for long-term benefits.

However, based on our preliminary evaluation, we are concerned that FAA may be proceeding with its system concept design efforts before it defines more fully the functional requirements and design oriented specifications associated with the higher levels of automation leading to AERA. This could adversely impact the capability or flexibility of the AAS design to sufficiently or cost-effectively achieve the levels of services and automation desired in AERA.

It appears that FAA's design and acquisition strategy is driven by the desire to achieve some controller productivity gains as quickly as possible. While initial controller productivity gains may be an important benefit, they should be considered within the perspective of all the mission goals and benefits related to higher levels of services and automation--particularly if the acquisition strategy to achieve the initial benefits may hamper the ability to achieve greater long term benefits.

Purpose of concept design phase

As discussed earlier, FAA had requested, received, and is currently evaluating contractor proposals to conduct a Design Competition Phase. The purpose of the current decision FAA is preparing to make is not to choose a specific AAS concept, design, or architecture; but to choose two contractors who will competively perform a concept and architecture design. That is, given the requirements which the AAS must satisfy, FAA is attempting to decide which contractors have the best approach and methodology for identifying, evaluating, and selecting a system design and architecture; for defining the detailed design; and for performing the necessary development.

To make its decision, FAA has asked each interested contractor to describe a minimum of two candidate system architectures for meeting AAS requirements. FAA has explained that it will not do a technical evaluation of the proposed architectures per se but will use them as a basis to evaluate the technical merits of each contractors' proposed approach and methodology. FAA has attempted to define these issues such that to address them, the contractors must demonstrate an understanding of the air traffic control mission and that the contractor can reduce its design methodology to practice. FAA has explained that it is not requiring that the Host computer remain an integral piece of the AAS if the contractor can demonstrate a more effective and economic architecture without it.

Undefined AAS requirements could adversely impact AERA

Based on our past experience with design efforts for major systems, perhaps the most important ingredient in this process is the definition of the requirements which FAA intends to use the AAS to satisfy. It does appear that FAA has fully described the functional requirements and design oriented specifications related to the functions provided by the existing system; those additional functions to be implemented on the Host computer; and two lower level automation functions associated with AERA. However because, as discussed earlier, AERA is still in its developmental stages, FAA has not yet fully and sufficiently defined the functional requirements and design oriented specifications which the AAS must satisfy to achieve the benefits anticipated for the higher levels of services and automation in the 1990s.

This includes the capability and flexibility to accomodate major advances in communication and surveillance technologies which, as discussed earlier, may also be necessary to accomplish the high levels of service and automation. Based on our discussions with agency, private industry and other technically qualified staff, it appears that the use of space-based systems to provide the surveillance and/or communications capability could have a significant impact on the design of the ADP capability. Such flexibility was a very important part of FAA's July 1981 Mission Need Statement for the advanced automation program. Included in that statement was a need for the en route automation system to be flexibile enough to permit the evolution of satellite based supporting surveillance, communication, navigation, and weather detection and forecasting systems.

Also, OMB Circular A-109 specifies that as general policy, Federal agencies, when acquiring major systems, will express needs and program objectives in mission terms rather than in terms of the existing system, to encourage innovation and competition in creating, exploring, and developing alternative design concepts. In its guidance to interested contractors, FAA specified the number of control centers, types of computer complexes, and has to some degree used references to the existing system to define needs for the AAS. FAA did explain that this was done only for the ease and clarity of specifying requirements and that there was no intent or desire to require the AAS duplicate the existing system. FAA did require that the AAS provide the equivalent functions of the existing system and be compatible with new models of "skin tracking" radar and Mode S.

It is unclear how the above factors may have impacted the number and type of contractors who may have bid for the concept design phase. However, based on our discussion with knowledgable and technically qualified staff, these factors could restrict the range of system concepts and architectures likely to be proposed and evaluated. This obviously presents the risk that the completed AAS design may not provide sufficient or cost-effective capability or flexibility to achieve the higher levels of automation and services of AERA.

It appears that the strategy to proceed with system design efforts prior to a complete and specific definition of functional and design oriented requirements is being driven by FAA's desire to achieve some initial controller productivity savings. As discussed on page 16, FAA plans to achieve these gains via the early implementation of the ISSS phase of the overall AAS program. Recent FAA testimony before the Subcommittee indicated that the early implementation of ISSS could save up to 800 controller positions.

We recognize that controller productivity gains are an important part of FAA's mission goals. However as currently envisioned under AERA, there are additional mission goals including improved services to users, enhanced safety, and even greater controller productivity gains. A design and acquisition strategy focused on achieving quick, initial controller productivity gains must be carefully weighed against the potential adverse impact it may have on achieving greater long term mission goals and benefits. Several of the analyses we reviewed and technical staff we interviewed had similar concerns. An analysis prepared by the Transportation Systems Center (TSC) for the TSARC pointed out that FAA's design and acquisition strategy for AAS leads to a compressed schedule which has program and cost risks. Also, despite FAA's intent that this be a "clean sheet" approach, several technically qualified staff told us that the compressed schedule could dictate that the Host Computer remain an integral part of the AAS architecture even though this may not be the most capable or cost-effective design.

According to the TSC analyses, FAA is aware of the considerable uncertainty in the future needs, structure, and configuration of an evolving air traffic management system. FAA has attempted to counter this risk through flexibility -- mainly by requiring that the new AAS be based on distributive processing and communications networks and high-order language modular software. FAA also believes this flexibility will accomodate the compressed design and acquisition schedule without increasing risks.

An alternative for reducing concept design risk

Another way to potentially further reduce these risks is to use a strategy which considers awards to several contractors of detailed design and subsystem demonstration contracts based on a complete set of design oriented AERA specifications. Following this phase, at least two contractors would proceed with developing and testing a prototype of the full AAS. The prototype would also allow the new AERA functions to be evaluated and "fine-tuned". In fact, FAA could require the two contractors to actually demonstrate AERA functions, as part of the prototype evaluation. Under FAA's current approach, the contractor only has to show he can complete system design and test the prototype sector suite console to assure FAA that all program objectives can be met. Finally, a single contractor could then be selected to deliver and implement the system. Thus, this approach not only assures that the AAS can provide the performance necessary for AERA, it also minimizes program risk by maintaining competition through demonstration of the full AAS prototype.

FAA did consider a design and acquisition strategy similar to this approach. However, FAA rejected the strategy because of its higher costs and the greater time required to implement the system, particularly considering the controller productivity gains offered by the early delivery of the ISSS under their desired approach.

We believe that the potentially higher early costs to identify and consider a broad range of alternative system concepts and architectures may be warranted. This is in accordance with OMB Circular A-109, which states that research and development efforts should emphasize early competitive exploration of alternatives, as relatively inexpensive insurance against premature or preordained choice of a system that may prove to be either more costly or less effective.