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ADVANCED AIR TRAFFIC MANAGEMENT SYSTEM STUDY
EXECUTIVE SUMMARY

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FINAL REPORT

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16. Abstract

This report summarizes the U.S. Department of Transportation study and development plans for the air traffic management system of the late 1980's and beyond. The plans are presented in the framework of an evolutionary system concept of traffic management, building upon the Upgraded Third Generation Air Traffic Control System, and defined to meet the projected demands for service, safety, and flexibility in a cost effective manner. In order to provide the information needed for planning future system developments, a program of research and development is described for the system concept presented in the report.

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ADVANCED AIR TRAFFIC MANAGEMENT SYSTEM STUDY

EXECUTIVE SUMMARY

The Advanced Air Traffic Management System (AATMS) Study was conducted by the U. S. Department of Transportation, Transportation Systems Center, under the sponsorship of the Office of the Assistant Secretary for Systems Development and Technology. The Study was initiated by the U. S. Department of Transportation in 1970 in response to recommendations by the Department's Air Traffic Control Advisory Committee which published its findings in 1969.[1] The Committee was formed in 1968 to address the pressing need for an improved air traffic control system. The Committee's recommendations formed the basis for much of the present FAA Upgraded Third Generation Air Traffic Control System Engineering and Development Program, including the Discrete Address Beacon System, Intermittent Positive Control, and upgraded automation of ATC facilities.[2] However, the Committee was concerned with potential deficiencies in capacity and coverage of this system in the 1990 time frame and with increasing system operating and maintenance costs. Consequently, the Committee recommended that ". . .A Fourth Generation System should be in orderly development which can supplant the upgraded Third Generation System" In its recommendations the Committee established system and technology priorities for the formulation and definition of an advanced concept of air traffic management:

> ". . .The Committee's review of future possibilities identified space and computer technology as offering the greatest potential advantages."

In acting on the Committee's recommendations, the U. S. Department of Transportation initiated a four-year multi-phased study of concept formulation, to consider future system alternatives; concept definition, to consider specific future system features in detail and develop a supporting technology base; and evaluation leading to selection of a preferred advanced air traffic management system concept and recommendations for research and development activities supplementing the present FAA Engineering and Development Program. Study objectives were that the selected concept handle the projected air traffic estimated for the 1990's, evolve from the Upgraded Third Generation System now in development, maintain system safety, be cost effective, and pose minimal technological risk in concept realization.[3]

The resulting concept for a potential Fourth Generation System, preferably called the Advanced Air Traffic Management System (AATMS), was one of several alternative advanced air traffic management system concepts considered. The selected AATMS concept is characterized by the following features:

- Use of satellites over the conterminous United States and contiguous oceanic regions as a primary mechanization for universal coverage surveillance, navigation, and data link communication, in conjunction with aircraft avionics integrated at the functional level.
- Continuation of the current philosophy of ground-based air traffic management by Tactical Control, augmented by Strategic Control, a technique emphasizing extensive pre-planned, time-scheduled, conflict-free flights, especially in regions of high air traffic density.
- Centralization of the control and data processing network into two or three en route control facilities.
- A high degree of automation to constrain the growth in operational costs.

As shown in Figure 1, the AATMS Concept proposed the application of satellite technology for surveillance, navigation, and data link communication with aircraft, as well as continuation of VOR-DME navigation facilities, VHF voice communication facilities, and the ground-based Discrete Address Beacon System of the Upgraded Third Generation System. The centralization of highly automated air traffic control facilities are also shown. The communication links shown in Figure 1 provide C-band data exchange between the ground control centers and the satellites, and L-band channels for signals between satellites and aircraft. The same satellite constellation used for aircraft surveillance and data link communication can also provide signals for aircraft navigation.

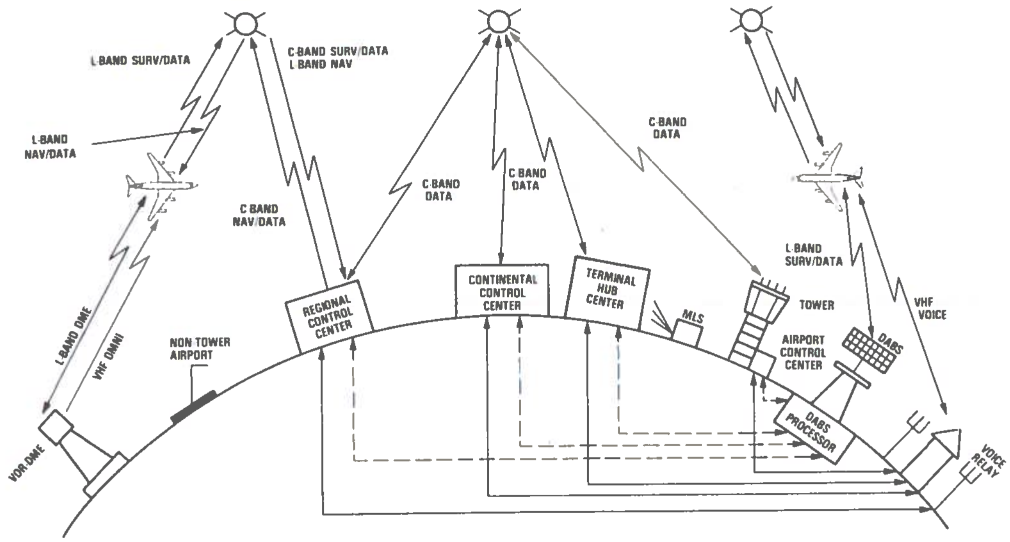

Figure 1. AATMS Surveillance, Navigation, and Communication Concept

Certain research and development efforts are required to support system specification decisions in the early 1980's. This provides the lead time necessary if a modified system concept is to be implemented by the 1990's.[4] Such near term research and exploratory development, augmenting ongoing FAA programs, are required in the areas of satellite surveillance, communication and navigation, compatible avionics, facility centralization, control techniques and automation. The system level aspects of satellites and facility centralization are relatively well understood, so that research and development in these areas can be oriented more toward selective engineering designs and the broader, but critical, economic and operational feasibility questions. For example, technical advancements are required if the low cost avionics necessary for feasible system implementation are to be provided. Such advancements are also required to provide high reliability equipment, and mechanization alternatives to determine acceptable avionics configurations. Study efforts on control techniques will also follow predictable lines of inquiry. The hardware and software aspects of computer technology are well understood, but the application of this technology to the management of the air traffic system will require additional research and development. In particular the relative roles that men and machines would assume in an automated system, the interfaces between men and machines, and the economic feasibility of high levels of automation must be determined. Automation is particularly important since it holds promise of high payoff in terms of either lower operating costs or holding the cost line while meeting increased traffic demands. The primary means for accomplishing this is to improve the productivity of air traffic management personnel which, in turn, will reduce the labor-intensiveness of the system.

Study Description and Results

The existing or Third Generation Air Traffic Control System is currently being extensively modified to keep pace with expanding requirements and, late in this decade, will result in the so-called Upgraded Third Generation System. The improvements to the present system include nine major elements: Intermittent Positive Control, Discrete Address Beacon System, Flight Service Station Automation, Upgraded En Route and Terminal Automation, Airport Surface Traffic Control, Wake Vortex Avoidance Systems, Area Navigation, Microwave Landing Systems, and Aeronautical Oceanic Satellites.[2] These features will improve the system and enable it to handle the forecast traffic loads in an effective manner at least into the late 1980's.

In looking beyond the 1980's, the Advanced Air Traffic Management System Study was concerned with formulating a system concept that could supplant the Upgraded Third Generation System. Consequently, as part of this Study, a Baseline System comprised of the above nine major elements as well as portions of the present system was projected as a point of departure for the AATMS Study. This Baseline System, considered the in-being system for the year 1982, incorporated 106 DABS sites, 1,100 VOR-DME sites, 1,100 VHF voice communication outlets, 20 Air Route Traffic Control Centers, 492 Towers, 407 automated radar terminal systems, deployment of the Microwave Landing System, Flight Service Station automation and other general automation enhancements.

Based on evolution from the Baseline System, the AATMS Study considered various concepts for a system of the 1990's. Figure 2 shows the structure of the AATMS Study, indicating the major system-level studies that were carried out and the contract resources that supported the Transportation Systems Center in the Study. The Study had three basic phases. The first phase was the Concept Formulation or "clean sheet of paper" phase in which feasible concept

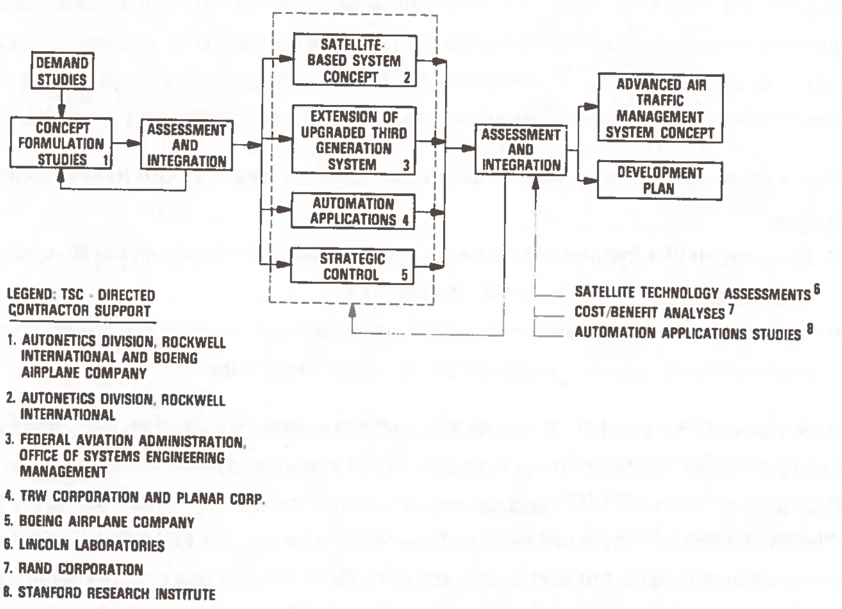

Figure 2. Advanced Air Traffic Management System Study Elements

alternatives were considered without imposing the traditional constraint of evolutionary transition from the in-being system. These studies, originally based upon demand estimates made by the Air Traffic Control Advisory Committee and later by refined estimates made by the Transportation Systems Center, considered the relative merits of ground, space, and airborne sensor systems and traffic control techniques for operations in the conterminous United States and contiguous oceanic airspace.[5,6] These alternative concepts were assessed in terms of capacity, safety, adaptability, technical risk, cost, compatibility, and schedule. After assessment and integration of the results, the following guidelines were used in subsequent system considerations and work in the other study phases:

- Continuation of the current philosophy of ground-based control of air traffic, modified by centralized and more extensive pre-planning of flights in regions of high traffic density.
- Centralization of the current distributed data processing network into two or three facilities.
- Use of satellites over the conterminous United States as the primary mechanization for surveillance, navigation, and communications, operating in conjunction with functionally integrated avionics in user aircraft.

In arriving at these guidelines no advantage was seen in abandoning the existing philosophy of centralized ground-based air traffic management. Further, control facility centralization offered the possibility of significant cost savings by reducing the labor-intensive aspects of the ATC system; savings augmented by the use of satellites which provide communication links at less cost than equivalent ground-based links.[7] In addition, satellites provide universal coverage over the area of interest, the conterminous United States.

In the second phase of the Study, shown in the middle of Figure 2, the foregoing guidelines led to the definition of a satellite-based system concept, including a plan to transition from the Upgraded Third Generation System.[7,8] As an alternative to such an All-Satellite System, an extension of the Upgraded Third Generation System into the projected environment of the 1990's was also defined: namely, the Extended Upgraded Third Generation System.[9] In the final Assessment and Integration phase of the Study these two system mechanization concepts were compared and the best features of each were used in determining the final AATMS mechanization concept. Since these alternatives were judged to be comparable in terms of performance (accuracy and functional capability), costs of facilities, equipment, operations and maintenance became determining factors in selecting the AATMS mechanization concept.

In addition to these system mechanization studies, two specific operational studies were conducted during the second Study phase.[10,11,12]

a) Investigation of automation levels beyond incremental improvement to the National Airspace System/Automated Radar Terminal System (NAS/ARTS).
b) Conceptual development of Strategic Control, a technique for use in high traffic density airspace, and characterized by aircraft flying pre-planned, conflict-free routes.

From these study efforts a specific Advanced Air Traffic Management System concept emerged. A concept derived from an evolutionary extension of the Upgraded Third Generation System, it builds on that system's equipment, facilities, and subsystems. As more fully explained and rationalized later in this Study Summary, Flow Control, Intermittent Positive Control, Metering and Spacing, Separation Assurance and Strategic Control are important techniques used in the concept to assist and control aircraft traffic flow. The concept employs highly centralized facilities to provide both control and flight information/assistance services. High levels of automation are used to minimize costs and to permit operators to serve as system managers, acting principally to resolve unusual control situations.

Specifically, the Advanced Air Traffic Management System concept resulting from the Study is characterized by the following:

- A constellation of satellites over the continental United States and contiguous oceanic regions for surveillance, navigation, and data link communications.
- Use of the Discrete Address Beacon System (DABS) in high density airspace regions to obtain aircraft location and identification information and to provide data link communications with aircraft.
- Continued use of the existing ground-based, very-high-frequency (VHF) communications network.
- Precision approach and landing guidance with Microwave Landing Systems and Instrument Landing System equipment.
- Centralized control facilities characterized by three en route centers, twenty terminal-hub control centers, and about 500 airport control centers. The remote control of traffic at some secondary airports will be improved and expanded.
- High levels of automation, with approximately 70% of the tasks being automated, thus permitting air traffic personnel to be more effective and efficient in the management of air traffic since machines carry out more of the routine functions.
- Flight planning, through the use of Strategic Control techniques, to augment the Upgraded Third Generation System technqiues of Flow Control, Metering and Spacing, and Separation Assurance.

DABS and the VHF communication networks not only fill AATMS functional requirements, but also conform to the idea of an evolutionary system. The ATCAC recommendation concerning universal coverage is met by the use of satellites, while system capacity and safety concerns are augmented by techniques such as Strategic Control, in conjunction with increased terminal area navigational capabilities resulting from Microwave Instrument Landing Systems.

The centralization of control facilities as well as the increased levels of automation can provide major cost savings by constraining the continued growth in the number of required air traffic personnel in the face of increasing demands for air traffic services. These savings are expected to be additionally increased by using satellites for interfacility communications and reducing intersite communications dependence on costly ground-based equipment.

Achieving the benefits projected for the Advanced Air Traffic Management System, however, will require additional research and development effort. These activities, supplementing the present FAA Engineering and Development Program, were identified in the final phase of the AATMS Study and are discussed later in this Summary. Basically the research and development activities involve design studies and experiments for satellite-based systems for CONUS air traffic control, continued development of the Strategic Control Concept to enhance system capacity and safety, and extensive research and exploratory development into the introduction of high levels of automation into the air traffic system.

Discussion of Study Results and System Benefits

Current limitations in air traffic control system capacity directly due to the communications, navigation, surveillance or ground control systems should be resolved with the successful implementation of the Upgraded Third Generation System. In addition, it appears that Intermittent Positive Control will significantly reduce the potential for mid-air collisions. Development of a system allowing avoidance of dangerous wake vortices will allow safe reduction of aircraft separations in terminal areas, with resulting increased landing rates.

The demands on the system due to air traffic are expected to continue to grow in the 1980-90 period.[3] Air transportation system capacity in the 1990 time period will probably be limited by both the air traffic control system and the ability of major hub airports to handle traffic if no significant changes are made. The peak landing and takeoff rates will depend on the number and configuration of the available runways, runway and taxiway designs, weather, and aircraft traffic spacing constraints. Although one of the objectives of the Study was to assess the air traffic control system capacity in the 1990's, the Study was not defined to address the airport constraints. The Study concluded that the surveillance, navigation, and control elements of all the system concepts considered could be designed so that they do not constrain that inherent capacity.

The AATMS Study, in its final stages, considered two system concepts; the Extended Upgraded Third Generation System and an All-Satellite System. Both offered a number of attractive advantages and the AATMS Concept is a synthesis of the best aspects of the two. The AATMS concept mechanization elements for the surveillance, navigation and communication subsystems, include DABS, satellites, VOR, the existing communications net and the Microwave Instrument Landing Systems. The AATMS control concept derives from that projected for the Upgraded Third Generation System; namely, Flow Control, Metering and Spacing and Separation Assurance Techniques, and from a higher level control concept, Strategic Control. The automation features concerning level of automation and facility configuration result from generic studies that are not dependent on specific hardware configurations and are, therefore, applicable to each advanced air traffic management system concept alternative considered.

The application of advanced automation techniques for controlling aircraft holds high potential for reducing system operating costs. In the area of system operating and maintenance costs, the controller workforce is by far the dominating item, representing, in 1973, about 43% of the National Airspace System annual operating and maintenance costs.[13] The Federal Aviation Administration is presently evaluating state-of-the art aids to increase controller productivity. Further research into decreasing the controller's involvement in "tactical" control of air traffic, modifying his function to one of system manager, should also be pursued. Current findings indicate that an optimum division of responsibility between the controller and machines might lead to automating about 70% of air traffic management tasks in the system.[10] This is a significant change from the present labor-intensive system which has only about 20% of the tasks automated, and the projected Baseline System that would have about 35% of the tasks automated.

The AATMS Automation Study considered automated system operations and the payoffs of high levels of automation. The potential annual savings in 1995 with a 70% level of automation (70% of the system tasks are performed by machine) appears to be in the range of $600 to $800 million in contrast to a hypothetical capability of continuing the present (Third Generation) concept of labor-intensive air traffic control to meet projected 1995 air traffic demand.[3,7,9,10] More realistically, if the automation techniques associated with the 35% level of automation assumed in the 1982 Baseline System of the AATMS Study are continued into the 1995 timeframe, the potential annual savings of the AATMS Concept (measured against the Baseline System) would be about $200 million. The design of computer hardware and software systems to achieve these payoffs was not considered in depth in this Study. The present FAA development program addresses some of these problems.

The AATMS Concept also includes augmenting system management in high density airspace with Strategic Control Techniques, under which aircraft fly preplanned, conflict-free routes on a strict time schedule, as illustrated in Figure 3 for the high density terminal application. Strategic Control promises improved airspace utilization and arrival time control which, in conjunction with the higher precision terminal control provided by Microwave Instrument Approach

Landing Guidance Systems and the Wake Vortex Avoidance System, will lead to increased airport capacities. Strategic Control was selected as an alternative to currently planned metering and spacing techniques in high density airspace because, although functionally equivalent, it offers a reduction in both air-ground communications and pilot and controller workloads. It also leads to more efficient airspace utilization and, when teamed with higher precision terminal control, to increases in airport capacities. Strategic Control minimizes the time dispersion of aircraft, a way of saying that it magnages their progress over many paths to arrive at some point such as a runway threshold in an orderly, scheduled fashion. Time dispersion reduction means more aricraft can be safely handled in a given time. This means

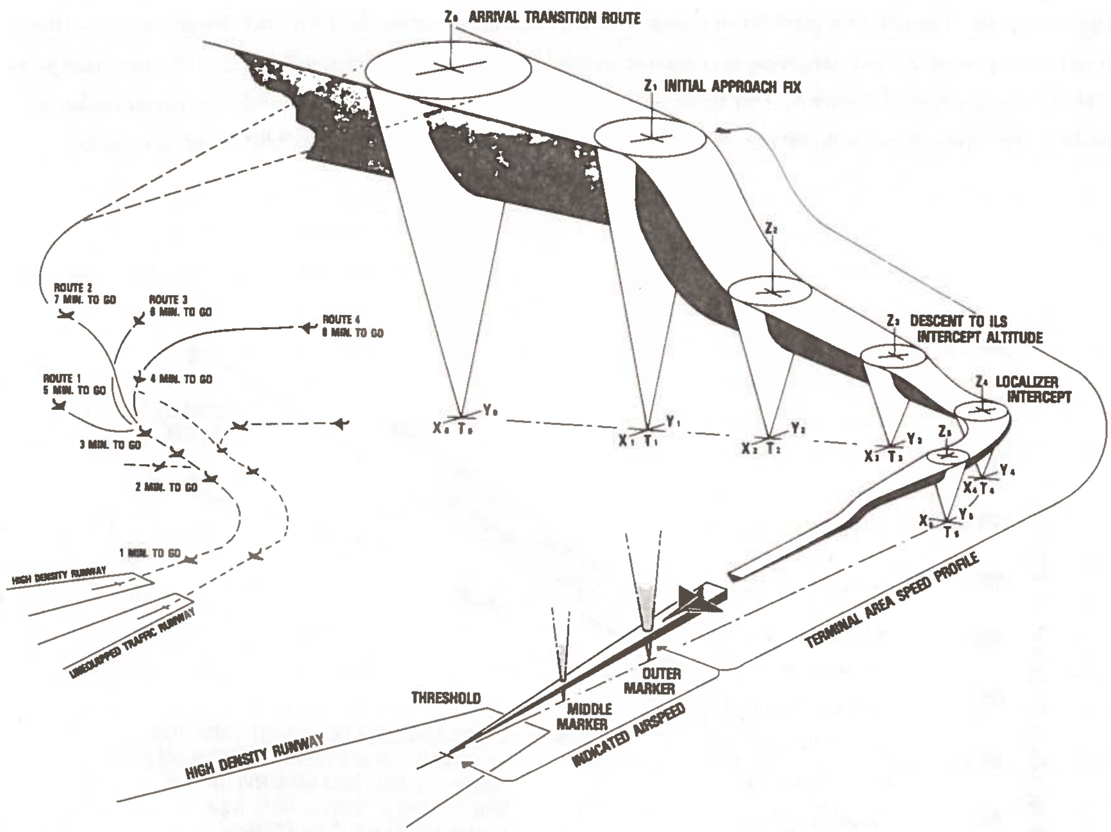

Figure 3. Strategic Control Arrival Trajectory

fewer delays for a given demand level. The benefits of Strategic Control in reducing delays during IFR operations were estimated for one high density terminal (Los Angeles) as an example. Relative to the Baseline System's Metering and Spacing control concept, Strategic Control combined with an effective Wake Vortex Avoidance System appears to have potential for reducing the daily average number of delay minutes by a factor of ten.[12]

The study also indicates that centralization of control facilities for en route air traffic holds potential for reducing operations and maintenance costs over those of the current distributed facility network. Such savings result from equipment sharing, reduction in interfacility communication costs, and reduced personnel requirements related to a projected 1995 demand level. These perceived benefits are based upon comparative evaluation of the AATMS Concept with the Baseline System. However, the benefits due to centralized control facility configurations are not unique to just the configuration selected for the AATMS Concept. Centralization cost benefits however may not be achievable independently of the control techniques or the mechanization of the surveillance, navigation, and communication subsystem.

Satellites are a technically feasible and potentially cost-effective method of extending surveillance and data link coverage anticipated for the Upgraded Third Generation System to all airspace, and of providing universally available navigation signals. The potential cumulative savings of using satellites in the selected AATMS Concept for surveillance, data link communication, and navigation as compared to the Extended Upgraded Third Generation System used in the AATMS Study, is shown in Figure 4. This figure shows two cumulative cost curves associated with the surveillance, navigation, and data link communications mechanization elements of the Extended Upgraded Third Generation

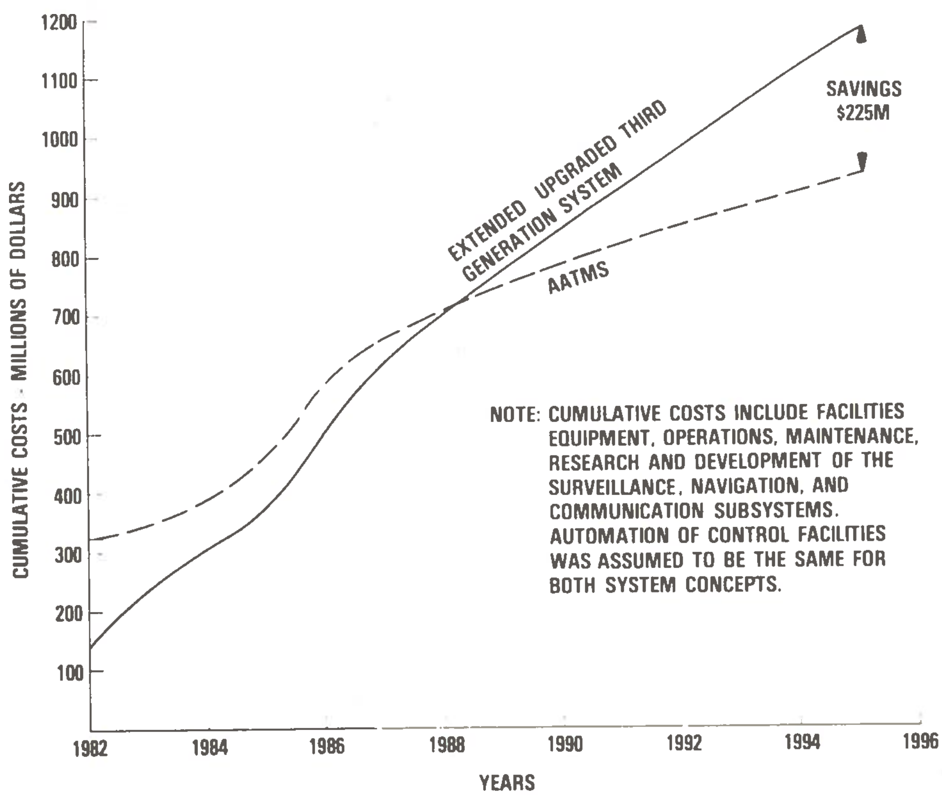

Figure 4. Relative Subsystem Cost - Advanced Air Traffic Management System and Extended Upgraded Third Generation System

System Concept as defined in the AATMS Study, and the selected AATMS Concept. In the Extended Upgraded Third Generation System Concept, the number of DABS sites would be increased from 106 to 291 between 1982 and 1987; 310 special-purpose DABS sites (Mini DABS) are added between 1982 and 1995 to provide air traffic services to airports without towers, nearly all VOR sites are equipped with special DABS-based one-way ranging equipment (Synchro-DABS) and the number of VOR sites is increased to about 1,100 in 1995. In the selected AATMS mechanization concept no DABS or VOR sites are added beyond the 106 and 1025 sites, respectively, projected to be in place in 1982 as part of the Study's Baseline System; 13 to 15 satellites are placed in orbit during the 1985 to 1990 time period, and the number of VOR sites are incrementally reduced, during the transition phase, from 1,025 in 1990 to 300 in 1995. Initial costs reflected at the start of the plotted time period reflect the investment cost, up to 1982, of the surveillance, navigation, and data link communication equipment of the assumed Baseline System, and an estimated $175 million in expenditures for satellite developments and preliminary operational system deployment for the AATMS Concept. Figure 4 indicates that potential cumulative difference in costs would approximate $225 million by 1995. These include potential savings on facilities, equipment, operations, maintenance, research and development costs. Voice communications costs are not included in the curves since they are common to both system concepts. The space shuttle is assumed available to launch the satellite system elements. If, however, the cost savings associated with use of the space shuttle rather than conventional launch vehicles are not realized and full launch costs must be met, system emplacement costs increase. Cost savings would still be worthwhile, although reduced by about $100 million.

The initial deployment costs for the AATMS Satellite-DABS System would be offset, as contrasted to the Extended Upgraded Third Generation System, by operations and maintenance cost savings within about six years after completion of the research and development program and about three years after deployment of the satellites, again assuming existence of the space shuttle.

The Study also considered the user impact of going to a satellite-DABS system and concludes that functionally integrated, satellite-compatible avionics may be less expensive than the present incremental avionics complement, although research and development will be necessary to realize this potential, especially for general aviation aircraft. The satellite-DABS approach has a number of attractive features including the provision of approach service at <u>all</u> airfields, universal surveillance coverage resulting in the provision of separation assurance service without altitude or geographic constraints, and commonality with the oceanic surveillance and communication systems. Another important benefit is the complete coverage provided by satellites; a latent and minimum cost solution to providing extended coverage as demand for service increases or geographically shifts.

In realizing the attendant benefits from using satellites in the air traffic control system there may be some concern as to their vulnerability, especially in terms of their susceptibility to intentional electromagnetic interference or "jamming". The AATMS Study considered this problem and determined that an adequate range of solutions exist to assure little or no service degradation in all but the most severe electromagnetic environments. Future availability of the satellite-based system should, accordingly, be able to exceed that of contemporary equipment.

Strategic Control, by improving airspace utilization and arrival time control, reduces the random nature of airport arrivals. For the air carrier user, this translates into flight time and delay reduction and a consequent major fuel savings benefit. Figure 5 summarizes the benefits to both the general aviation and air carrier users.

USER	SYSTEM CHARACTERISTIC	USER BENEFITS
AIR CARRIER	REDUCED FLIGHT TIME AND DELAYS THROUGH USE OF STRATEGIC CONTROL TECHNIQUES	FUEL SAVINGS TIME SAVINGS
GENERAL AVIATION	TOTAL COVERAGE THROUGH USE OF SATELLITE	INTERMITTENT POSITIVE CONTROL SERVICE WITHOUT ALTITUDE OR GEOGRAPHIC CONSTRAINTS UNIVERSALLY AVAILABLE SERVICE INCLUDING APPROACH AND DEPARTURE AIDS AT ALL REMOTE AIRPORTS

Figure 5. Primary User Benefits of AATMS

Table 1 summarizes the major cost benefits derived from not only the use of satellites in the air traffic control system, but also from the introduction of the projected 70 percent level of automation, a centralized facility configuration, and Strategic Control techniques. Benefits are stated relative to the extension to 1995 of the Baseline System Concept assumed during the AATMS Study. The importance of automation developments is illustrated in this Table since this potential annual operations and maintenance cost saving is larger than that associated with facility centralization and satellites, although it is closely interrelated to these benefits.

TABLE 1. BENEFITS OF AATMS IN 1995 RELATIVE TO THE BASELINE SYSTEM

- $200 MILLION ANNUAL OPERATIONS AND MAINTENANCE COST SAVINGS WITH THE USE OF ADVANCED AUTOMATION TECHNIQUES
- $100 MILLION ANNUAL OPERATIONS AND MAINTENANCE COST SAVINGS DUE TO CONTROL FACILITY CENTRALIZATION
- $50 MILLION ANNUAL OPERATIONS AND MAINTENANCE COST SAVINGS DUE TO SATELLITE/DABS SENSOR CONFIGURATION
- REDUCED SUBSYSTEM FACILITY AND EQUIPMENT (IMPLEMENTATION) COSTS DUE TO UNIVERSAL COVERAGE PROVIDED BY SATELLITES
- INCREASED AIRPORT CAPACITY AND MORE EFFICIENT HIGH DENSITY POSITIVE CONTROL AIRSPACE UTILIZATION DUE TO USE OF STRATEGIC CONTROL IN PLACE OF TACTICAL CONTROL MODES

The time phasing implementation strategy of the introduction of the various features of the AATMS Concept is shown in Figure 6. Based on results of the research and development program associated with the Advanced Air Traffic Management System Program shown in Figure 7, a decision on system implementation could be made by 1984. The ongoing Upgraded Third Generation System program was assumed to have resulted in the Baseline System used in this Study by 1982; 106 DABS sites deployed in high density terminal and en route air space regions, 1,025 VOT sites and about 1,100 VHF voice communication outlets. Between 1985 and 1990, 13 to 15 satellites would be used to supplement the Baseline System to complete the AATMS surveillance, navigation, and data link communications mechanization configuration. Satellite data would be distributed initially on existing interfacility communication lines to the facility having jurisdiction over aircraft flying with satellite-based avionics. Control facility modernization, including upgrading of the facility automation, would begin in 1986. The centralized en route facilities would be operational in 1990, while the Terminal-Hub and Airport Control Centers would continue to be upgraded and brought into operational status. By 1995, all AATMS facilities would be operating. Figure 6 also shows the cost associated with mechanization and facility implementation and operation. An estimated $1,200 million is required between 1982 and 1995 for AATMS implementation. Thereafter, operations and maintenance costs for the mechanization elements and facilities and personnel is estimated at $720 million per year. Estimated savings reflected by this last figure are expected to pay back the implementation costs in about a five-year period.

IMPLEMENTATION/COST ELEMENT	IMPLEMENTATION SCHEDULE (FISCAL YEAR) 82 83 84 85 86 87 88 89 90 91 92 93 94 95	1982-1995 F&E COST [1]	1995 O&M COST [2]
APPROVAL FOR AATMS IMPLEMENTATION BASED ON R&D PROGRAM RESULTS	△ (84)	-	-
MECHANIZATION SUBSYSTEMS			
● SATELLITES	10-15 SATELLITES DEPLOYED △ (85) — △ (90)	$140	$20
● DABS	△ 106 DABS SITES PREVIOUSLY DEPLOYED IN BASELINE SYSTEM	-	5
● VOR NAVIGATION SYSTEM	△ 1025 VOR SITES PREVIOUSLY DEPLOYED IN BASELINE SYSTEM; PHASE DOWN TO 300 VOR SITES △ (91) — △ (95)	-	5
● VHF VOICE COMMUNICATIONS SUBSYSTEM	△ 1100 VHF VOICE COMMUNICATIONS OUTLETS PREVIOUSLY DEPLOYED	-	30
FACILITIES/AUTOMATION/ OPERATING PERSONNEL			
● CONTINENTAL CONTROL CENTER	CONSTRUCTION/ CKECKOUT-1 SITE △ (86) — △ (90)	$30	$20
● REGIONAL CONTROL CENTER	CONSTRUCTION/ CHECKOUT-2 SITES △ (86) — △ (90)	100	60
● TERMINAL-HUB CONTROL CENTERS	△ (86) CONSTRUCTION/CHECKOUT-20 SITES △ (95)	300	330
● AIRPORT CONTROL CENTERS	△ (86) CONSTRUCTION/CHECKOUT- 492 SITES △ (95)	630	250
COST TOTALS		$1200	$720

1. F&E (FACILITIES AND EQUIPMENT) COSTS REFER TO THE INITIAL EXPENSE TO OBTAIN, INSTALL, AND CERTIFY A PARTICULAR SYSTEM ELEMENT. NO DEVELOPMENT COSTS ARE INCLUDED.

2. O&M (OPERATIONS AND MAINTENANCE) COSTS ARE THE RECURRING ANNUAL EXPENSES TO OPERATE, MAINTAIN, RELOCATE, AND MODERNIZE EACH SYSTEM ELEMENT. OPERATING/CONTROL PERSONNEL COSTS APPEAR IN THIS COST FACTOR FOR FACILITIES.

Figure 6. AATMS Implementation Schedule and Costs (Costs in Millions of 1973 Dollars)

There are, of course, hurdles to be crossed prior to implementation of AATMS including the need for research on various elements to more fully determine economic and technical feasibility. The use of satellites for this application, for example, has not been fully demonstrated and such feasibility must be investigated and demonstrated. The determination of methods and levels of automation required for system optimization also calls for research and development efforts, as does the determination of the optimum facility configuration and associated reliability ramifications. Although the Strategic Control Concept promises improved airspace usage on arrival time control, actual methods of optimum implementation must be determined. In particular, better ways of providing accurate route-time navigation to all users must be developed, as well as economically acceptable avionics.

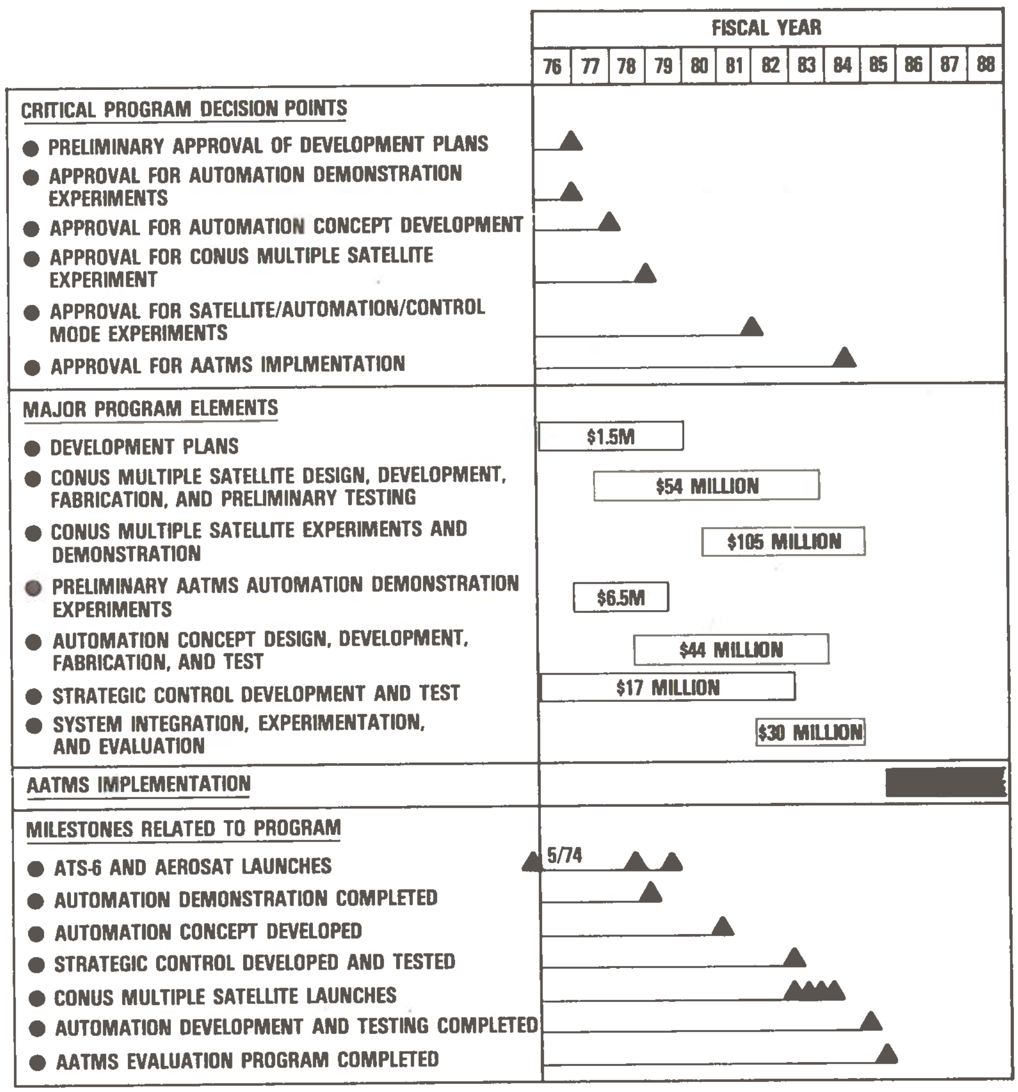

Figure 7. Advanced Air Traffic Management System Development Program

Recommended Research and Development

A system for air traffic management employing satellites, beacons (DABS), centralized control facilities, high levels of automation and Strategic Control techniques is considered attainable. Additional decision-supporting research and development is required in the FY-1976-1984 time period if a Fourth Generation System is to be operational by the mid-1990's.

This research and development would augment current FAA programs and, in addition, would include feasibility studies to further verify certain economic and technical assumptions concerning satellites, automation, control facility centralization, and Strategic Control. In the satellite area, results of ATS-6 and AEROSAT programs will influence what research needs to be done in terms of CONUS satellite applications. Automation and Strategic Control research, discussed below, may require modification as the results of the development program for the Upgraded Third Generation System are obtained in the areas of upgraded automation and Metering and Spacing.

The following research and development efforts are required and are more fully described in the AATMS Study Technical Summary.

(a) Experiments conducted with a network of satellites providing coverage of the conterminous United States are required to verify and further evaluate mechanization approaches for surveillance, navigation and communications over this region, to extend the technology data base to be gotten from currently planned Application Technology Satellite (ATS-6) and the Aeronautical Satellite (AEROSAT) programs, and to validate the economic feasibility of satellites in this application. Development of special avionics compatible with the proposed satellite elements, is also required for purposes of tying the aircraft more directly into the control function. Such avionics development would include airborne data processing equipment and special antennas and transmitters.

(b) Research and exploratory development is required to demonstrate that the high levels of automation incorporated in this system concept are functionally, operationally, and economically achievable. In addition, the development of a data base for the design of an advanced automation system is necessary. To support these efforts functional requirements must be determined and used to define computer systems sizes, architectures and interfaces, software requirements, efficient facility configurations, and appropriate man-machine interfaces. The strategy for coping with failure of the automated and man-operated portions of the system must be demonstrated in order to ensure a high order of safety to all users, and acceptability to the control workforce.

(c) Research is required on better ways to effectively control arrivals at airports, including the provision of combined route (three dimensional) and time navigation capability in high density terminal airspace. Further work to define the Strategic Control Concept, including a comparative assessment with advanced Metering and Spacing techniques, is also necessary.

The following specific research and development should be initiated in FY-1975 and 1976 in order to take advantage of planned and ongoing related programs, and to develop the information on which timely implementation decisions can be made.

- Experiments in conjunction with the currently planned ATS-6 and AEROSAT satellite programs to characterize the aircraft-satellite channel in terms of noise and ionospheric effects, both of which influence system position accuracy. Concurrently, an assessment of the ground-based system and airborne hardware and software required to process satellite-derived signals should be made.

- Development of low-cost, satellite-compatible prototype avionics focusing on advanced, but potentially low-cost components such as surface acoustic wave devices and techniques for improving reliability, e.g., integrated avionics rather than today's multiple element avionics.
- Design studies of system automation including more effective fail-operational concepts, analysis of alternative centralized air traffic control facility designs, feasibility demonstration of automatic air traffic operations, and design analysis and evaluation of advanced air traffic control man-machine interfaces.
- Flight tests under simulated operational conditions to evaluate aircraft capabilities of flying specified routes on pre-set schedules, and the impact that application of such capabilities would have on both the air traffic control system and on users.

Figure 7 summarizes the critical decision points related to the AATMS Program and indicates the timing and costs associated with the various research and development efforts. The total research and development program recommended by this Study is estimated at about $260 million (in 1973 dollars) and spans ten years.

LIST OF REFERENCES

1. Report of the Department of Transportation Air Traffic Control Advisory Committee (ATCAC) (2 Vols.), Department of Transportation, Washington, D. C., December 1969.

2. Concept, Design and Description of the Upgraded Third Generation Air Traffic Control System, FAA-ED-01-1, Department of Transportation, Federal Aviation Administration, Office of Systems Engineering Management, Washington, D. C., August 1972.

3. Air Traffic Demand Estimates for 1995, DOT-TSC-OST-74-18, Department of Transportation, Transportation Systems Center, Cambridge, Massachusetts, estimated publication date December 1974.

4. Civil Aviation Research and Development Policy Study Report, DOT TST-10-4, NASA SP-265, Department of Transportation and National Aeronautics and Space Administration, Washington, D. C., March 1971.

5. Fourth Generation Air Traffic Control Study, (4 Vols.), DOT-TSC-304-1, North American Rockwell Corporation, Autonetics Division, Anaheim, California, June 1972.

6. Study and Concept Formulation of a Fourth Generation Air Traffic Control System, (5 Vols.), DOT-TSC-506-1, Boeing Company, Commercial Airplane Group, Renton, Washington, April 1972.

7. Concept for a Satellite-Based Advanced Air Traffic Management System, (10 Vols.), Report No. DOT-TSC-OST-73-29, Rockwell International Corporation, Autonetics Division, Anaheim, California, 1974.

8. Technical Assessment of Satellites for CONUS Air Traffic Control, (4 Vols.), Report No. DOT-TSC-RA-3-8-5; Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Massachusetts, January 1974.

9. An Advanced Air Traffic Management Concept Based on Extensions of the Upgraded Third Generation ATC System, Report FAA-EM-73-10A., by The Mitre Corporation, Department of Transportation, Federal Aviation Administration, Washington, D. C., March 1974.

10. Automation Applications in an Advanced Air Traffic Management System, (10 Vols.), Report No. DOT-TSC-OST-74-14, TRW Systems Group, McLean, Virginia, August 1974.

11. Systems Engineering Support for Automation in Advanced Air Traffic Management, Stanford Research Institute, Menlo Park, California, April 1974.

12. Strategic Control Algorithm Development, DOT-TSC-OST-74-3, (4 Vols.), Boeing Commercial Airplane Company, Seattle, Washington, December 1973.

13. The National Aviation System Plan — Ten-Year Plan 1973-1982, Document No. 1000.27, Appendix 2, Department of Transportation, Federal Aviation Administration, Washington, D. C., March 1973.