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CONCEPT FOR A SATELLITE-BASED ADVANCED AIR TRAFFIC MANAGEMENT SYSTEM

Volume VII. System Cost

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16. Abstract

This volume presents estimates of the federal government and user costs for the Satellite-Based Advanced Air Traffic Management System and the supporting rationale. The system configuration is that presented in Volumes II and III. The cost estimates are also based upon the development and transition plans in Volume VI. The costing methodology and procedures used are presented. Cost summaries and detailed cost breakdowns by Research and Development, Facilities and Equipment, and Operations and Maintenance costs for the ground sites and satellites are provided for the federal government costs. Summaries and breakdowns by user class and by purchase, installation, and maintenance costs are provided for the user avionics costs. Various cost analyses are also provided, including the estimated annual expenditures for various transition schedules and comparisons with ground-based ATC systems.

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GLOSSARY

AATMS	Advanced Air Traffic Management System
ACC	Airport Control Center
ADF	Automatic Direction Finder
ADIZ	Air Defense Identification Zone
AGL	Above Ground Level
AMF	Analog Matched Filter
AOPA	Aircraft Owners and Pilots Association
ARINC	Aeronautical Radio, Inc.
ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal System
ATC	Air Traffic Control
ATCAC	Air Traffic Control Advisory Committee
ATCRBS	Air Traffic Control Radar Beacon System
ATCS	Air Traffic Control System
ATM	Air Traffic Management
CA	California
CARD	Civil Aviation Research and Development
CAS	Collision Avoidance System
CCC	Continental Control Center
CNI	Communication Navigation Identification
CNMAC	Critical Near Midair Collisions
COMM	Communications
CONUS	Continental United States
CP	Central Processor
CST	Central Standard Time
CW	Continuous Wave

GLOSSARY (continued)

DABS	Discrete Address Beacon System
DOD	Department of Defense
DOT	Department of Transportation
DME	Distance Measuring Equipment
DNSDP	Defense Navigation Satellite Development Program
DNSS	Defense Navigation Satellite System
ERP	Effective Radiated Power
ESRO	European Satellite Reserach Organization
EST	Eastern Standard Time
ETA	Estimated Time of Arrival
FAA	Federal Aviation Administration
F&E	Facilities and Equipment
FL	Florida
FM	Frequency Modulation
FSS	Flight Service Station
GA	General Aviation
GAATMS	Ground-Based Advanced Air Traffic Management System
GDOP	Geometric Dilution of Precision
GFE	Government Furnished Equipment
IAC	Instantaneous Airborne Count
ICAO	International Civil Aviation Organization
ID	Identification
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions

GLOSSARY (continued)

I/O	Input/Output
IOP	Input Output Processor
IPC	Intermittent Positive Control
IPS	Instructions Per Second
IR	Infrared
JFK	Kennedy International Airport
LA	Los Angeles
LAT	Latitude
LAX	Los Angeles International Airport
LORAN	Long Range Navigation
LOS	Line-of-sight
LRR	Long Range Radar
MIPS	Million Instructions Per Second
MLS	Microwave Landing System
MODEM	Modulator-Demodulator
MSL	Mean Sea Level
MTBF	Mean Time Between Failures
NAFEC	National Aviation Facilities Experimental Center
NAD	North American Datum
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NAV	Navigation
NDB	Non-Directional Radio Beacon
NEF	Noise Exposure Factor
NFCC	National Flow Control Center

GLOSSARY (continued)

NMAC	Near Midair Collisions
NOTAM	Notice to Airmen
NOZ	Normal Operating Zone
NWS	National Weather Service
O&M	Operations and Maintenance
PCA	Positively Controlled Airspace
PIREPS	Pilot Reports
PN	Pseudo-Noise
PPM	Pulse Position Modulation
PWI	Pilot Warning Indicator
RAM	Random Access Memory
RCAG	Remote Control Air-to-Ground Facility (Present System)
RCAGT	Remote Communication Air-Ground Terminal
RCC	Regional Control Center
R&D	Research and Development
RDT&E	Research, Development, Test, and Evaluation
RF	Radio Frequency
RNAV	Area Navigation
ROM	Read-Only Memory
SAATMS	Satellite-Based Advanced Air Traffic Management System
SAMUS	State Space Analysis of Multisensor System
SID	Standard Instrument Departure
S/N	Signal-to-Noise
SNC	Surveillance, Navigation, Communication
STAR	Standard Arrival Routes
STC	Satellite Tracking Center
STOL	Short Takeoff and Landing

GLOSSARY (continued)

TACAN	Tactical Air Navigation
T&E	Test and Evaluation
TCA	Terminal Controlled Airspace
TOA	Time of Arrival
TRACAB	Terminal Radar Approach/Tower Cab
TRACON	Terminal Radar Approach Control
TRSA	Terminal Radar Service Areas
TRW	Thompson Ramo Wooldridge
TSC	Transportation Systems Center
TX	Texas
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOR	Very High Frequency Omni-Directional Range
VORTAC	Very High Frequency Omni-Range TACAN
VVOR	Virtual VOR
2D	Two Dimensional
3D	Three Dimensional
4D	Four Dimensional

1. INTRODUCTION

The purpose of this volume is to present an estimate of the total government and user costs for the SAATMS and the supporting rationale for the estimate. The system and subsystem configurations are those presented and described in detail in Volumes II and III of this report. The cost estimates are also based upon additional material in this report, such as the Development Plan and the Transition Plan (Volume VI).

Determining the cost of a system concept which will not be implemented until the 1980-1995 time frame is difficult. It is not possible at this time to foresee all of the changes in technology, public usage and acceptance, or political action which may occur in the interim. In addition, it is not easy to predict the exact configuration of the in-being system which will be operational at the time implementation of the proposed system concept will begin. Thus, some of the costs presented herein may represent expenditures which will have been funded as part of previous system improvement (i.e., prior to the 1980-1995 time period); thus, the SAATMS costs may be overstated. The converse may also be true; i.e., the costs may be understated if assumed system changes and improvements have not been effected. Nevertheless, the cost estimates presented here can provide a basis for comparisons of the relative costs of different system concepts under consideration as well as a starting point for future planning.

The next section presents a discussion of the costing methodology and procedures used to develop the cost estimates, including a listing of the ground rules and assumptions employed. The succeeding sections present a summary of the total SAATMS costs, the Federal Government costs, the user costs, and a series of system cost comparisons. These comparisons include spreading the costs by year and comparing these costs to the estimated GAATMS costs. The GAATMS configuration used comparison purposes was the one defined in the 1973 version of the FAA 10-year plan.

2. METHODOLOGY

Before presenting the SAATMS cost estimates, a brief discussion of the sources and methods used in arriving at these estimates is in order along with a description of the formats used.

2.1 Objectives

The objective of the costing effort was to arrive at the best estimate of the SAATMS costs consistent with the data and time available. The main effort was oriented to obtaining estimates. Some effort was also devoted to summing and presenting these costs by system functional categories and spreading these costs by time. Additional presentations and tabulations will be available from the results of the Rand Corporation (Ref. 3) cost comparison effort, using their AATMS computerized cost model. The data presented herein are designed to provide the proper inputs to the Rand model. (The references used here appear in Section 9.)

2.2 Cost Data Sources

A number of sources of cost data were used for the SAATMS costing effort. The major sources are listed in Section 9, while others are listed in the notes which accompany the cost tables. The last, but certainly not the least significant, source of data may be termed "engineering judgment" or "engineering experience." Since SAATMS is an "advanced" air traffic system concept, many of the components of the system have no direct, identifiable, commercial or military counterpart. Thus, the costs of such items can only be estimated (1) by consultations with experienced designers and engineers, both in-house and associated with other companies or research organizations, (2) by comparison of the proposed system components with known, available, similar components, and (3) by application of considerable judgment as to the "reasonableness" of the cost estimates.

2.3 Ground Rules

The list of the cost estimating ground rules and assumptions is as follows:

(1) All cost estimates are expressed in 1973 dollars.

(2) Federal Government F&E and O&M costs and user costs are estimated in two ways:

   (a) Assuming current (1973) technology (e.g., off-the-shelf components and/or presently known techniques).

   (b) Assuming any technology advances as projected to the time period the costs would be incurred.

      Note: Since the technology required for the implementation of the SAATMS is currently available, the bulk of the cost estimates were prepared and presented on that basis. Any special cases of technology advance impact on estimated system costs are discussed separately.

(3) All references to years are calendar years.

(4) The "nominal" demand level provided by TSC in January 1973 shall be assumed, i.e., 362,000 total aircraft with 35,000 Instantaneous Airborne Count (IAC).

(5) All cost estimates shall include the "acquisition" or "purchase" cost to the Federal Government or to the user, as applicable.

(6) Large quantity production by several competitive commercial firms is assumed for the user avionics costs.

(7) The user costs (avionics) are only for the minimum equipment required for each class. Additional and/or higher quality equipment for better accuracy, reduced pilot workload, redundancy, operating convenience, etc., are assumed to be user options and are not considered part of the SAATMS basic costs.

(8) The use or adaptation of existing government facilities was assumed, whenever possible, to minimize duplication and total costs.

(9) Where given site equipment, facilities, or services are common to or shared by two or more functions (i.e., surveillance, navigation, communication, or control), a total cost estimate was provided and this cost allocated to the individual functions in order to arrive at the Federal Government costs by functions.

(10) The costs of in-being facilities, equipment, and/or operations, including those now planned for implementation before or at the same time as the SAATMS, are excluded from the SAATMS costs.

(11) Equipment replacement costs are O&M costs.

(12) No estimates are included for Flight Service Stations, the FAA Academy, Airport Improvements, Airport Operations (other than for controllers and directly related maintenance) Flight Standards, NAFEC, FAA aircraft, mobile facilities and housing, and Weather Data Acquisition Systems.

2.4 Cost Element Diagram

The TSC AATMS Data Formats Specification (Ref. 10) defines the major cost categories and other cost-related data required of the SAATMS costing effort. The specification also defines the major cost elements to be used. These cost elements and categories are those required by the Rand cost model previously mentioned (see Ref. 3). Based upon these requirements, an overall cost diagram was developed. Figure 2.4-1 presents the SAATMS cost diagram. The diagram defines the relationship of the various cost categories and cost elements which add to the total system cost. The diagram was followed in developing the outline and presentation formats for the detailed and summary cost estimates.

SAATMS COST
ELEMENT DIAGRAM

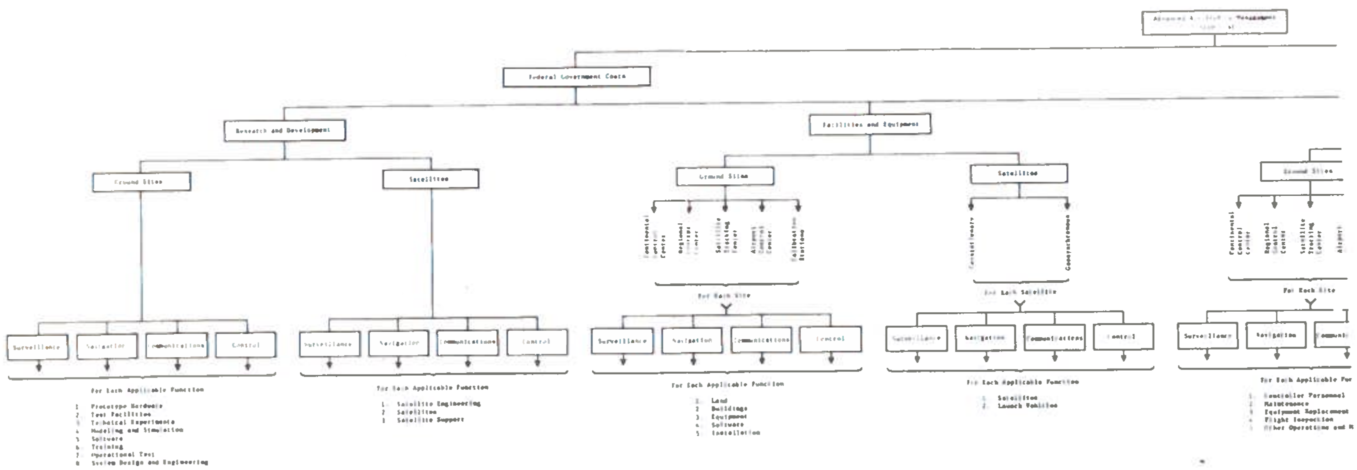


Figure 2.4-1. SAATMS Cost Element Diagram

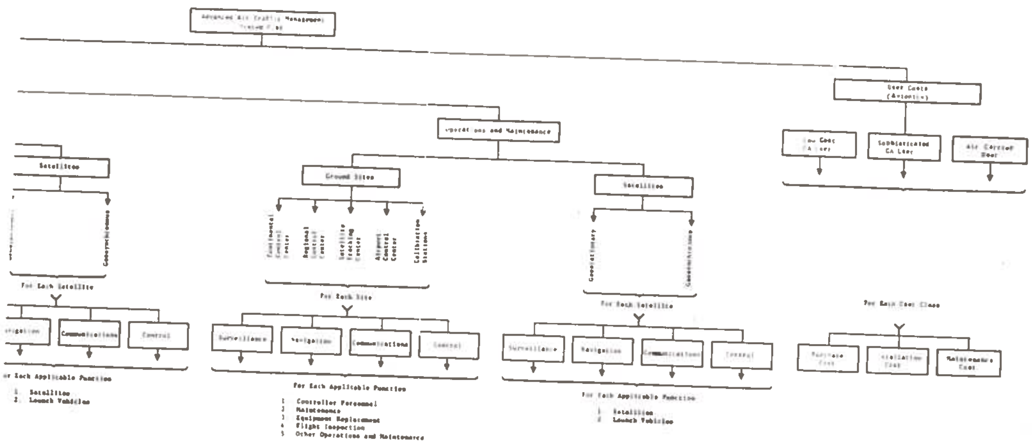


Figure 2.4-1. SAATMS Cost Element Diagram (Continued)

2.5 Presentation Formats

The philosophy adopted for the presentation of the SAATMS cost data had as its goal the requirement that each cost table be independent and able to stand alone as much as possible. To this end, except for general introductory remarks, there is a minimum of text accompanying the cost summaries and tabulations. Instead, all required notes, remarks, and references which pertain to a given table are included with the table and keyed directly to the appropriate item in the table. Furthermore, the tables refer to each other when required so that data or totals obtained from another table are so indicated. The sequences of tables follow the relationships shown in Fig. 2.4-1.

3. SYSTEM COST SUMMARY

Table 3-1 presents a summary of the total SAATMS costs. The O&M costs are shown for 10 full years of operation, assuming that all transition and initial acquisition have been accomplished and that the demand remains constant at the 1995 level. It should be noted that the Federal Government O&M costs as well as the user maintenance costs include the equipment replacement costs. The equipment replacement costs represent the costs of replacing worn-out equipment at the end of the equipment operational life (typically 7 to 10 years) during the operational life of the system. Such replacement is necessary to maintain the initial operational capability of the system and is in addition to the costs associated with routine maintenance and repair. This treatment differs from that used in the FAA 10-year plan (Ref. 2), where the costs of procuring replacement equipment are typically included under the annual F&E budgets. It is, however, in agreement with the approach used by Rand Corporation in connection with their AATMS cost study.

Table 3-1. SAATMS Cost Summary

	Annual Costs ($ Millions)	10-Year Total ($ Millions)
Federal Government Costs		
Research and Development		178.0
Facilities and Equipment		926.2
Operations and Maintenance*	599.9	5,998.9
TOTAL		7,103.1
User Costs**		
Low Cost General Aviation		
Purchase and Installation		906.3
Maintenance*	150.0	1,500.0
Sophisticated General Aviation		
Purchase and Installation		1,351.5
Maintenance*	225.3	2,253.0
Aircarrier		
Purchase and Installation		270.5
Maintenance	45.1	451.0
TOTAL		6,732.3
GRAND TOTAL		13,835.4

*Includes equipment replacement costs. Note that these are the 1995 costs. They will be subject to change after 1995 with changes in the demand levels.
**Civil aviation only; military avionics will be equivalent to the aircarrier equipment.

4. FEDERAL GOVERNMENT COSTS

The SAATMS Federal Government costs are divided into three parts: The Research and Development (R&D) costs, the Facilities and Equipment (F&E) costs, and the Operations and Maintenance (O&M) costs as diagrammed in Fig. 2.4-1. A summary of the Federal Government costs is included in Table 3-1.

The following paragraphs present summaries of each of the Federal Government costs (R&D, F&E, and O&M). The detailed cost estimates tabulated by SAATMS functions (surveillance, navigation, communication, and control), site (ground sites and satellites), or cost element as well as the supporting notes and tables are provided following the summaries.

4.1 Research and Development Costs

The RDT&E plan (described in Volume VI) presents a detailed discussion of the necessary RDT&E tasks, task descriptions, and time schedules. The cost estimates for these RDT&E activities are presented in Table 4.1-1.

The RDT&E costs are defined as all those costs required to perform the RDT&E tasks which result in the final definition of the desired system. The results of the RDT&E effort would typically be the detailed procurement specifications, designs, operational procedures, and analyses required to purchase, install, and begin operation of the system. The actual purchase, installation, and operation costs are considered F&E or O&M costs.

It should be noted, however, that the RDT&E costs shown in Table 4.1-1 are only those Department of Transportation (DOT) costs directly related to the SAATMS RDT&E effort. By integrating the SAATMS test objectives with those satellite tests planned by DOD/NASA and employing an overall systems management approach to the subsystem and system developments, substantial cost savings can be effected.

Coordinating the SAATMS satellite tests with those planned by ATS-F, Aerosat, and DNSDP will obviate the need for special SAATMS satellite research launches. All SAATMS techniques and operational concepts can be evaluated using these programs. After these initial evaluations are performed and the SAATMS subsystems optimized, a SAATMS-specific satellite constellation can be launched and pre-operational tests performed.

With care, the equipment, subsystems, and systems used during the pre-operational testing will be suitable for use during the initial SAATMS implementation and transition phase. Thus, the satellites and the initial versions of the CCC, RCC, and ACC used during the RDT&E phase will be employed during transition. This permits a sharing of costs between RDT&E and F&E.

Utilizing this approach, the DOT costs directly related to RDT&E, which are not later recoverable, amount to $178 million, as shown in Table 4.1-1. The total RDT&E program will effectively cost over $570 million, as shown in Table 4.1-2.

Table 4.1-1. Summary of Federal Government R&D Costs

	$ Millions				
	SURV	NAV	COMM	Control	Total
Ground Sites					
Prototype Hardware	8	4	8	5	25
Test Facilities	*	*	*	*	*
Technical Experiments	5	3	4	6	18
Modeling and Simulation	3	3	2	2	10
Software	2	1	0	3	6
Training	2	1	2	1	6
Operational Test	5	5	5	10	25
System Design and Engineering	10	5	10	8	33
Total	35	22	31	35	123
Satellites					
Satellite Engineering	3	3	4	0	10
Satellites	10	10	11	0	31
Satellite Support	5	4	5	0	14
Total	18	17	20	0	55
Total R&D Costs	53	39	51	35	178
*Included in the other categories					

Table 4.1-2. Total SAATMS RDT&E Costs

SAATMS RDT&E	$178 Million
DOD/NASA Planned Satellite Test Program ATS-F Aerosat DNSDP	$224 Million (If included in SAATMS RDT&E)
F&E Cost Satellites Facilities	$170 Million (If included in SAATMS RDT&E)
Total	$572 Million

4.2 Facilities and Equipment Costs

This section presents the estimated SAATMS Federal Government F&E costs. The F&E costs are defined as all those costs necessary to acquire the system and bring it to initial operating capability. The F&E costs are, therefore, "one-time-only" costs, although the actual expenditures will be spread over a number of years. F&E costs will also be incurred while some R&D tasks are still in progress and while some portions of the system have reached operational status.

By the definitions used here, the F&E costs do not include replacing equipment (with identical or equivalent equipment) at the end of its operating life. Such costs are considered O&M costs and are included in the next section.

4.2.1 Summary

Table 4.2-1 presents the summary of the Federal Government F&E costs. The entries in this table are obtained from the detailed ground site and satellite cost tables where the particulars of the individual cost estimates and accompanying explanations are presented.

TABLE 4.2-1. SUMMARY OF FEDERAL GOVERNMENT F AND E COSTS

Site	Number of Sites	Cost Element	$ Thousands				
			SURV	NAV	COMM	Control	Total
CCC	1	Land	10	0	10	30	50
		Building	3,000	0	3,000	9,000	15,000
		Equipment	13,870	2,084	7,383	79,618	102,955
		Software	3,608	328	14,760	14,104	32,800
		Installation and Checkout	3,015	453	1,605	17,305	22,378
		Total	23,503	2,865	26,758	120,057	173,183
RCC	2	Land	20	5	30	45	100
		Building	6,000	1,500	9,000	13,500	30,000
		Equipment	21,236	2,800	13,474	141,104	178,614
		Software	2,880	192	9,600	6,528	19,200
		Installation and Checkout	4,616	608	2,928	30,674	38,826
		Total	34,752	5,105	35,032	191,851	266,740
STC	7	Land	70	0	0	0	70
		Building	245	0	0	0	245
		Equipment	616	0	0	0	616
		Software	0	0	0	0	0
		Installation and Checkout	161	0	0	0	161
		Total	1,092	0	0	0	1,092

TABLE 4.2-1. SUMMARY OF FEDERAL GOVERNMENT F AND E COSTS (Continued)

Site	Number of Sites	Cost Element	$ Thousands				
			SURV	NAV	COMM	Control	Total
ACC	700	Land	0	0	0	0	0
		Building	8,680	0	17,360	17,360	43,400
		Equipment	37,807	0	109,480	86,250	233,537
		Software	0	0	0	17,500	17,500
		Installation and Checkout	8,220	0	23,800	18,750	50,770
		Total	54,707	0	150,640	139,860	345,207
Calibration Stations	50	Land	100	0	0	0	100
		Building	1,200	0	0	0	1,200
		Equipment	519	0	0	0	519
		Software	0	0	0	0	0
		Installation and Checkout	113	0	0	0	113
		Total	1,932	0	0	0	1,932
		Total Ground Sites	115,986	7,970	212,430	451,768	788,154
Geo-Stationary Satellites	6	Satellites	3,244	1,622	27,574		32,440
		Launch Vehicles	5,600	2,800	47,600		56,000
		Total	8,844	4,422	75,174		88,440

TABLE 4.2-1. SUMMARY OF FEDERAL GOVERNMENT F AND E COSTS (Continued)

Site	Number of Sites	Cost Element	$ Thousands				
			SURV	NAV	COMM	Control	Total
Geo-Synchronous Satellites	9	Satellites	4,324	1,081	16,215		21,620
		Launch Vehicles	5,600	1,400	21,000		28,000
		Total	9,924	2,481	37,215		49,620
		Total Satellites	18,768	6,903	112,389	0	138,060
		Total System F&E	134,754	14,873	324,819	451,768	926,214

4.2.2 Ground Sites

The detailed F&E cost estimates for the ground sites are presented by site and by function as follows:

Continental Control Center: Table 4.2-2

Regional Control Centers: Table 4.2-3

Satellite Tracking Centers: Table 4.2-4

Airport Control Centers: Table 4.2-5

Calibration Stations: Table 4.2-6

The notes accompanying each table give the source of the cost estimate and any additional reference information or explanation. The references are listed in Section 9. Supplementary F&E information is presented in Tables 4.2-7 through 4.2-22.

4.2.3 Satellites

The detailed F&E cost estimates for the satellites are presented in Table 4.2-23.

The satellite costs were obtained by the MITRE cost estimating relationship (Ref. 11). The estimates of the satellite weights are given in Table 4.2-24.

TABLE 4.2-2. FEDERAL GOVERNMENT FACILITIES AND EQUIPMENT COSTS - CONTINENTAL CONTROL CENTER

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation				
			Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)		
LAND	Purchase Cost				0	0	1					
	Site Selection and Survey				0	0	1					
	Site Preparation				50	50	2					
	Total Land Cost					50						
	TOTAL LAND COST ALLOCATED TO EACH FUNCTION	1				10	3				0	3
BUILDING	Engineering and Documentation				1800	1800	4					
	Construction Cost				10000	10000	4					
	Power:											
	Conventional				600	600	4					
	Emergency				100	100	4					
	Environmental Controls:											
	Heating				50	50	5					
	Air Conditioning				100	100	4					
	Miscellaneous Facilities:											
	Safety/Sanitation				50	50	5					
	Fencing/Security				50	50	5					
	Cabling and Miscellaneous Structures				100	100	5					
	Administrative				50	50	5					
	Employee Areas				50	50	5					
	Maintenance Areas				100	100	5					
	Internal Communications				500	500	4					
	Other Building Costs:											
	Architectural/ Supervision				300	300	4					
	Transportation of Materials				50	50	4					
	Inspection and Checkout				100	100	5					
	Miscellaneous				1000	1000	4					
	Total Building Costs				15000	15000						
	TOTAL BUILDING COST ALLOCATED TO THIS FUNCTION	1				3000	3				0	3

TABLE 4.2-2. (CONTINUED)

Communication					Control Processing					Total ($×K)
Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	
Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
			10	3				30	3	50
			3000	3				9000	3	15000

TABLE 4.2-2. (CONTINUED)

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation				
			Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)		
EQUIPMENT	Surveillance Signal Receiver				1020	1020	6					
	Antennas				177	177	12					
	Digital Data Receiver (Ground-to-Ground)											
	Digital Data Transmitter (Ground-to-Ground)											
	Digital Data Receiver (Aircraft-to-Ground)											
	Digital Data Transmitter (Ground-to-Aircraft)											
	Voice Receiver											
	Voice Transmitter											
	Displays and Controls											
	Computer/Processor/ Memories				10864	10864	7			1811	1811	7
	Initial Spares				603	603	8			91	91	8
	Special Test and Maintenance Equipment				603	603	8			91	91	8
	Documentation and Miscellaneous				603	603	8			91	91	8
	Total Equipment Cost	1			13870	13870				2084	2084	
SOFT-WARE	Programming				3608	3608	11			328	328	11
	Total Software Costs	1			3608	3608				328	328	

TABLE 4.2-2. (CONTINUED)

		Communication					Control Processing					
		Each Site					Each Site					
Total Cost ($×K)	Notes	Unit Cost ($×K)	No. of Units	Site Cost ($×K)	Total Cost ($×K)	Notes	Unit Cost ($×K)	No. of Units	Site Cost ($×K)	Total Cost ($×K)	Notes	Total ($×K)
				412	412	12						
				144	144	13						
				170	170	14						
				47	47	15						
				50	50	16						
				90	90	17						
				75	75	18						
							125	409	51125	51125	19	
1811	7			5432	5432	7			18107	18107	7	
91	8			321	321	8			3462	3462	8	
91	8			321	321	8			3462	3462	8	
91	8			321	321	8			3462	3462	8	
2084				7383	7383				79618	79618		102,955
328	11			14760	14760	11			14104	14104	11	
328				14760	14760				14104	14104		32,800

TABLE 4.2-2. (CONTINUED)

Cost Element	Cost Subelements	No. of Sites	Surveillance: Each Site: Unit Cost ($×K)	Surveillance: Each Site: No. of Units	Surveillance: Each Site: Site Cost ($×K)	Surveillance: Total Cost ($×K)	Surveillance: Notes	Navigation: Each Site: Unit Cost ($×K)	Navigation: Each Site: No. of Units	Navigation: Each Site: Site Cost ($×K)	Navigation: Total Cost ($×K)	Navigation: Notes	Communication: Each Site: Unit Cost ($×K)	Communication: Each Site: No. of Units	Communication: Each Site: Site Cost ($×K)	Communication: Total Cost ($×K)	Communication: Notes	Control Processing: Each Site: Unit Cost ($×K)	Control Processing: Each Site: No. of Units	Control Processing: Each Site: Site Cost ($×K)	Control Processing: Total Cost ($×K)	Control Processing: Notes	Total ($×K)
INSTALLATION AND CHECKOUT	Equipment Shipping and Transportation																						
	Surveillance Signal Receiver				60	60	8																
	Communications Equipment														49	49	8						
	Displays and Controls																			2555	2555	8	
	Computer/Processor/ Memories				543	543	8			91	91	8			272	272	8			905	905	8	
	Installation and Checkout																						
	Surveillance Signal Receiver				240	240	20																
	Communications Equipment														198	198	20						
	Displays and Controls																			10225	10225	20	
	Computer/Processor/ Memories				2172	2172	20			362	362	20			1086	1086	20			3620	3620	20	
	Total Installation and Checkout Costs	1			3015	3015				453	453				1605	1605				17305	17305		22378
	TOTALS				23503	23503				2865	2865				26758	26758				120057	120057		173183

Notes:

1. The CCC is assumed to be located on government land, probably in or near an existing ARTCC. Approximately 15 acres will be required for the CCC, including 2.5 acres for the buildings and peripherals and 12.5 acres for parking, assuming 150 cars per acre, negligible mass-transit, car-pooling, and 100 percent shift overlap.
2. Estimated from Ref. 1, Table D.2-7, D-16. Includes minor clearing and grading and a short (less than one mile) access road.
3. The facilities and equipment are, for the most part, shared by two or more functions. Accordingly, it is not easy to separate out the portion of the facilities devoted to each particular function. However, the major visible portion of the CCC will be devoted to the operating controls and displays and the related computer systems. Assuming that the administrative and "overhead" facilities follow proportionally the facilities requirements for the four functions. The following facilities distribution was considered reasonable:

Surveillance	20%
Navigation	0%
Communications	20%
Control Processing	60%

4. Adapted from Ref. 1, Table D.2-7, D-16, where a CCC is taken as equivalent to, or more complex than, the satellite control center of the reference.

TABLE 4.2-2. (CONTINUED)

5. This amount is considered reasonable for a facility of this size.

6. See Table 4.2-8.

7. The total computer/processor/peripherals cost given in Table 4.2-21 is allocated among the functions as follows:

Surveillance	30%	Communication	15%
Navigation (and Miscellaneous)	5%	Control Processing	50%

This allocation was derived from an analysis of the MIPS identified for the various tasks performed by the computer system, as given in Volume III. By the assumed multi-processor computer design, the MIPS requirements are directly related to the computer hardware requirements.

8. Five percent of the basic equipment cost is the typical allowance each for initial spares, special test and maintenance equipment (delivered), documentation and miscellaneous, and equipment shipping and transportation. See, for example, Ref. 4, page 96-7.

9. This number not used.

10. This number not used.

11. Recent in-house experience with programming for complex, real-time systems has resulted in estimates ranging from $50 to $500 total programming cost per executable instruction, including design and analysis (given the basic requirements and algorithms output from the R&D effort), coding, checkout, documentation, and integration and test resulting in an operating system. The upper figure ($500) is probably too high. It was experienced for an effort involving a small airborne computer with limited storage. The $50 is probably too low, because of the complexity of the SAATMS control processing function, when considering the real-time processing requirement, the enormity of the data transfer that is required, and the executive and control required for the proposed multi-computer configuration. Accordingly, a figure of $200 per instruction was selected as reasonable for the SAATMS, including design, analysis, coding, checkout, integration, and documentation. Note that the $50 per instruction cost is equivalent to that obtained using the Rand cost model (Ref. 3, Appendix B, pages 86-112). The total number of executable instructions for the CCC is estimated at 164,000, from Volume III. The total software cost is therefore estimated as $32,800,000.

The data in Volume III were also examined to determine the number of instructions identified for each function. The result was as follows:

Surveillance	10.0 K words	Control Processing	38.7 K words
Navigation	0.3 K words	Executive and Overhead	75.0 K words
Communication	40.0 K words		

Assuming the executive and overhead instructions are allocated in proportion to the four functions, the following distribution of the software costs among the four functions was obtained:

Surveillance	11%	Communication	45%
Navigation	1%	Control Processing	43%

12. Table 4.2-7

13. Table 4.2-9

14. Table 4.2-10

15. Table 4.2-11

16. Table 4.2-12

17. Table 4.2-13

18. Table 4.2-14

19. See Table 4.3-7 for the estimate of the number of displays required. A cost of $125,000 per display is estimated. See Ref. 3, page 189.

20. Twenty percent of the basic equipment cost is the typical allowance for installation and checkout cost. See, for example, Ref. 3, page 189.

TABLE 4.2-3. FEDERAL GOVERNMENT FACILITIES AND EQUIPMENT COSTS - REGIONAL CONTROL CENTER

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total ($×K)
			Each Site					Each Site					Each Site					Each Site					
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)	Total Cost ($×K)	Notes	Unit Cost ($×K)	No. of Units	Site Cost ($×K)	Total Cost ($×K)	Notes	Unit Cost ($×K)	No. of Units	Site Cost ($×K)	Total Cost ($×K)	Notes	Unit Cost ($×K)	No. of Units	Site Cost ($×K)	Total Cost ($×K)	Notes	
LAND	Purchase Cost				0	0	1																
	Site Selection and Survey				0	0	1																
	Site Preparation				50	100	2																
	Total Land Cost	2			50	100																	
	TOTAL LAND COST ALLOCATED TO THIS FUNCTION	2				20	3				5	3				30	3				45	3	100
BUILDING	Engineering and Documentation				1800	3600	4																
	Construction Cost				10000	20000	4																
	Power:																						
	Conventional				600	1200	4																
	Emergency				100	200	4																
	Environmental Controls:																						
	Heating				50	100	5																
	Air Conditioning				100	200	4																
	Miscellaneous Facilities:																						
	Safety/Sanitation				50	100	5																
	Fencing/Security				50	100	5																
	Cabling and Miscellaneous Structures				100	200	5																
	Administrative				50	100	5																
	Employee Areas				50	100	5																
	Maintenance Areas				100	200	5																
	Internal Communication				500	1000	4																
	Other Building Costs:																						
	Arch./Supvn				300	600	4																
	Transportation of Materials				50	100	4																
	Inspection and Checkout				100	200	5																
	Miscellaneous				1000	2000	4																
	Total Building Costs	2				30000																	
	TOTAL BUILDING COST ALLOCATED TO THIS FUNCTION	2				6000	3				1500	3				9000	3				13500	3	30000

TABLE 4.2-3. FEDERAL GOVERMENT FACILITIES AND EQUIPMENT COSTS - REGIONAL CONTROL CENTER (Continued)

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total ($×K)
			Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
EQUIPMENT	Surveillance Signal Receiver				1020	2040	6																
	Antennas				177	354	12								412	824	12						
	Digital Data Receiver (Ground-to-Ground)														144	288	13						
	Digital Data Transmitter (Ground-to-Ground)														170	340	14						
	Digital Data Receiver (Aircraft-to-Ground)														47	94	15						
	Digital Data Transmitter (Ground-to-Aircraft)														50	100	16						
	Voice Receiver														90	180	17						
	Voice Transmitter														75	150	18						
	Displays and Controls																	125	409	51125	102250	19	
	Computer/Processor/ Memories				8035	16070	7			1217	2434	7			4870	9740	7			10226	20452	7	
	Initial Spares				462	924	8			61	122	8			293	586	8			3067	6134	8	
	Special Test and Maintenance Equipment				462	924	8			61	122	8			293	586	8			3067	6134	8	
	Documentation and Miscellaneous				462	924	8			61	122	8			293	586	8			3067	6134	8	
	Total Equipment Cost	2			10618	21236				1400	2800				6737	13474				70552	141104		178614
SOFTWARE	Programming				1440	2880	11			96	192	11			4800	9600	11			3264	6528	11	
	Total Software Costs	2			1440	2880				96	192				4800	9600				3264	6528		19200

TABLE 4.2-3. FEDERAL GOVERNMENT FACILITIES AND EQUIPMENT COSTS - REGIONAL CONTROL CENTER (Continued)

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total Annual Cost ($×K)
			Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
INSTALLATION AND CHECKOUT	Equipment Shipping and Transportation																						
	Surveillance Signal Receiver				60	120	8																
	Communication Equipment														49	98	8						
	Displays and Controls																			2555	5110	8	
	Computer/Processor/ Memories				401	802	8			61	122	8			243	486	8			512	1024	8	
	Installation and Checkout																						
	Surveillance Signal Receiver				240	480	20																
	Communication Equipment														198	396	20						
	Displays and Controls																			10225	20450	20	
	Computer/Processor/ Memories				1607	3214	20			243	486	20			974	1948	20			2045	4090	20	
	Total Installation and Checkout Costs	2			2308	4616				304	608				1464	2928				15337	30674		38826
	Totals	2			17376	34752				2552	5105				17516	35032				95925	191851		266740

Notes:

1. The RCC is assumed to be located on government land, probably in or near an existing ARTCC. Approximately 15 acres will be required for the RCC, including 2.5 acres for the buildings and peripherals and 12.5 acres for parking, assuming 150 cars per acre, negligible mass-transit, car-pooling, and 100 percent shift overlap.
2. Estimated from Ref. 1, Table D.2-7, D-16. Includes minor clearing and grading and a short (less than one mile) access road.
3. The facilities and equipment are for the most part, shared by two or more functions. Accordingly, it is not easy to separate out the portion of the facilities devoted to each particular function. However, the major visible portion of the RCC will be devoted to the operating controls and displays and the related computer systems. Assuming that the administrative and "overhead" facilities follow proportionally the facilities requirements for the four functions. The following facilities distribution was considered reasonable:

   Surveillance 20% — Communication 30%
   Navigation 5% — Control Processing 45%

4. Adapted from Ref. 1, Table D.2-7, page D-16, where an RCC is taken as equivalent to, or more complex than, the satellite control center of the reference.
5. This amount is considered reasonable for a facility of this size.
6. See Table 4.2-8

TABLE 4.2-3. FEDERAL GOVERNMENT FACILITIES AND EQUIPMENT COSTS - REGIONAL CONTROL CENTER (Continued)

7. The total computer/processor/peripherals cost given in Table 4.2-22 is allocated among the functions as follows:

Surveillance	33%	Communication	20%
Navigation and Miscellaneous	5%	Control Processing	42%

This allocation was derived from an analysis of the MIPS identified for the various tasks performed by the computer system, as given in Volume III. By the assumed multi-processor computer design, the MIPS requirements are directly related to the computer hardware requirements.

8. Five percent of the basic equipment cost is the typical allowance each for initial spares, special test and maintenance equipment (delivered), documentation and miscellaneous, and equipment shipping and transportation. See, for example, Ref. 4, pages 96-7.

9. This number not used.

10. This number not used.

11. According to the transition schedules presented in Volume VI, the CCC will be placed into operation first. The CCC computer program must accomplish nearly all that required of each RCC, including transition and arrival control. It is estimated that of the 120,000 (from Volume III) executable instructions for each RCC, approximately 60 percent will be common or easily modified from the corresponding CCC program. The remainder must be tailored to the specific RCC, including the differences in computer/processor configuration. This also assumes that the same computer hardware will be used for all three centers, that is, reprogramming will not be required because of changes in computer structure, organization, operating system, word length, cycle time, compiler, etc. A $200 per instruction cost is estimated (see Note 11, Table 4.2-2). This includes design, analysis, coding, checkout, integration, and documentation. The programming cost for each RCC is therefore 40 percent of $200 x 120,000 or $9,600,000 each.

The data in Volume III were also examined to determine the number of instructions identified for each function. The result was as follows:

Surveillance	9.4 K words	Control Processing	20.8 K words
Navigation	0.2 K words	Executive and Overhead	60.0 K words
Communication	30.0 K words		

Assuming the executive and overhead instructions are allocated in proportion to the four functions, the following distribution of the software costs among the four functions was obtained:

Surveillance	15%	Communication	50%
Navigation	1%	Control Processing	34%

12. Table 4.2-7

13. Table 4.2-9

14. Table 4.2-10

15. Table 4.2-11

16. Table 4.2-12

17. Table 4.2-13

18. Table 4.2-14

19. See Table 4.3-15 for estimate of the number of displays required. A cost of $125,000 per display is estimated. See Ref. 3, page 189.

20. Twenty percent of the basic equipment cost is the typical allowance for installation and checkout cost. See, for example, Ref. 3, page 189.

TABLE 4.2-4. FEDERAL GOVERNMENT FACILITIES AND EQUIPMENT COSTS - SATELLITE TRACKING CENTER

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total ($×K)
			Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
LAND	Purchase Cost				0	0	1																
	Site Selection and Survey				0	0	1																
	Site Preparation				10	70	2																
	Total Land Cost	7			10	70																	70
BUILDING	Engineering and Documentation				5	35	3																
	Construction Cost				5	35	3																
	Power:																						
	Conventional				1	7	3																
	Emergency				1	7	3																
	Environmental Controls:																						
	Heating						4																
	Air Conditioning				2	14	3																
	Miscellaneous Facilities:																						
	Safety/Sanitation						4																
	Fencing/Security				4	28	3																
	Cabling and Miscellaneous Structures				2	14	3																
	Administrative						4																
	Employee Areas						4																
	Maintenance Areas						4																
	Internal Communication						4																
	Other Building Costs:																						
	Arch./Supvn				3	21	3																
	Transportation of Materials				2	14	3																
	Inspection and Checkout				9	63	3																
	Miscellaneous				1	7	3																
	Total Building Costs	7			35	245																	245

TABLE 4.2-4. FEDERAL GOVERNMENT FACILITIES AND EQUIPMENT COSTS - SATELLITE TRACKING CENTER (Continued)

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total ($×K)
			Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
EQUIPMENT	Antennas (Fixed)		4	4	16	112	5																
	Antenna Supports		3	4	12	84	5																
	L-Band Receiver		2	1	2	14	6																
	RF Interface to Antennas		1	4	4	28	7																
	Navigation Data AMF		0.1	2	0.2	1	6																
	Threshold Detector		0.2	2	0.4	3	6																
	TOA Measurement Circuit		1	1	1	7	6																
	TOA Preprocessor		2	1	2	14	6																
	Navigation Data Decoder		2	1	2	14	6																
	Clock		10	1	10	70	6																
	Interface to Collocated Center		1	2	2	14	8																
	Chassis/Mount		2	1	2	14	9																
	Power Supply		1	2	2	14	9																
	Assembly and Integration				20	140	10																
	Initial Spares				4	28	11																
	Special Test and Maintenance Equipment				4	28	11																
	Documentation and Miscellaneous				4	28	11																
	Total Equipment	7			88	616																	616
	Software					0	12																0
INSTALLATION AND CHECKOUT	Equipment Shipping and Transportation				5	35	11																
	Installation and Checkout				18	126	13																
	Total Installation and Checkout Costs				23	161																	161
	Totals				156	1092																	1092

TABLE 4.2-4. FEDERAL GOVERNMENT FACILITIES AND EQUIPMENT COSTS - SATELLITE TRACKING CENTER (Continued)

Notes:

1. The STC's are assumed located on government land, in or near the RCC's (two sites), the CCC (one site), and ACC's (four sites).
2. Provides for minor clearing and grading and preparation of the site. See Ref. 1, Table D.4-3.
3. Only minor modifications or additions to the collocated control center facilites are assumed required for the STC's. See Ref. 1, Table D.4-3.
4. Not required at the STC site.
5. Four fixed L-band antennas will provide hemispheric satellite coverage (see Volume III). Costs are derived from the typical costs given in Ref. 4, page 22.3-3.
6. The STC electronics will be functionally similar to the navigation signal receiver portion of the aircraft avionics except that continuous operation and greater accuracy capability will be provided.
7. Based upon Ref. 4, page 22.3-3.
8. A simple hardwire interface is all that is required.
9. Per installation
10. This accounts for the costs of assembling and integrating the components listed (except antennas) into a complete unit. A single value is used instead of a parts-to-purchase price conversion factor.
11. Five percent of the basic equipment cost is the typical allowance each for initial spares, special test and maintenance equipment (delivered), documentation and miscellaneous, and equipment shipping and transportation. See, for example, Ref. 4, page 96-7.
12. All computations are handled by the CCC.
13. Twenty percent of the basic equipment cost is the typical allowance for installation and checkout. See, for example, Ref. 3, page 189.

TABLE 4.2-5. FEDERAL GOVERNMENT FACILITIES AND EQUIPMENT COSTS - AIRPORT CONTROL CENTERS

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total ($×K)
			Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
LAND	Purchase Cost																						
	Site Selection and Survey																						
	Site Preparation																						
	Total Land Cost	700			0	0	1				0	1				0	1				0	1	0
BUILDING	Engineering and Documentation				15	10500	2																
	Construction Cost				25	17500	2																
	Power:																						
	Conventional					0	3																
	Emergency					0	3																
	Environmental Controls:																						
	Heating					0	3																
	Air Conditioning					0	3																
	Miscellaneous Facilities:																						
	Safety/Sanitation					0	3																
	Fencing/Security					0	3																
	Cabling and Miscellaneous Structures					0	3																
	Administrative					0	3																
	Employee Areas					0	3																
	Maintenance Areas					0	3																
	Internal Communication					0	3																
	Other Building Costs:																						
	Arch./Supvn				2	1400	2																
	Transportation of Materials				5	3500	2																
	Inspection & Checkout				5	3500	2																
	Miscellaneous				10	7000	2																
	Total Building Costs	700			62	43400																	
	TOTAL BUILDING COST ALLOCATED TO THIS FUNCTION					8680	4				0	4				17360	4				17360	4	43400

TABLE 4.2-5. FEDERAL GOVERNMENT FACILITIES AND EQUIPMENT COSTS - AIRPORT CONTROL CENTERS (Continued)

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total ($×K)
			Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
EQUIPMENT	Ground Surveillance System (Trilateration):																						
	Surveillance Towers	25	4	5	20	500	5																
	L-Band Surveillance Signal Receiver	25	60	5	300	7500	6																
	Antenna	25	3	5	15	375	7																
	Computer/Processor	25	10	1	10	250	8																
	Ground Surveillance System (IR Array):																						
	IR Installations (runway)	700			20	14000	9																
	Interface to Computer	700	5	1	5	3500	9																
	Computer/Processor/ Memories	675	10	1	10	6750	8																
	Antennas	700													24	16800	10						
	Digital Data Receiver (Ground-to-Ground)	700													13	9100	11						
	Digital Data Transmitter (Ground-to-Ground)	700													13	9100	12						
	Digital Data Transmitter (Ground-to-Aircraft)	700													18	12600	13						
	Voice Receiver	700													32	22400	14						
	Voice Transmitter	700													36	25200	15						
	Display and Controls:																						
	Primary Airports	100																125	2	250	25000	16	
	Secondary and Feeder Airports	600																60	1	60	36000	16	
	Computer/Processor/ Memories	700																20	1	20	14000	17	
	Initial Spares	700				1644	18									4760	18				3750	18	
	Special Test and Maintenance Equipment	700				1644	18									4760	18				3750	18	
	Documentation and Miscellaneous	700				1644	18									4760	18				3750	18	
	Total Equipment	700				37807					0	4				109480					86250		233537

TABLE 4.2-5. FEDERAL GOVERNMENT FACILITIES AND EQUIPMENT COSTS - AIRPORT CONTROL CENTERS (Continued)

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total Annual Cost ($×K)
			Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
SOFT-WARE	Programming	700					20				0						20			25	17500	19	
	Total Software Costs					0					0	4				0					17500		17500
INSTALLATION AND CHECKOUT	Equipment Shipping and Transportation					1644	18				0	18				4760	18				3750	18	
	Installation and Checkout					6576	20				0	20				19040	20				15000	20	
	Total Installation and Checkout Costs					8220					0					23800					18750		50770
	Totals					54707					0					150640					139860		345207

Notes:

1. Adequate land is assumed to be available at each controlled airport. In fact, the major portion of the required ACC equipment will be installed in the existing control tower.
2. Only minor modifications to existing facilities are assumed necessary. Average costs for such modifications are assumed. See Ref. 1, Table D.2-8, page D-17.
3. Assumed to be provided by the existing facilities.
4. The facilities and equipment are, for the most part, shared by two or more functions. Accordingly, it is not easy to separate out the portion of the facilities devoted to each particular function. However, the major visible portion of the ACC will be devoted to the operating controls and displays as well as the communications equipment. Assuming the administrative and "overhead" facilities follow proportionally the facilities requirements for the four functions, the following facilities distribution was considered reasonable:

Surveillance	20%	Communication	40%
Navigation	0%	Control Processing	40%

   Although the above allocation is zero for the navigation function, it should be noted that the costs of guidance and navigation facilities such as the Microwave Landing System are not included in the SAATMS costs. Such facilities are assumed to be already provided at those airports which require them.
5. Ref. 1, Fig. D.7-11. A maximum tower height of 100 ft is assumed. Actually most receivers will be installed on top of existing airport buildings and towers, depending upon the visibility requirements. Note that the ground trilateration surveillance system will only be required at selected primary airports whose traffic density and ground visibility conditions (e.g., fog) are such that the expense of the trilateration ground surveillance system is warranted. It is estimated that approximately 25 percent of the 100 primary airports will require such a system.
6. This receiver will be essentially identical to the CCC/RCC surveillance signal receiver, except at L-Band (see Table 4.2-8).
7. See Table 4.2-7.
8. A small mini-computer or special-purpose digital processor will perform the surveillance pre-processing at each airport. The results will be transmitted to the control processor for final processing and display.
9. Average cost for typical airport installation. All airports will have some form of this ground surveillance system.
10. Assumes four fixed C-Band transmitting and receiving antennas for airport-to-RCC communication via the stationary satellites (including backup), and two fixed omni-directional L-Band antennas for ground-to-aircraft communication. See Table 4.2-7. The ACC antennas are assumed to be lower cost versions.

TABLE 4.2-5. FEDERAL GOVERNMENT FACILITIES AND EQUIPMENT COSTS - AIRPORT CONTROL CENTERS (Continued)

11. Table 4.2-15.
12. Table 4.2-16.
13. Table 4.2-17.
14. Table 4.2-18.
15. Table 4.2-19.
16. The primary airports are assumed to require two displays per tower. The secondary and feeder airports require one display per tower. A cost of $125,000 per display is estimated (see Ref. 3, page 189) for the larger airports. A simpler, lower cost display is required at the smaller airports.
17. A small, mini-computer is assumed adequate to handle the display processing load at each airport. This computer will also perform the necessary digital data communication processing.
18. Five percent of the basic equipment cost is the typical allowance each for initial spares, special test and maintenance equipment (delivered), documentation and miscellaneous, and equipment shipping and transportation. See, for example, Ref. 4, page 96-7.
19. Because of the similarity of processing functions to be performed, it is anticipated that a general software package will be developed which, with minor tailoring (perhaps by means of flags or key constants), will be applicable to all airports. Thus, an average programming cost of $25,000 is estimated for each airport. This includes the initial flow charting, programming, checkout, and integration. Refer also to the discussion in Volume III.
20. Included in the control processing estimate.

TABLE 4.2-6. FEDERAL GOVERNMENT FACILITIES AND EQUIPMENT COSTS - CALIBRATION STATIONS

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total ($×K)
			Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
LAND	Purchase Cost				0	0	1																
	Site Selection and Survey				0	0	1																
	Site Preparation				2	100	2																100
	Total Land Cost					100																	
BUILDING	Engineering and Documentation				5	250	2																
	Construction Cost				5	250	2																
	Power:																						
	Conventional				1	50	2																
	Emergency					0	3																
	Environmental Controls:																						
	Heating					0	3																
	Air Conditioning					0	3																
	Miscellaneous Facilities:																						
	Safety/Sanitation					0	3																
	Fencing/Security				4	200	2																
	Cabling and Miscellaneous Structures				2	100	2																
	Administrative					0	3																
	Employee Areas					0	3																
	Maintenance Areas					0	3																
	Internal Communication					0	3																
	Other Building Costs:																						
	Arch./Supvn				3	150	2																
	Transportation of Materials				2	100	2																
	Inspection & Checkout				2	100	2																1200
	Total Building Costs					1200																	

TABLE 4.2-6. FEDERAL GOVERNMENT FACILITIES AND EQUIPMENT COSTS - CALIBRATION STATIONS (Continued)

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total ($×K)
			Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
EQUIPMENT	Antenna and Support (L-Band)		5	1	5	250	4																
	L-Band Surveillance Signal Transmitter		4	1	4	200	5																
	Spares				0.45	23	6																
	Special Test and Maintenance Equipment				0.45	23	6																
	Documentation and Miscellaneous				0.45	23	6																519
	Total Equipment	50			10	519																	
SOFT-WARE	Total Software Costs	50				0																	0
INSTALLATION AND CHECKOUT	Equipment Shipping and Transportation				0.45	23	6																
	Installation and Checkout				1.8	90	7																
	Total Installation and Checkout Costs	50				113																	113
	Totals	50				1932																	1932

Notes:

1. The calibration stations are assumed to be located on existing government land in or near major airports.
2. Derived from Ref. 1, Table D.4-3, page D-83, assuming a minimum of facilities will be required.
3. None required.
4. See Table 4.2-7. A single omni-directional antenna is all that is required.
5. Functionally the same as an airborne surveillance signal transmitter, modified for a ground installation, continuous duty. See Section 5 of this volume.
6. Five percent of the basic equipment cost is the typical allowance each for initial spares, special test and maintenance equipment (delivered), documentation and miscellaneous, and equipment shipping and transportation. See, for example, Ref. 4, page 96-7.
7. Twenty percent of the basic equipment cost is the typical allowance for installation and checkout cost. See, for example, Ref. 3, page 189.

Table 4.2-7. Federal Government Facilities and Equipment Costs, CCC/RCC Antennas

Cost Subelements	Communication				Surveillance			
	Unit Cost ($×K)	Number Units Required	Site Cost ($×K)	Notes	Unit Cost ($×K)	Number Units Required	Site Cost ($×K)	Notes
Transmitting								
Fixed				1				
Antenna (15 ft.)	4	8	32	2				
Antenna Support	3	8	24	2				
Steerable								
Antenna (15 ft.)	4	12	48	2				
Antenna Support (Steerable)	8	12	96	3				
Antenna Control/ Drives	3	12	36	4				
Receiving								
Fixed				1				1
Antenna (15 ft.)	4	8	32	2	4	6	24	2
Antenna Support	3	8	24	2	3	6	18	2
Steerable								
Antenna (15 ft.)	4	8	32	2	4	9	36	2
Antenna Support (Steerable)	8	8	64	3	8	9	72	3
Antenna Control/ Drives	3	8	24	4	3	9	27	4
Total Antennas			412				177	

Notes:

1. Refer to Table 2.10-1 in Volume III for the antenna requirements and the breakdown of these antennas among the functions.
2. Derived from the typical costs given in Ref. 4, page 22.3-3.
3. Derived from the typical costs given in Ref. 4, page 23.2-2.
4. Assumes a simple positioning type of antenna control electronics responding to external positioning inputs.

Table 4.2-8. Federal Government Facilities and Equipment Costs, CCC/RCC Surveillance Signal Receiver

Cost Subelements	Number of Receivers Required	For Each Site: Unit Cost ($×K)	For Each Site: Number of Units Required	For Each Site: Site Cost ($×K)	Total Cost ($×K)	Notes
RF Interface to Antenna	15	1	1	1	15	2
C_1-Band Receiver	15	2	1	2	30	1
Delay Trimmer, Amplifiers, AMF's	15	0.1	16	2	30	1
Threshold Detector	15	0.2	16	3	45	3
TOA Measurement Circuit	15	1	16	16	240	1
High Speed Clock (40 to 80 MHz)	15	10	1	10	150	1
Interface to Surveillance Processor	15	0.5	10	5	75	3
Chassis/Mount	15	2	1	2	30	4
Power Supply	15	1	2	2	30	5
Assembly and Integration	15			25	375	6
Total	15			60	1020	

Notes:

1. Based upon Ref. 1, Table D.6-3.
2. Based upon Ref. 4, page 22.3-3.
3. Assumes integrated circuits.
4. Assumes each receiver will require one rack.
5. Two power supplies for redundancy.
6. This accounts for the costs of assembling and integrating the components listed into a complete receiver. A single value is used instead of a parts-to-purchase price conversion factor.

Table 4.2-9. Federal Government Facilities and Equipment Costs, CCC/RCC Digital Data Receiver (Ground-to-Ground)

Cost Subelements	Unit Cost ($×K)	Number of Units Required	Site Cost ($×K)	Notes
RF Interface to Antenna	1	5	5	1
C_5-Band Receiver	2	5	10	2
VCO	0.5	5	2.5	4
Sync Channel Filter	0.5	5	2.5	4
Distribution Switch	5	1	5	4
Channel Filter	0.1	1200	12	3
Biphase Demodulator	0.1	1200	12	3
Interfaces to Data Users	0.1	1200	12	3
Chassis/Mount	5	1	5	3
Power Supplies	3	6	18	3
Assembly and Integration			60	5
Total			144	

Notes:

1. Based upon Ref. 4, page 22.3-3.
2. Based upon Ref. 1, Table D.6-3. One for each communication link.
3. Per installation.
4. Assumes use of integrated circuits.
5. This accounts for the costs of assembling and integrating the components listed into a complete unit. A single value is used instead of a parts-to-purchase price conversion factor.

Table 4.2-10. Federal Government Facilities and Equipment Costs, CCC/RCC Digital Data Transmitter (Ground-to-Ground)

Cost Subelements	Unit Cost ($×K)	Number of Units Required	Site Cost ($×K)	Notes
RF Interface to Antenna	1	5	5	1
C_4-Band Transmitter (1.6 kw peak)	5	5	25	2
Multiplexer/Switch (600 by 5)	5	1	5	3
Channel Filter	0.1	1200	12	3
Biphase Modulator	0.1	1200	12	3
Interfaces to Data Sources	0.1	1200	12	3
Chassis/Mount	5	1	5	3
Power Supplies	3	6	18	3
Assembly and Integration			76	4
Total			170	

Notes:

1. Based upon Ref. 4, page 22.3-3. One for each communication link antenna.
2. Based upon Ref. 4, Table D.6-3. One for each communication link antenna.
3. Per installation.
4. This accounts for the costs of assembling and integrating the components listed into a complete unit. A single value is used instead of a parts-to-purchase price conversion factor.

Table 4.2-11. Federal Government Facilities and Equipment Costs, CCC/RCC Digital Data Receiver (Aircraft-to-Ground)

Cost Subelements	Unit Cost ($×K)	Number of Units Required	Site Cost ($×K)	Notes
RF Interface to Antenna	1	4	4	1
C_3-Band Receiver	2	4	8	2
AMF's, Amplifiers	0.1	16	2	3
Threshold Detector	0.2	16	3	3
Communications Preprocessor	2	1	2	4
PPM Sync Detector	1	1	1	4
PPM Decoder	2	1	2	4
Power Supply	1	1	1	4
Interface to Data User	1	1	1	4
Assembly and Integration			20	5
Total			47	

Notes:

1. Based upon Ref. 4, page 22.3-3.
2. Based upon Ref. 1, Table D.6-3. Four aircraft-to-ground links are required.
3. Assumes use of integrated circuits. Per installation.
4. Per installation.
5. This accounts for the costs of assembling and integrating the components listed into a complete receiver. A single value is used instead of a parts-to-purchase price conversion factor.

Table 4.2-12. Federal Government Facilities and Equipment Costs, CCC/RCC Digital Data Transmitter (Ground-to-Aircraft)

Cost Subelements	Unit Cost ($×K)	Number of Units Required	Site Cost ($×K)	Notes
RF Interface to Antenna	1	4	4	1
C_2-Band Transmitter (100 w peak)	2	4	8	2
Biphase Modulator	0.5	4	2	3
Local Oscillator/Mixer	0.5	4	2	3
Distribution Switch	2	1	2	4
PPM Encoder	0.5	1	0.5	4
Navigation Code Generator	1	1	1	4
Communication Code Generator	1	1	1	4
Sync and Address Generator Circuit	1	1	1	4
Interfaces to Data Sources	1	1	1	4
Chassis/Mount	2	1	2	4
Power Supply	1	4	4	4
Assembly and Integration			21.5	5
Total			50	

Notes:

1. Based upon Ref. 4, page 22.3-3.
2. Based upon Ref. 1, Table D.6-3. Four ground-to-aircraft transmitter links are required.
3. Assumes use of integrated circuits. Per installation.
4. Per installation.
5. This accounts for the costs of assemblying and integrating the components listed into a complete unit. A single value is used instead of parts-to-purchase price conversion factor.

Table 4.2-13. Federal Government Facilities and Equipment Costs, CCC/RCC Voice Receiver

Cost Subelements	Unit Cost ($×K)	Number of Units Required	Site Cost ($×K)	Notes
RF Interface to Antenna	1	4	4	1
C_7-Band Receiver/Demodulator	2	4	8	2
Channel Filters	0.1	100	10	3
Subcarrier Demodulator	0.1	100	10	3
Interfaces to Voice Users	0.1	100	10	3
Chassis/Mount	1	4	1	3
Power Supply	2	4	8	3
Assembly and Integration			39	4
Total			90	

Notes:

1. Based upon Ref. 4, page 22.3-3.
2. Based upon Ref. 1, Table D.6-3. Four aircraft-to-ground receiver links are required.
3. Per installation.
4. This accounts for the costs of assembling and integrating the components listed into a complete unit. A single value is used instead of a parts-to-purchase price conversion factor.

Table 4.2-14. Federal Government Facilities and Equipment Costs, CCC/RCC Voice Transmitter

Cost Subelements	Unit Cost ($×K)	Number of Units Required	Site Cost ($×K)	Notes
RF Interface to Antenna	1	4	4	1
C_6-Band Transmitter (100 w peak)	2	4	8	2
Frequency Modulator	0.5	4	2	3
Local Oscillator	0.5	4	2	3
Multiplexer (100 input)	3	1	3	3
Subcarrier Oscillator	0.1	100	10	3
Interfaces to Voice Sources	0.1	100	10	3
Chassis/Mount	2	1	2	3
Power Supply	1	4	4	3
Assembly and Integration			30	4
Total			75	

Notes:

1. Based upon Ref. 4, page 22.3-3.
2. Based upon Ref. 1, Table D.6-3. Four ground-to-aircraft links are required.
3. Per installation.
4. This accounts for the costs of assembling and integrating the components listed into a complete unit. A simple value is used instead of a parts-to-purchase price conversion factor.

Table 4.2-15. Federal Government Facilities and Equipment Costs, Airport Digital Data Receiver (Ground-to-Ground)

Cost Subelements	Unit Cost ($×K)	Number of Units Required	Site Cost ($×K)	Notes
RF Interface to Antenna	1	1	1	1
C_5-Band Receiver	2	1	2	2
VCO	0.5	1	0.5	2
Sync Channel Filter	0.5	1	0.5	2
Channel Filter	0.1	2	0.2	2
Biphase Demodulator	0.1	2	0.2	2
Interface to Data User	0.1	2	0.2	2
Chassis/Mount	1	1	1	2
Power Supply	1	1	1	2
Assembly and Integration			7	3
Total			13	

Notes:

1. Based upon Ref. 4, page 22.3-3.
2. The airport equipment will be less complex and less expensive than the CCC/RCC equipment.
3. This accounts for the costs of assembling and integrating the components listed into a complete unit. A single value is used instead of a parts-to-purchase price conversion factor.

Table 4.2-16. Federal Government Facilities and Equipment Costs, Airport Digital Data Transmitter (Ground-to-Ground)

Cost Subelements	Unit Cost ($×K)	Number of Units Required	Site Cost ($×K)	Notes
RF Interface to Antenna	1	1	1	1
C_4-Band Transmitter (10 w peak)	2	1	2	2
Multiplexer	1	1	1	2
Channel Filter	0.1	2	0.2	2
Biphase Modulator	0.1	2	0.2	2
Interfaces to Data Sources	0.1	2	0.2	2
Chassis/Mount	1	1	1	2
Power Supply	1	1	1	2
Assembly and Integration			7	3
Total			13	

Notes:

1. Based upon Ref. 4, page 22.3-3.
2. The airport equipment will be less complex and less expensive than the CCC/RCC equipment.
3. This accounts for the costs of assembling and integrating the components listed into a complete unit. A single value is used instead of a parts-to-purchase price conversion factor.

Table 4.2-17. Federal Government Facilities and Equipment Costs, Airport Digital Data Transmitter (Ground-to-Aircraft)

Cost Subelements	Unit Cost ($×K)	Number of Units Required	Site Cost ($×K)	Notes
RF Interface to Antenna	1	1	1	1
L_3-Band Transmitter (10 w peak)	2	1	2	2
Biphase Modulator	0.5	1	0.5	3
Local Oscillator	0.5	1	0.5	3
PPM Encoder	0.5	1	0.5	3
Navigation Code Generator	1	1	1	3
Communication Code Generator	1	1	1	3
Sync and Address Generator Circuit	1	1	1	3
Interface to Data Source	0.5	1	0.5	3
Chassis/Mount	2	1	2	3
Power Supply	1	1	1	3
Assembly and Integration			7	4
Total			18	

Notes:

1. Based upon Ref. 4, page 22.3-3.
2. The airport requires only a low power transmitter for line-of-sight communication.
3. The aiport equipment will be less complex and less expensive than the CCC/RCC equipment.
4. This accounts for the costs of assembling and integrating the components listed into a complete unit. A single value is used instead of a parts-to-purchase price conversion factor.

Table 4.2-18. Federal Government Facilities and Equipment Costs, Airport Voice Receiver

Cost Subelements	Unit Cost ($×K)	Number of Units Required	Site Cost ($×K)	Notes
RF Interface to Antenna	1	1	1	1
L_5-Band Receiver/Demodulator	2	1	2	2
Channel Filters	0.1	50	5	2
Subcarrier Demodulators	0.1	50	5	2
Interfaces to Voice Users	0.1	50	5	2
Chassis/Mount	2	1	2	2
Power Supply	2	1	2	2
Assembly and Integration			10	3
Total			32	

Notes:

1. Based upon Ref. 4, page 22.3-3.
2. The airport equipment will be less complex and less expensive than the CCC/RCC equipment.
3. This accounts for the costs of assembling and integrating the components listed into a complete unit. A single value is used instead of a parts-to-purchase price conversion.

Table 4.2-19. Federal Government Facilities and Equipment Costs, Airport Voice Transmitter

Cost Subelements	Unit Cost ($×K)	Number of Units Required	Site Cost ($×K)	Notes
RF Interface to Antenna	1	1	1	1
L_7-Band Transmitter (10 w peak)	2	1	2	2
Frequency Modulator	0.5	1	0.5	3
Local Oscillator	0.5	1	0.5	3
Multiplexer (50 input)	3	1	3	3
Subcarrier Oscillator	0.1	50	5	3
Interfaces to Voice Sources	0.1	50	5	3
Chassis/Mount	2	1	2	3
Power Supply	2	1	2	3
Assembly and Integration			15	4
Total			36	

Notes:

1. Based upon Ref. 4, page 22.3-3.
2. The airport requires only a low power transmitter for line-of-sight communication.
3. The airport equipment will be less complex and less expensive than the CCC/RCC equipment.
4. This accounts for the costs of assembling and integrating the components listed into a complete unit. A single value is used instead of a parts-to-purchase price conversion factor.

TABLE 4.2-20. CCC/RCC COMPUTER REQUIREMENTS

Site	Site Computer Number	Total MIPS	Number of CPU's	Number of IOP's	Main Memory Total ($\times 10^3$) (1)	Auxiliary Memory Total ($\times 10^3$) (1)	I/O Keyboard	Card Reader	Line Printer	Tape Drive and Control	Additional Special Equipment Required
CCC	1	4.00	4	1	72	-	1	-	-	-	Special purpose and associative processors
	2	0.25	1	1	33	-	1	1	1	1	
	3	5.92	7	1	3200	-	1	-	-	-	Communications processor (0.1 MIPS)
	4	1.11	2	1	45	30,405	1	1	1	1	
	5	4.00	4	1	72	-	1	-	-	-	Special purpose and associate processors
	6	0.25	1	1	33	-	1	1	1	1	
	7	1.23	2	1	862	200	1	1	1	1	
	8	17.10	17	1	1285	3,750	1	-	-	-	
RCC	1	4.00	4	1	72	-	1	-	-	-	Special purpose and associative processors
	2	0.25	1	1	33	-	1	1	1	1	
	3	3.95	5	1	2200	-	1	-	-	-	Communication processor (0.1 MIPS)
	4	0.49	1	1	26	234	1	1	1	1	
	5	4.00	4	1	72	-	1	-	-	-	Special purpose and associative processors
	6	0.25	1	1	33	-	1	1	1	1	
	7	0.49	1	1	251	100	1	1	1	1	
	8	10.10	10	1	720	2,100	1	-	-	-	

Notes:

(1) Assumes 32-bit words.

Refer to Volume III for the block diagram of the processor configurations, the functions performed in each computer, and for the speed and memory estimates by function.

TABLE 4.2-21. CCC COMPUTER/PROCESSING COSTS

Cost Subelements	Unit Cost ($×K)	Number of Units Required	Site Cost ($×K)	Notes
Computer No. 1				
CPU's	650	4	200	1
Special Purpose Processor	130	2	260	7
Associative Processor	133	2	266	8
I/O Keyboard/Printer	6	1	6	6
Computer No. 2				
CPU's	650	1	650	1
I/O Keyboard/Printer	6	1	6	6
Card Reader	16	1	16	6
Line Printer	35	1	35	6
Tape Drive and Control	28	1	28	6
Computer No. 3				
CPU's	1600	7	11200	2
Communication Processor	30	1	30	9
I/O Keyboard/Printer	6	1	6	6
Computer No. 4				
CPU's	650	2	1300	1
Auxiliary Memory	60	23	1380	3
Auxiliary Memory Control	18	6	108	3
I/O Keyboard/Printer	6	1	6	6
Card Reader	16	1	16	6
Line Printer	35	1	35	6
Tape Drive and Control	28	1	28	6
Computer No. 5				
CPU's	650	4	2600	1
Special Purpose Processor	130	2	260	7
Associative Processor	133	2	266	8
I/O Keyboard/Printer	6	1	6	6
Computer No. 6				
CPU's	650	1	650	1
I/O Keyboard/Printer	6	1	6	6
Card Reader	16	1	16	6
Line Printer	35	1	35	6
Tape Drive and Control	28	1	28	6

TABLE 4.2-21. CCC COMPUTER/PROCESSING COSTS (Continued)

Cost Subelements	Unit Cost ($×K)	Number of Units Required	Site Cost ($×K)	Notes
Computer No. 7				
CPU's	1500	2	3000	2
Auxiliary Memory	24	1	24	4
Auxiliary Memory Control	8	1	8	4
I/O Keyboard/Printer	6	1	6	6
Card Reader	16	1	16	6
Line Printer	35	1	35	6
Tape Drive and Control	28	1	28	6
Computer No. 8				
CPU's	650	17	11050	1
Auxiliary Memory	60	3	180	5
Auxiliary Memory Control	18	1	18	5
I/O Keyboard/Printer	6	1	6	6
Total			36214	

General Note:

The costs estimated here are based upon the costs of currently available computer equipment, such as the Xerox Sigma 9 series. The Rand computer cost estimating relationship (Ref. 3, page 30) was not used because it does not correctly model the computer architecture assumed for the SAATMS. The computer costs are arrived at by assuming identical central processors, with integral input/output processors, with the required working (main) memory distributed among them. A processing speed of approximately 1 MIPS is assumed for each processor. This is somewhat higher than that currently available (0.5 to 0.7 MIPS) but is assumed to be achievable with current technology. Refer to Table 4.2-20 for the required speed and memory for each computer.

Notes:

1. Basic price for 64,000 words of working memory.
2. Includes provision for the additional words of working memory required.
3. A total of twenty three 5.4-mega byte (1.35 mega words) rapid access data storage units is required, at $60 K each, with one rapid access data controller for each four storage units, at $18 K each.
4. One 0.75×10^6 byte rapid access storage unit and one data controller are required.
5. Three 5.4×10^6 byte rapid access storage units and a data controller are required.

TABLE 4.2-21. CCC COMPUTER/PROCESSING COSTS (Continued)

6. Typical cost

7. The special purpose processor decodes the incoming aircraft ID. Estimated number of IC's = 400. The fabrication cost is (using typical in-house costs and fabrication factors) as follows:

   Fabrication cost = Number of IC's × (cost/IC) × packaging factor
   × manufacturing factor × quality assurance factor
   = 400 × $1 × 2 × 4 × 3 ≃ $10 K per unit

   Each site has 13 receivers, thus the total cost is $130 K. Two complete units are required for redundancy, since they are special purpose.

8. The associate processor provides a content-addressable memory. Estimated number of IC's = 150. Estimated number of associative elements = 270. The fabrication cost (see factors in Note 7) is:

   Fabrication cost = (150 × $1 + 270 × $20)× 2 × 4 × 3 = $133 K per unit

   Two units are required for redundancy.

9. The communication processor is a minicomputer.

Table 4.2-22. RCC Computer/Processing Costs

Cost Subelements	Unit Cost ($×K)	Number of Units Required	Site Cost ($×K)	Notes
Computer No. 1				
CPU's	650	4	2600	1
Special Purpose Processor	130	2	260	6
Associative Processor	133	2	266	7
I/O Keyboard/Printer	6	1	6	5
Computer No. 2				
CPU's	650	1	650	1
I/O Keyboard/Printer	6	1	6	5
Card Reader	16	1	16	5
Line Printer	35	1	35	5
Tape Drive and Control	28	1	28	5
Computer No. 3				
CPU's	1600	5	8000	2
Communication Processor	30	1	30	8
I/O Keyboard/Printer	6	1	6	5
Computer No. 4				
CPU's	650	1	650	1
Auxiliary Memory	24	1	24	3
Auxiliary Memory Control	8	1	8	3
I/O Keyboard/Printer	6	1	6	5
Card Reader	16	1	16	5
Line Printer	35	1	35	5
Tape Drive and Control	28	1	28	5
Computer No. 5				
CPU's	650	4	2600	1
Special Purpose Processor	130	2	260	6
Associative Processor	133	2	266	7
I/O Keyboard/Printer	6	1	6	5
Computer No. 6				
CPU's	650	1	650	1
I/O Keyboard/Printer	6	1	6	5
Card Reader	16	1	16	5
Line Printer	35	1	35	5
Tape Drive and Control	28	1	28	5

Table 4.2-22. (continued)

Cost Subelements	Unit Cost ($×K)	Number of Units Required	Site Cost ($×K)	Notes
Computer No. 7				
CPU's	1050	1	1050	2
Auxiliary Memory	24	1	24	3
Auxiliary Memory Control	8	1	8	3
I/O Keyboard/Printer	6	1	6	5
Card Reader	16	1	16	5
Line Printer	35	1	35	5
Tape Drive and Control	28	1	28	5
Computer No. 8				
CPU's	650	10	6500	1
Auxiliary Memory	60	2	120	4
Auxiliary Memory Control	18	1	18	4
I/O Keyboard Printer	6	1	6	5
Total			24348	

General Note:

Refer to the General Note accompanying Table 4.2-21.

Notes:

1. Basic price for 64,000 words of working memory.
2. Includes provision for the additional words of memory required.
3. One 0.75×10^6 byte rapid access storage unit and one data controller are required.
4. Two 5.4×10^6 byte rapid access storage units and a data controller are required.
5. Typical cost.
6. See Note 7, Table 4.2-21.
7. See Note 8, Table 4.2-21.
8. The communication processor is a minicomputer.

Table 4.2-23. Federal Government Facilities and Equipment Costs - Satellites

Cost Subelements	Number of Sites	Surveillance Total Cost ($×K)	Surveillance Notes	Navigation Total Cost ($×K)	Navigation Notes	Communication Total Cost ($×K)	Communication Notes	Control Processing Total Cost ($×K)	Control Processing Notes	Total ($×K)
Geostationary:	6									
Satellites		3244	1	1622	1	27574	1	0	1	32440
Launch Vehicles		5600	2	2800	2	47600	2	0	2	56000
Total	6	8844		4422		75174		0		88440
Geosynchronous:	9									
Satellites		4324	3	1081	3	16215	3	0	3	21620
Launch Vehicles		5600	4	1400	4	21000	4	0	4	28000
Total	9	9924		2481		37215		0		49620
Totals	15	18768		6903		112389				138060

Notes:

1. The Mitre satellite cost estimating relationship was used (Ref. 11, Figure 14, page 53). The estimator is as follows:

$$\text{Satellite cost} = 0.026\ K\ (n \times Ws)^{2/3} = \$32.44\ \text{Million}$$

where

$K = 2.4$ (from the referenced figure)

n = number of satellites = 6

Ws = satellite weight = 2000 lb (see Table 4.2-24).

This estimator accounts for the "learning curve" effect in producing a number of identical satellites (see Ref. 11, pages 6-8). It should be noted that the Rand satellite cost estimators (Ref. 3, pages 38-42) yield a slightly higher cost: $50.66 M if one R&D satellite is assumed per the Rand procedure.

Since the satellite cost estimating relationships use the satellite RF power output as the basis, the geostationary satellite costs were apportioned to the functions using the required RF power as the guide (see Volume III), as follows:

Surveillance	10%	Communication	85%
Navigation	5%	Control Processing	0%

Table 4.2-23. (continued)

2. A Titan III E/Centaur launch vehicle is assumed. This vehicle will place up to 7200 pounds in synchronous orbit for a cost of about $28 million and will have the capability for placing multiple satellites (Ref. 12). Two launches will be required, carrying three satellites (6000 lbs. plus ejection structures) each. The launch vehicle costs are apportioned by the same percentages used above (note 1).

   A launch cost reduction is possible with the advent of the space shuttle. The space shuttle will have the capability of placing 8000 pounds in geostationary orbit at a cost of $10.5 million plus $1 million for the space tug (Ref. 12). Two launches will be required. A further cost reduction option is available if the shuttle payload can be shared with other users, since one or both launches will have excess capability.

3. The Mitre satellite cost estimating relationship was used (Ref. 11, Figure 14, page 53). The estimator is as follows

$$\text{Satellite cost} = 0.026\ K\ (n \times Ws)^{2/3} = \$21.62\ \text{Million}$$

   where

$$K = 2.4 \text{ (from the referenced figure)}$$

$$n = \text{number of satellites} = 9$$

$$Ws = \text{satellite weight} = 735 \text{ lb (see Table 4.2-24).}$$

   This estimator accounts for the "learning curve" effect in producing a number of identical satellites (see Ref. 11, pages 6-8). It should be noted that the Rand satellite cost estimators (Ref. 3, pages 38-42) yield a slightly higher cost: $31.883 million if two R&D satellites are assumed per the Rand procedure.

   The geosynchronous costs were apportioned to the functions as follows (see note 1 above):

Surveillance	20%	Communication	75%
Navigation	5%	Control Processing	0%

4. A Titan III E/Centaur launch vehicle is assumed. This vehicle will place up to 7200 lb in synchronous orbit for a cost of about $28 million and will have the capability for placing multiple satellites (Ref. 12). One launch will be required for the nine satellites (9 × 735 = 6615 lb, plus 10 percent for ejection structures = 7200 lb). If emplacing all nine satellites at once is undesirable, then more than one launch will be required, either another Titan III E/Centaur, or one or more Thor-Deltas ($5.5 million each), at a slightly higher total launch cost. The Thor-Delta vehicle can place only one satellite in orbit (Ref. 12). The launch costs are apportioned by the same percentages used above (note 3).

   A launch cost reduction is possible with the advent of the space shuttle. The space shuttle will have the capability of placing 8000 lb in synchronous orbit at a cost of $10.5 million plus $1 million for the space tug (Ref. 12). One launch will be required.

TABLE 4.2-24. SATELLITE WEIGHTS

Satellite	Average RF Power (w)	DC Input Power (3) (w)	Satellite Subsystem Weights (lb) (5)						Total Weight (lb)
			Power (4)	Communication and Antennas	Attitude Control	Structure	Thermal Control	Miscellaneous	
Geostationary	1600 (1)	5333	850	250	328	232	96	174	1930
Geosynchronous	540 (2)	1800	324	96	125	88	37	66	735

Notes:

(1.) The geostationary satellites include provision for 25 L-band voice channels each. See Volume III for the power requirements.

(2.) The geosynchronous satellites do not include the L-band voice links or the ground-to-ground digital communication links. See Volume III for the power requirements.

(3.) Assuming 30 percent efficiency.

(4.) The Mitre report contains estimating relationships for the satellite power subsystem given the required dc power. See Ref. 11, page 48.

(5.) Reference 11, page 44, gives estimated proportions of the subsystem weights to the total satellite weight: power 44 percent, communications (including antennas) 13 percent, attitude control 17 percent, structure 12 percent, thermal control 5 percent, weight margin/miscellaneous 9 percent.

4.3 Operations and Maintenance Costs

This section presents the estimated SAATMS Federal Government O&M costs. The O&M costs are defined as all those costs required to operate the system and to maintain it in an operational state. The O&M costs are, therefore, the recurring costs and are estimated on an average, annual basis for the fully operational system. The O&M costs may be incurred on some portions of the system while other portions of the system are still in the process of acquisition or development.

By the definitions here, the cost of maintaining the system in an operational state includes the cost of replacing worn-out equipment with identical or equivalent equipment (not equipment with added capabilities). Such equipment replacement costs are based upon the original equipment F&E costs and the estimated equipment life and are included as O&M costs.

4.3.1 Summary

Table 4.3-1 presents the summary of the Federal Government O&M costs. The entries in this table are obtained from the detailed ground site and satellite cost tables where the particulars of the individual cost estimates and accompanying explanations are presented.

It should be noted again that the O&M costs are estimated on an average annual cost basis for a fully operational system or system element. This average annual cost can then be used to estimate O&M costs during the phase-in period of the particular system element. The 1995 demand levels were used as the basis for computing the O&M costs.

4.3.2 Ground Sites

The detailed O&M cost estimates for the ground sites are presented by site and by function as follows:

Continental Control Center: Table 4.3-2

Regional Control Center: Table 4.3-3

Satellite Tracking Center: Table 4.3-4

Airport Control Center: Table 4.3-5

Calibration Stations: Table 4.3-6

The notes accompanying each table give the source of the cost estimate and any additional reference information or explanation. The references are listed in Section 9. The controller and supporting personnel estimates are shown in Tables 4.3-7 and 4.3-8.

Table 4.3-1. Summary of Federal Government O&M Costs

Site	Number of Sites	Cost Element	$ Thousands				
			SURV	NAV	COMM	Control	Total
CCC	1	Controller Personnel	216	36	108	71855	72215
		Maintenance	318	88	632	1248	2286
		Equipment Replacement	1446	208	787	10481	12922
		Flight Inspection	36	36	36	36	144
		Other O&M	240	0	180	835	1255
		Total	2256	368	1743	84455	88822
RCC	2	Controller Personnel	468	72	288	143602	144430
		Maintenance	698	106	1066	2752	4622
		Equipment Replacement	2242	280	1444	19150	23116
		Flight Inspection	72	72	72	72	288
		Other O&M	560	0	410	1590	2560
		Total	4040	530	3280	167166	175016
STC	7	Controller Personnel	0	0	0	0	0
		Maintenance	630	0	0	0	630
		Equipment Replacement	91	0	0	0	91
		Flight Inspection	0	0	0	0	0
		Other O&M	700	0	0	0	700
		Total	1421	0	0	0	1421

TABLE 4.3-1. Summary of Federal Government O&M Costs (Continued)

Site	Number of Sites	Cost Element	$ Thousands				
			SURV	NAV	COMM	Control	Total
ACC	700	Controller Personnel	4500	0	0	176000	180500
		Maintenance	9800	5100	16460	28140	59500
		Equipment Replacement	5051	0	15640	11700	32391
		Flight Inspection	0	0	0	0	0
		Other O&M	11400	6700	11900	11900	41900
		Total	30751	11800	44000	227740	314291
Calibration Stations	50	Controller Personnel	0	0	0	0	0
		Maintenance	350	0	0	0	350
		Equipment Replacement	71	0	0	0	71
		Flight Inspection	0	0	0	0	0
		Other O&M	200	0	0	0	200
		Total	621	0	0	0	621
Total Ground Site	760		39089	12698	49023	479361	580171
Geostationary Satellites	6	Satellites	463	232	3939	0	4634
		Launch Vehicles	800	400	6800	0	8000
		Total	1263	632	10739	0	12634
Geosynchronous Satellites	9	Satellites	618	154	2317	0	3089
		Launch Vehicles	800	200	3000	0	4000
		Total	1418	354	5317	0	7089
Total Satellites	15		2681	986	16056	0	19723
Total System O&M			41770	13684	65079	479361	599894

TABLE 4.3-2. FEDERAL GOVERNMENT OPERATIONS AND MAINTENANCE COSTS - CONTINENTAL CONTROL CENTER

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total ($×K)
			Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	Each Site			Total Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
CONTROLLER PERSONNEL	Salary Costs:																						
	Controllers																	20	3231	64620	64620	1	
	Supervisors																	25	269	6725	6725	1	
	Managers/Chiefs																	30	5	150	150	1	
	Computer Operators		18	12	216	216	2	18	2	36	36	2	18	6	108	108	2	18	20	360	360	2	
	Total Controller Costs	1			216	216				36	36				108	108					71855		72215
MAINTENANCE	Equipment Maintenance:																						
	Technicians		20	3	60	60	3	20	1	20	20	3	20	2	40	40	3	20	18	360	360	3	
	Engineers		18	2	36	36	3	18	0	0	0	3	18	1	18	18	3	18	9	162	162	3	
	Supervisors		25	1	25	25	3	25	0	0	0	3	25	1	25	25	3	25	6	150	150	3	
	Software Maintenance Programmers		18	4	72	72	4	18	1	18	18	4	18	18	324	324	4	18	17	306	306	4	
	Maintenance Materials and Supplies				100	100	5			50	50	5			200	200	5			200	200	5	
	Building and Grounds Maintenance Personnel		10	2.5	25	25	6	10	0	0	0	6	10	2.5	25	25	6	10	7	70	70	6	
	Total Maintenance Costs	1			318	318				88	88				632	632				1248	1248		2286
EQUIPMENT REPLACEMENT	Cost of Replacement Equipment:																						
	Surveillance Signal Receivers				197	197	8																
	Communication Equipment														162	162	8						
	Displays and Controls																			8399	8399	8	
	Computer/Processor/Memories				1249	1249	8			208	208	8			625	625	8			2082	2082	8	
	Total Equipment Replacement Costs	1			1446	1446				208	208				787	787				10481	10481		12922
FLIGHT INSPECTION	Flight Inspection Cost	1	0.300	120	36	36	7	0.300	120	36	36	7	0.300	120	36	36	7	0.300	120	36	36	7	144

TABLE 4.3-2. FEDERAL GOVERNMENT OPERATIONS AND MAINTENANCE COSTS - CONTINENTAL CONTROL CENTER (Continued)

Cost Element	Cost Subelements	No. of Sites	Surveillance Each Site Unit Cost ($×K)	Surveillance Each Site No. of Units	Surveillance Each Site Site Cost ($×K)	Surveillance Total Cost ($×K)	Surveillance Notes	Navigation Each Site Unit Cost ($×K)	Navigation Each Site No. of Units	Navigation Each Site Site Cost ($×K)	Navigation Total Cost ($×K)	Navigation Notes	Communication Each Site Unit Cost ($×K)	Communication Each Site No. of Units	Communication Each Site Site Cost ($×K)	Communication Total Cost ($×K)	Communication Notes	Control Processing Each Site Unit Cost ($×K)	Control Processing Each Site No. of Units	Control Processing Each Site Site Cost ($×K)	Control Processing Total Cost ($×K)	Control Processing Notes	Total ($×K)
OTHER OPERATIONS AND MAINTENANCE	Indirect Personnel:																						
	Office		10	1	10	10	6	10	0	0	0	6	10	2	20	20	6	10	5	50	50	6	
	Security		10	1	10	10	6	10	0	0	0	6	10	2	20	20	6	10	5	50	50	6	
	Employee Services		10	1	10	10	6	10	0	0	0	6	10	2	20	20	6	10	5	50	50	6	
	Other		10	1	10	10	6	10	0	0	0	6	10	2	20	20	6	10	5	50	50	6	
	Site Operating Costs:																						
	Utilities				100	100	9			0	0	9			50	50	9			150	150	9	
	Expendables and Miscellaneous Supplies				100	100	9			0	0	9			50	50	9			485	485	9	
	Total Other O&M Costs	1			240	240				0	0				180	180				835	835		1255
	Totals	1			2256	2256				368	368				1743	1743				84455	84455		88822

Notes:

1. Table 4.3-7. The salaries are obtained from Ref. 1, Table D.2-19, page D-29. This includes a factor for fringe benefits and training. The manager's salaries are estimates.

2. The computer operators are allocated (rounded to the nearest "whole person") among the functions according to the proportion of the computer hardware allocated to each function (Table 4.2-2, Note 7), that is,

Surveillance	30%	Communication	15%
Navigation and Miscellaneous	5%	Control Processing	50%

The total number of computer operators (30) is given in Table 4.3-8. Salary costs are taken from Ref. 1, Table D.3-11.

3. The equipment maintenance personnel are allocated (rounded to the nearest "whole person") among the functions by the proportion of the F&E equipment cost for each function to the total CCC F&E equipment cost. Using the data in Table 4.2-2,

Surveillance	14%	Communication	7%
Navigation	2%	Control Processing	77%

The total number of equipment maintenance personnel given in Table 4.3-8 is as follows:

Technicians	24
Engineers	12
Supervisors	8

The salary costs are estimated from Ref. 1, Table D.3-11.

4. The computer programmers are allocated (rounded to the nearest "whole person") among the functions according to the proportion of the computer software allocated to each function (Table 4.2-2, Note 11), that is,

Surveillance	11%	Communication	45%
Navigation	1%	Control Processing	43%

TABLE 4.3-2. FEDERAL GOVERNMENT OPERATIONS AND MAINTENANCE COSTS - CONTINENTAL CONTROL CENTER (Continued)

The total number of programmers (40) is given in Table 4.3-8. Salary costs are estimated from Ref. 1, Table D.3-11.

5. Based upon Ref. 1, Table D.3-11 and Ref. 3, page 118.

6. The building and grounds maintenance personnel and indirect personnel are allocated (rounded to the nearest "whole person") among the functions according to the proportion of the facilities allocated to each function (Table 4.2-2, Note 3), that is:

Surveillance	20%
Navigation	0%
Communication	20%
Control Processing	60%

The total number of building and grounds maintenance and indirect personnel is given in Table 4.3-8. The salaries are estimated from Ref. 1, Table D.3-11.

7. Ref. 3, page 118. The value shown in the reference for the Satellite Control Center is used here for all functions.

8. Based upon a 7-year equipment life (10 years for computers) and the equipment F&E cost (Table 4.2-2).

9. Based upon Ref. 1, Tables D.3-11 and D.2-10. The values shown in the reference for the Satellite Control Center are used here.

TABLE 4.3-3. FEDERAL GOVERNMENT OPERATING AND MAINTENANCE COSTS - REGIONAL CONTROL CENTER

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total Annual Cost ($×K)
			Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
CONTROLLER PERSONNEL	Salary Costs:																						
	Controllers																	20	3231	64620	129240	1	
	Supervisors																	25	269	6725	13450	1	
	Managers/Chiefs																	30	5	150	300	1	
	Computer Operators		18	13	234	468	2	18	2	36	72	2	18	8	144	288	2	18	17	306	612	2	
	Total Controller Costs	2			234	468				36	72				144	288				71801	143602		144430
MAINTENANCE	Equipment Maintenance:																						
	Technicians		20	3	60	120	3	20	0	0	0	3	20	2	40	80	3	20	19	380	760	3	
	Engineers		18	2	36	72	3	18	0	0	0	3	18	1	18	36	3	18	9	162	324	3	
	Supervisors		25	1	25	50	3	25	0	0	0	3	25	1	25	50	3	25	6	150	300	3	
	Software Maintenance Programmers		18	6	108	216	4	18	1	18	36	4	18	20	360	720	4	18	13	234	468	4	
	Maintenance Materials and Supplies				100	200	5			25	50	5			50	100	5			400	800	5	
	Building and Grounds Maintenance Personnel		10	2	20	40	6	10	1	10	20	6	10	4	40	80	6	10	5	50	100	6	
	Total Maintenance Costs	2			349	698				53	106				533	1066				1376	2752		4622
EQUIPMENT REPLACEMENT	Cost of Replacement Equipment:																						
	Surveillance Signal Receiver				197	394	8																
	Communication Equipment														162	324	8						
	Displays and Controls																			8399	16798	8	
	Computers/Processors/ Memories				924	1848	8			140	280	8			560	1120	8			1176	2352	8	
	Total Equipment Replacement Cost	2			1121	2242				140	280				722	1444				9575	19150		23116
FLIGHT INSPECTION	Flight Inspection Cost	2	0.300	120	36	72	7	0.300	120	36	72	7	0.300	120	36	72	7	0.300	120	36	72	7	288

TABLE 4.3-3. FEDERAL GOVERNMENT OPERATING AND MAINTENANCE COSTS - REGIONAL CONTROL CENTER (Continued)

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total Annual Cost ($×K)
			Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
OTHER OPERATIONS AND MAINTENANCE	Indirect Personnel:																						
	Office		10	2	20	40	6	10	0	0	0	6	10	2	20	40	6	10	4	40	80	6	
	Security		10	2	20	40	6	10	0	0	0	6	10	2	20	40	6	10	4	40	80	6	
	Employee Services		10	2	20	40	6	10	0	0	0	6	10	2	20	40	6	10	4	40	80	6	
	Others		10	2	20	40	6	10	0	0	0	6	10	2	20	40	6	10	4	40	80	6	
	Site Operating Costs:																						
	Utilities				100	200	9			0	0	9			75	150	9			150	300	9	
	Expendables and Miscellaneous Supplies				100	200	9			0	0	9			50	100	9			485	970	9	
	Total Other O&M Costs	2			280	560				0	0				205	410				795	1590		2560
	Totals	2			2020	4040				265	530				1640	3280				83583	167166		175016

Notes

1. Table 4.3-7. The salaries are obtained from Ref. 1, Table D.2-19, page D-29. This includes a factor for fringe benefits and training. The manager's salaries are an estimate.

2. The computer operators are allocated (rounded to the nearest "whole person") among the functions according to the proportion of the computer hardware allocated to each function (Table 4.2-3, Note 7), that is,

   Surveillance 33% — Communication 20%
   Navigation and Miscellaneous 5% — Control Processing 42%

   The total number of computer operators (40) is given in Table 4.3-8. Salary costs are taken from Ref. 1, Table D.3-11.

3. The equipment maintenance personnel are allocated (rounded to the nearest "whole person") among the functions by the proportion of the F&E equipment cost for each function to the total RCC F&E equipment cost. Using the data in Table 4.2-3,

   Surveillance 12% — Communication 7%
   Navigation 1% — Control Processing 80%

   The total number of equipment maintenance personnel given in Table 4.3-8 is as follows:

   Technicians 24
   Engineers 12
   Supervisors 8

   The salary costs are estimated from Ref. 1, Table D.3-11.

4. The computer programmers are allocated (rounded to the nearest "whole person") among the functions according to the proportion of the computer software allocated to each function (Table 4.2-3, Note 11), that is,

   Surveillance 15% — Communication 50%
   Navigation 1% — Control Processing 34%

TABLE 4.3-3. FEDERAL GOVERNMENT OPERATING AND MAINTENANCE COSTS - REGIONAL CONTROL CENTER (Continued)

The total number of programmers (40) is given in Table 4.3-8. Salary costs are estimated from Ref. 1, Table D.3-11.

5. Based upon Ref. 1, Table D.2-10.

6. The building and grounds maintenance personnel and indirect personnel are allocated (rounded to the nearest "whole person") among the functions according to the proportion of the facilities allocated to each function (Table 4.2-3, Note 3), that is,

Surveillance	20%
Navigation	5%
Communication	30%
Control Processing	45%

The total number of building and grounds maintenance and indirect personnel is given in Table 4.3-8. The salaries are estimated from Ref. 1, Table D.3-11.

7. Ref. 3, page 118. The value shown in the reference for the Satellite Control Center is used here for all functions.

8. Based upon a 7-year equipment life (10 years for computers) and the equipment F&E cost (Table 4.2-3).

9. Based upon Ref. 1, Table D.3-11 and D.2-10. The values shown in the reference for the Satellite Control Center are used here.

TABLE 4.3-4. FEDERAL GOVERNMENT OPERATIONS AND MAINTENANCE COSTS - SATELLITE TRACKING CENTER

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total Annual Cost ($×K)
			Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
CONTROLLER PERSONNEL	Total Controller Costs	7				0	1																0
MAINTENANCE	Equipment Maintenance:																						
	Technicians		20	2	40	280	2																
	Engineers			0	0	0	2																
	Supervisors			0	0	0	2																
	Software Maintenance Programmers			0	0	0	2																
	Maintenance Materials and Supplies				50	350	3																
	Building and Grounds Maintenance Personnel			0	0	0	2																
	Total Maintenance Costs	7			90	630																	630
EQUIPMENT REPLACE-MENT	Cost of Replacement Equipment				13	91																	
	Total Equipment Replacement Costs	7			13	91	5																91
	Flight Inspection Cost	7			0	0	4																0
OTHER OPERATIONS AND MAINTENANCE	Indirect Personnel:																						
	Office				0	0	2																
	Security				0	0	2																
	Employee Services				0	0	2																
	Other				0	0	2																
	Site Operating Costs:																						
	Utilities				50	350	3																
	Expendables and Miscellaneous Supplies				50	350	3																
	Total Other O&M Costs	7			100	700																	700
	Totals	7			203	1421																	1421

TABLE 4.3-4. FEDERAL GOVERNMENT OPERATIONS AND MAINTENANCE COSTS - SATELLITE TRACKING CENTER (Continued)

Notes:

1. No controllers are required at the STC.
2. Table 4.3-8. The salaries are estimated from Ref. 1, Table D.3-11, page D-38.
3. Based upon Ref. 1, Table D.2-10, page D-19. See also Ref. 1, Tables D.3-15 and D.6-4.
4. None required.
5. Based upon a 7-year equipment life and the equipment F&E costs.

TABLE 4.3-5. FEDERAL GOVERNMENT OPERATIONS AND MAINTENANCE COSTS - AIRPORT CONTROL CENTERS

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total Annual Cost ($×K)
			Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
CONTROLLER PERSONNEL	Salary Costs:																						
	Controllers																						
	Primary	100																20	16	320	32000	1	
	Secondary	200																20	11	220	44000	1	
	Feeder	400																20	7	140	56000	1	
	Supervisors																						
	Primary	100																25	4	100	10000	1	
	Secondary	200																25	3	75	15000	1	
	Feeder	400																25	1	25	10000	1	
	Managers/Chiefs																						
	Primary	100																0	0	0	0	1	
	Secondary	200																0	0	0	0	1	
	Feeder	400																0	0	0	0	1	
	Computer Operators																						
	Primary	100	18	0.5	9	900	2											18	1.0	18	1800	2	
	Secondary	200	18	0.33	6	1200	2											18	0.67	12	2400	2	
	Feeder	400	18	0.33	6	2400	2											18	0.67	12	4800	2	
	Total Controller Costs	700				4500					0					0					176000		180500
MAINTENANCE	Equipment Maintenance:																						
	Technicians																						
	Primary	100	20	0.24	4.8	480	3		0	0	0	3	20	0.71	14.2	1420	3	20	0.55	11.0	1100	3	
	Secondary	200	20	0.16	3.2	640	3		0	0	0	3	20	0.47	9.4	1880	3	20	0.37	7.4	1480	3	
	Feeder	400	20	0.16	3.2	1280	3		0	0	0	3	20	0.47	9.4	3760	3	20	0.37	7.4	2960	3	
	Engineers	700		0	0	0	3		0	0	0	3		0	0	0	3		0	0	0	3	
	Supervisors	700		0	0	0	3		0	0	0	3		0	0	0	3		0	0	0	3	
	Software Maintenance Programmers:																						
	Primary	100																18	1.5	24	2400	4	
	Secondary	200																18	1.0	18	3600	4	
	Feeder	400																18	1.0	18	7200	4	
	Continued on next page																						

TABLE 4.3-5. FEDERAL GOVERNMENT OPERATIONS AND MAINTENANCE COSTS - AIRPORT CONTROL CENTERS (Continued)

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total Annual Cost ($×K)
			Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
MAINTENANCE	Maintenance Materials and Supplies:																						
	Primary	100			10	1000	5			5	500	5			10	1000	5			10	1000	5	
	Secondary	200			5	1000	5			2	400	5			5	1000	5			5	1000	5	
	Feeder	400			5	2000	5			2	800	5			5	4000	5			5	4000	5	
	Building and Ground Maintenance Personnel:																						
	Primary	100	10	1	10	1000	6	10	1	10	1000	6	10	1	10	1000	6	10	1	10	1000	6	
	Secondary	200	10	0.4	4	800	6	10	0.4	4	800	6	10	0.4	4	800	6	10	0.4	4	800	6	
	Feeder	400	10	0.4	4	1600	6	10	0.4	4	1600	6	10	0.4	4	1600	6	10	0.4	4	1600	6	
	Total Maintenance Costs	700				9800					5100					16460					28140		59500
EQUIPMENT REPLACEMENT	Cost of Replacement Equipment:																						
	Ground Surveillance System (Trilateration)	25			56	1400	8																
	Ground Surveillance System (IR)	675			5.4	3651	8																
	Communication Equipment	700													22	15640	8						
	Displays and Controls:																						
	Primary	100																		41	4100	8	
	Secondary	600																		10	6000	8	
	Computer/Processor/ Memories	700																		2.3	1600	8	
	Total Equipment Replacement Costs	700				5051					0					15640					11700		32391
FLIGHT INSPECTION	Flight Inspection Cost	700				0	7				0	7				0	7				0	7	0

TABLE 4.3-5. FEDERAL GOVERNMENT OPERATIONS AND MAINTENANCE COSTS - AIRPORT CONTROL CENTERS (Continued)

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total Annual Cost ($×K)
			Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
OTHER O & M	Indirect Personnel:																						
	Office																						
	Primary	100	10	0.5	5	500	6	10	0.5	5	500	6	10	0.5	5	500	6	10	0.5	5	500	6	
	Secondary	200	10	0.4	4	800	6	10	0.4	4	800	6	10	0.4	4	800	6	10	0.4	4	800	6	
	Feeder	400	10	0.4	4	1600	6	10	0.4	4	1600	6	10	0.4	4	1600	6	10	0.4	4	1600	6	
	Security																						
	Primary	100	10	0.5	5	500	6	10	0.5	5	500	6	10	0.5	5	500	6	10	0.5	5	500	6	
	Secondary	200	0	0	0	0	6		0	0	0	6		0	0	0	6		0	0	0	6	
	Feeder	400		0	0	0	6		0	0	0	6		0	0	0	6		0	0	0	6	
	Employee Services and Other	700		0	0	0	6		0	0	0	6		0	0	0	6		0	0	0	6	
	Site Operating Costs:																						
	Primary	100			10	1000	9			6	600	9			10	1000	9			10	1000	9	
	Secondary	200			5	1000	9			2	400	9			5	1000	9			5	1000	9	
	Feeder	400			5	2000	9			2	800	9			5	2000	9			5	2000	9	
	Expendables and Miscellaneous Supplies:																						
	Primary	100			10	1000	9			3	300	9			15	1500	9			15	1500	9	
	Secondary	200			5	1000	9			2	400	9			5	1000	9			5	1000	9	
	Feeder	400			5	2000	9			2	800	9			5	2000	9			5	2000	9	
	Total Other O&M Costs	700				11400					6700					11900					11900		41900
	Totals	700				30751					11800					44000					227740		314291

Notes:

1. Table 4.3-7. The salaries are obtained from Ref. 1, Table D.2-19, page D-29. This includes a factor for fringe benefits and training.
2. The computer operators are allocated among the functions according to the proportion of the computer hardware allocated to each function (Table 4.2-5) that is,

Surveillance	33%	Communication	0%
Navigation and Miscellaneous	0%	Control Processing	67%

The total number of computer operators is given in Table 4.3-8. Salary costs are taken from Ref. 1, Table D.3-11.

3. The equipment maintenance personnel are allocated among the functions by the proportion of the average F&E equipment cost for each function to the average total ACC F&E equipment cost. Using the data in Table 4.2-5:

Surveillance	16%	Communication	47%
Navigation	0%	Control Processing	37%

TABLE 4.3-5. FEDERAL GOVERNMENT OPERATIONS AND MAINTENANCE COSTS - AIRPORT CONTROL CENTER (Continued)

The total number of equipment maintenance personnel is given in Table 4.3-8. The salary costs are estimated from Ref. 1, Table D.3-11.

4. All of the programmers are allocated to the control processing function, as was done for the software costs in Table 4.2-5. The total number of programmers is given in Table 4.3-8. Salary costs are estimated from Ref. 1, Table D.3-11.

5. Average for all airports in the class.

6. The building and grounds maintenance personnel and indirect personnel are allocated among the functions. The total number of building and grounds maintenance personnel is given in Table 4.3-8. The salaries are estimated from Ref. 1, Table D.3-11.

7. Ref. 3, page 118.

8. Based upon a 7-year equipment life (10 years for computers) and the equipment F&E cost (Table 4.2-5).

9. Average costs for all airports in the class.

TABLE 4.3-6. FEDERAL GOVERNMENT OPERATIONS AND MAINTENANCE COSTS - CALIBRATION STATIONS

Cost Element	Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total Annual Cost ($×K)
			Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	
			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
CONTROLLER PERSONNEL	Total Controller Costs	50			0	0	1																0
MAINTENANCE	Equipment Maintenance:																						
	Technicians		20	0.25	5	250	2																
	Engineers			0	0	0	2																
	Supervisors			0	0	0	2																
	Software Maintenance Programmers			0	0	0	2																
	Maintenance Materials and Supplies				2	100	4																
	Building and Grounds Maintenance Personnel			0	0	0	2																
	Total Maintenance Costs	50			7	350																	350
EQUIPMENT REPLACEMENT	Cost of Replacement Equipment				1.4	71	5																71
	Total Equipment Replacement Cost	50			1.4	71																	
	Flight Inspection Cost	50			0	0	3																
OTHER O&M	Indirect Personnel:																						
	Office			0	0	0	2																
	Security			0	0	0	2																
	Employee Services			0	0	0	2																
	Other			0	0	0	2																
	Site Operating Costs:																						
	Utilities				2	100	4																
	Expendables and Miscellaneous Supplies				2	100	4																
	Total Annual O&M Costs	50			4	200																	200
	Totals	50			12.4	621																	621

TABLE 4.3-6. FEDERAL GOVERNMENT OPERATIONS AND MAINTENANCE COSTS - CALIBRATION STATIONS (Continued)

Notes:

1. No controllers are required at the calibration stations.
2. Table 4.3-8. The salaries are estimated from Ref. 1, Table D.3-11, page D-38.
3. None required.
4. Based upon Ref. 1, Table D.3-12, page D-39.
5. Based upon a 7-year equipment life and the equipment F&E cost (Table 4.2-6).

TABLE 4.3-7. CONTROLLER REQUIREMENTS

Site	Per Site Per Day Shift						Per Site							
	Number of Sites	Number of Displays	Controllers Per Display	Total Controllers	Supervisors	Controllers Plus Supervisors	Leave and 7-Day Factor	Shift Factor	Total Controllers	Total Supervisors	Total Controller Staff	Managers	Total Staff Per Site	Total Staff
RCC	2	409 ①	2.0 ②	818	68 ⑥	886	1.58	2.5	3231	269	3500	5 ⑦	3505	7,010
CCC	1	409 ①	2.0 ②	818	68 ⑥	886	1.58	2.5	3231	269	3500	5 ⑦	3505	3,505
Total Enroute Controllers														10,515
ACC														
Primary	100 ③	-	-	4 ④	1	5	1.58	2.5	16	4	20	-	20	2,000
Secondary	200 ③	-	-	3 ④	1	4	1.58	2.0 ⑤	11	3	14	-	13	2,800
Feeder	400 ③	-	-	2 ④	0.5	2.5	1.58	2.0 ⑤	7	1	8	-	8	3,200
Total Airport Controllers														8,000
Total Controllers														18,515

Notes:

①. Assuming 35,000 IAC in 1995, with 20,000 of these "enroute." Of the remaining 15,000, approximately 5.5 percent are landing and under ACC control. The aircraft under RCC control are, therefore,

$$\text{IAC/RCC Total} = 20{,}000 + 15{,}000\ (1 - 0.55) = 32{,}675$$

Since each RCC is responsible for essentially half of these aircraft, the IAC/RCC = 16,338. The CCC must be capable of backing up any RCC, so IAC/CCC = 16,338.

Assuming an automation level such that a controller can monitor 40 aircraft, average peak IAC (see Ref. 5), the number of displays required at each site is:

$$\text{RCC/CCC Displays/Sectors} = 16{,}338/40 = 409$$

TABLE 4.3-7. CONTROLLER REQUIREMENTS (Continued)

(2.) Although the automation level is assumed such that 40 aircraft can be monitored by a controller, it is assumed that the required sector manning level will change little from the planned present system sector design. Using the estimate in Ref. 6, page 3-14, an average of two controllers per sector per shift will be required as follows:

Sector Display monitor: 1.0 man
Sector Coordinator (one for every five sectors): 0.2 man
Sector Planner (four per every five sectors): 0.8 man

Total: 2.0 men per sector

(3.) See Ref. 13. Only the high density feeder airports are assumed to have a control tower.

(4.) With airport tower cab automation, the required staff can be reduced from the present levels (see Ref. 6, Table 2-8). These numbers represent the minimum tower staff required even with a high degree of automation, since at least one controller is required to monitor the runways with a another for ground control and backup, even at the smallest airports.

(5.) The secondary and feeder airports are not manned during the graveyard shift.

(6.) Assumed at a level of 1 supervisor for 10 to 15 controllers, averaging 1 per 12.5 (Ref. 1, Table D.2-14 and D.2-16).

(7.) One manager or chief level for each 200 to 250 staff. The managers are on a one-shift, five-day week.

TABLE 4.3-8. PERSONNEL REQUIREMENTS (EXCLUDING CONTROLLERS)

Site		Per Site Per Day Shift											Per Site											
		Maintenance						Other Personnel					Maintenance						Other Personnel					
	No. of Sites	Computer Operators	Programmers	Technicians	Engineers	Supervisors	Building and Ground Maintenance	Office	Security	Employee Services	Other	Total	Computer Operators	Programmers	Technicians	Engineers	Supervisors	Building and Ground Maintenance	Office	Security	Employee Services	Other	Total	Total Staff
RCC (1)	2	10	10	6	3	2	3	2	2	2	2	42	40	40	24	12	8	12	8	8	8	8	168	336
CCC (1)	1	10	10	6	3	2	3	2	2	2	2	42	40	40	24	12	8	12	8	8	8	8	168	168
STC (6)	7	0	0	1/2	0	0	0	0	0	0	0	1/2	0	0	2	0	0	0	0	0	0	0	2	14
Calibration Station (5)	50	0	0	1/4	0	0	0	0	0	0	0	1/4	0	0	1/4	0	0	0	0	0	0	0	1/4	13
Total Enroute Staff																								431
ACC:																								
Primary	100 (2)	1/3	1/3	1/3	0	0	1	1/2	1/2	0	0	3	1.5	1.5	1.5	0	0	4	2	2	0	0	12	1200
Secondary	200 (2)	1/3	1/3	1/3	0	0	1/2	1/2	0	0	0	2	1	1	1	0	0	1.5	1.5	0	0	0	6	1200
Feeder	400 (2)	1/3	1/3	1/3	0	0	1/2	1/2	0	0	0	2	1	1	1	0	0	1.5	1.5	0	0	0	6	2400
Total Airport Staff																								4800
Total Staff																								5231

Notes:

(1) See Ref. 1, Table D.2-9. The RCC's and CCC of the present concept are assumed to be more complex than the SCC's in Ref. 1, because of the added terminal and approach control activities.

(2) See Ref. 13. Only the high density feeder airports are assumed to have a control tower.

TABLE 4.3-8. PERSONNEL REQUIREMENTS (EXCLUDING CONTROLLERS) (Continued)

(3) The computer operators are shown here even though they may more properly be considered "direct operating" staff along with the controllers.

(4) Includes the 7-day week and leave factor of 1.58 as well as the 3-shift per day factor of 2.5, except for the secondary and feeder airports which are not manned during the graveyard shift.

(5) Assumes that one technician will be required to spend approximately one-quarter of his time servicing or maintaining the calibration station, on a one-shift, five-day week basis. The calibration stations will be located at or near controlled airports and thus be able to share facilities and operating personnel.

(6) Assumes that one technician will be required to spend approximately one-half of his time servicing or maintaining the satellite tracking station. These will be located at the two RCC's, one CCC, and at or near four controlled airports and thus be able to share facilities and operating personnel.

4.3.3 Satellites

The detailed O&M cost estimates for the satellites are presented in Table 4.3-9.

The satellite O&M costs consist basically of the replacement costs, since the operating costs of an orbiting satellite are negligible and are included implicitly as part of the ground system costs. A seven-year typical satellite lifetime is assumed. This procedure uses the initial satellite F&E costs as a basis.

TABLE 4.3-9. FEDERAL GOVERNMENT OPERATIONS AND MAINTENANCE COSTS - SATELLITES

Cost Subelements	No. of Sites	Surveillance					Navigation					Communication					Control Processing					Total Annual Cost ($×K)
		Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	Each Site			Total Annual Cost ($×K)	Notes	
		Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			Unit Cost ($×K)	No. of Units	Site Cost ($×K)			
Geostationary:	6																					
Satellites					463	1				232	1				3939	1				0	1	4634
Launch Vehicles					800	1				400	1				6800	1				0	1	8000
Total					1263	2				632	2				10739	2				0	2	12634
Geosynchronous:	9																					
Satellites					618	1				154	1				2317	1				0	1	3089
Launch Vehicles					800	1				200	1				3000	1				0	1	4000
Total					1418	2				354	2				5317	2				0	2	7089
Totals	15				2681					986					16056					0		19723

Notes:

1. A 7-year satellite life-time is assumed. The average annual replacement cost is therefore 1/7 of the original F&E cost (Table 4.2-23), including the launch vehicle costs.
2. The same apportionment to the functions as was used for the F&E costs (Table 4.2-23, Notes 1 and 3) is used here.

5. USER COSTS

The user costs consist of the cost of purchasing the avionics equipment required to interface with the SAATMS, the cost of installing this equipment, and the annual cost of maintaining the equipment. Only that equipment unique to the SAATMS is considered here. Furthermore, only the cost of the minimum required equipment, particularly for the GA users, is estimated for each class. Installation of additional equipment for redundancy or installation of higher quality equipment is assumed to be at the user's option.

The avionics costs were estimated by examining the major components or asssmblies required to accomplish the function (refer to block diagrams in Volume III), assigning a cost estimate for each part, and then using typical manufacturing and assembly factors to convert the manufacturer's parts cost to his selling price. Large quantity production by competitive manufacturers is assumed. Since units with the desired capability are not currently available, most costs were derived by comparisons with similar equipment, the estimates of potential manufacturers, and educated engineering judgments concerning the cost of a component of the required capability and complexity. The detailed discussions of the cost estimates and their rationale are presented later in this section.

As with the Federal Government costs, the annual user maintenance cost includes a provision for replacing worn-out equipment as well as the cost of maintaining the equipment. This assumes that the operating life (typically 10 years) is less than the SAATMS operating life and the operating life of the aircraft structure itself.

Three basic user classes are defined as follows:

Low Cost General Aviation

Sophisticated General Aviation

Aircarrier

The characteristics of these three classes are described more fully in subsequent paragraphs.

The military users (20,000 in 1995) are excluded from this discussion which is restricted to the civil aviation fleet. The military avionics complement will be equivalent to the aircarrier avionics.

5.1 Summary

Table 5.1-1 presents a summary of the user costs, showing both the cost per aircraft and the cost for the total number of aircraft of each classification. The estimated nominal 1995 demand level of 342,000 total registered aircraft is divided among the three classes as follows:

Low Cost General Aviation: 250,000

Sophisticated General Aviation: 85,000

Aircarrier: 7,000

It should be noted that the maintenance costs are given as average annual costs, while the purchase and installation costs are the one-time-only costs.

Table 5.1-1. Summary of User Costs

Class	Number of Aircraft	Per Aircraft ($)	Total Fleet ($ Millions)
Low Cost General Aviation	250,000		
Purchase and Installation		3,625	906.3
Maintenance		600*	150.0*
Sophisticated General Aviation	85,000		
Purchase and Installation		15,900 (16,250)**	1,351.5
Maintenance		2,650* (3,250)**	225.3*
Aircarrier	7,000		
Purchase and Installation		38,640	270.5
Maintenance		6,440*	45.1*
Total Purchase and Installation	342,000	-	2,528.3
Total Maintenance	342,000	-	420.4*

*Per year; includes equipment replacement cost.

**With optional MLS and Air-Air CAS.

5.2 Avionics Hardware Costs

The costs of major components of the user avionics equipment were estimated separately and then combined to arrive at the total costs for various avionics systems. These cost estimates, and their rationale, are presented in the paragraphs which follow. Table 5.2-1 summarizes these estimates and shows the total costs for various functional combinations of the hardware.

The cost estimates were based upon current technology projected to the 1995 time period. By "current technology" is meant that the techniques are known and demonstrated or are already in use. No radical technological breakthrough is required in order to implement any of the SAATMS avionics equipment. What is assumed, however, is that normal evolutionary progress in avionics component design, development, production, and cost improvement will occur between now and the 1985-1995 implementation time period. This progress, while naturally occurring, will be enhanced and accelerated when the commitment to SAATMS is known and manufacturers of avionics equipment strive to prepare their products for their desired share of the SAATMS avionics equipment market.

Thus, the intent here is not to specify the exact components which will be used in the 1985-1995 equipment but to identify those techniques and devices known today which have a reasonable potential of satisfying the SAATMS avionics performance requirements by 1985-1995 and to estimate their costs in that time period.

Although the various components of the avionics equipment are estimated separately, their costs are not independent. Except for the surveillance transmitter, the costs assume the sharing or multiple use of various circuits or components wherever possible. This is a result of the integrated avionics design philosophy. Thus, the surveillance transmitter is the basic core of the avionics system, and added functions and equipment are "deltas" to the surveillance transmitter hardware and its cost. This concept is illustrated in the manner in which Table 5.2-1 is organized.

Finally, the costs shown here are normally estimated just as "parts costs" and then converted to "selling price." The typical industry factors for converting parts costs to selling price range from 2.0 to 4.0. A factor of 3.5 was assumed here as reasonable and somewhat conservative.

The airborne surveillance/communication transmitter and navigation/communication receiver are shown in the block diagrams of Volume III.

TABLE 5.2-1. SAATMS BASIC AVIONICS COST

Function	Part	Parts Cost ($)	Selling Price ($)	Notes
Surveillance Transmitter	Power Amplifier	100		1
	Clock and Networks	100		1
	Antennas	80		1
	Total	280	980	2
Surveillance and Digital Communica-tion	Power Amplifier	100		1
	Clock and Networks	100		1
	Antennas	80		1
	Non-common Equipment	80		3
	Total	360	1250	2
Surveillance, Digital, and Voice Communication	Power Amplifier	200		4,1
	Clock and Networks	100		1
	Antennas	80		1
	Non-Common Equipment	80		3
	Voice Transceiver	-	895	4
	Subtotal	460	1605	2
	Total		2500	

Function	Part	Parts Cost ($)	Selling Price ($)	Notes
Surveillance, Digital, and Voice Communi-cation and Navigation	Power Amplifier	200		4,1
	Clock and Networks	100		1
	Antennas	80		1
	Non-Common Equipment	110		5,3
	Voice Transceiver	-	895	4
	Navigation Computer/Processor	200		5
	Subtotal	690	2405	2
	Total		3300	
Basic Displays	VVOR Panel and Display, Communi-cation and Conflict Intervention Display	150	525	2,6
	Communication Keyboard			
	Communication Control Panel			
Advanced Displays	Navigation Display Panel and Mode Panel	800	2800	2,7
Air-Air Conflict Avoidance System	Conflict Avoidance System Processor/Display (optional)	400	1400	2,8
Microwave Landing System	Microwave Landing System Receiver/Converter (optional)	-	1600	9

NOTES:

1. See Par. 5.2.1.
2. Typical industry factors for converting estimated parts costs to selling price range from 2.0 to 4.0; a factor of 3.5 is used here.
3. See Par. 5.2.2.
4. See Par. 5.2.3.
5. See Par. 5.2.5.
6. See Par. 5.2.4. Note that the voice communication controls are included in the voice transceiver costs.
7. See Par. 5.2.6.
8. See Par. 5.2.7.
9. See Par. 5.2.8.

5.2.1 Surveillance Transmitter

The surveillance transmitter is the basic and most critical part of the SAATMS avionics system. Of the surveillance transmitter, the critical component is the RF power amplifier. A peak output power of 2 kw at the L-band is required by the SAATMS design, as described elsewhere in this report. There are two possibilities for the RF power stages: ceramic triodes or solid-state devices.

The ceramic triode was investigated as a device currently available at a reasonable price. Discussions were held with the manufacturer of these devices, General Electric (GE) (Ref. 14). GE provided the results of a computer study of a power amplifier. This recommended planar triode device is the Y-1763. The results indicate that the SAATMS requirements could be met with existing devices with proper amplifier design. GE also suggested that the potential SAATMS demand would justify a device specifically tailored to the requirements.

However, the ceramic triodes have their disadvantages, among cost, operating lifetime, and the need for a high voltage power supply. These disadvantages make these triodes a second choice for the SAATMS application. The most promising approaches are those utilizing solid-state devices.

Microwave power transistors are currently available which can provide up to 100 w peak at L-band, priced at around $150 each in quantity. A number of such devices have been paralleled to provide 1 kw peak in a single structure (Ref. 15). With the projected availability of higher power transistors, the 2 kw SAATMS requirement will be achievable. However, the paralleling of more than perhaps four transistors results in an unwieldy, costly "kludge," with problems of matching, phasing, power splitting, and combining.

The most desirable approach is one which employs a single device (or at most two of three in parallel) which meets all of the requirements. Such devices are currently in the advanced development stages. In particular, Varian has demonstrated the feasibility of a printed circuit TWT approach (Ref. 16) at L-band. S-band prototypes have achieved 2 kw peak pulsed power with 8 percent duty and 20 db gain. Funded development (by the Army and Air Force) is presently proceeding in the L-, C-, S-, and X-band frequencies. The following capability at L-band is a current developmental goal:

4 kw peak pulsed, 200 w CW

20 db gain

500 μsec pulse width

25 percent or greater efficiency

The driver stage would have a required power output on the order of 20 w, a level easily achieved even with today's microwave power transistor technology, so that the remainder of the power amplifier should present little problem.

Varian's reported cost analyses show that these TWT devices can be produced in quantity for approximately $50 (Ref. 16). If it is assumed that the remainder of the power amplifier, including driver and connecting circuitry, will cost another $50, the total surveillance transmitter power amplifier cost will be $100, for a selling price of $350. These are the estimates shown in Table 5.2-1.

A rule-of-thumb frequently used states that the clock and networks portion of a transmitter will cost as much as the power amplifier portion. The clock and networks portion will include all clock, repetition rate, identification, code generation, and modulation circuits. Since these are low level and primarily digital circuits, few problems should be encountered in accommodating these circuits on one or more semiconductor chips. The estimate of $100 cost, $350 selling price, is felt to be reasonable for the clock and networks portion of the surveillance transmitter.

Present day antenna prices range from about $15 for the 1090 MHz transponder antenna to about $300 to $400 for the multifunction, streamlined, VHF NAV/COMM atennas. Typically, the price of the appropriate antenna is included in the costs of the NAV/COMM set. The L-band turnstile antenna of the type suggested for the SAATMS application, while not currently in use, should present no significantly greater difficulties in fabrication or mounting than present-day antennas. Accordingly, a cost of $80, selling price of $280, is estimated for the antenna and necessary feeds and connections.

The total selling price for the basic SAATMS surveillance transmitter, as listed in Table 5.2-1, is $980. This is almost double the price of the cheapest, present day, transponders.

5.2.2 Digital Communication

The SATTMS integrated avionics philosophy is implemented by the sharing or multi-use of all avionics equipment and components wherever possible. Thus, the addition of the digital data receiving and transmitting functions to the basic surveillance transmitter requires only the addition of certain "non-common equipment." The surveillance transmitter power amplifier, clock and networks, and antennas will be shared between the surveillance and digital communication functions. The "non-common equipment" will consist of all the additional equipment necessary to add the digital communication receiving and transmitting function.

Since nearly all of the circuits needed to accomplish the digital data transmission capability already exist in the surveillance transmitter described above, the non-common equipment will consist primarily of the L-band front end and other circuits needed to provide the digital data receiving capability.

A microwave integrated circuit transceiver front end was estimated by Texas Instruments at $4 per chip by 1980 in quantities of 1000 (Ref. 17). The total front end was estimated to cost $46 to manufacture, including circulators, IF fitters, mixer, local oscillators, IF amplifier, video amplifier, and pulse amplifier. Other semiconductor manufacturers have such integrated circuits under development also.

A total cost of $80 was therefore estimated for the non-common equipment, which includes the cost of the front end described above and any other required digital transmitting or receiving circuits. This results in a selling price estimate of $1250 for the surveillance and digital communication functions, as tabulated in Table 5.2-1.

It should be noted that the preceding prices do not include the cost of the necessary controls and displays, particularly for the digital communication function. The display costs are estimated separately.

5.2.3 Voice Communication

As for the digital communication capability described above, the addition of the voice communication function requires the addition of certain equipment to the basic surveillance and digital communication avionics. The voice channel RF and IF receiving and transmitting circuits, the audio frequency circuits, and the channel selection circuits are required. In addition, an L-band voice communication power amplifier is required for the transmitting section, in addition to the digital and surveillance system transmitter.

The voice power amplifier peak power requirements are not as stringent as for the digital power amplifier. It is estimated (Volume III of this report) that only 40 w, average, is required. This power level is nearly that available from single microwave power transistors at L-band (20 w CW is commercially available now), so that achieving the required power should present no technological problems. The microwave power transistors are currently selling in the $150 range in quantity. It is anticipated that this cost will drop to the $35 to $70 range by 1985-1995 so that the entire voice power amplifier should cost no more than $100, including the necessary drivers and interconnections.

The remainder of the voice transceiver is identical to the voice transceivers presently used, except for the frequency band (L-band rather than the present VHF). Such transceivers contain all the necessary audio circuits, RF and IF circuits (including power amplifier), channel generation and local oscillator circuits, and the appropriate controls. Accordingly, the cost estimate for this portion of the voice communication equipment is the cost of the equivalent present day voice transceiver. The NARCO COMM 11-A 360-channel voice transceiver is typical of the low priced, general aviation, voice transceivers. Its 1973 selling price is $895 and this is the value listed in Table 5.2-1. This price, it should be noted, includes the cost of an 8 w, VHF transmitter.

The present day VHF communication technology is relatively mature, so that dramatic price decreases are not likely to occur. There is some indication, if units of comparable performance are examined (in spite of the almost continuous change in specifications, packaging, finishes, etc), that the prices of voice transceivers have managed to hold their own even in the face of overall price inflation. This would indicate some price decrease, measured in constant dollars due to technology improvement and/or production efficiency increases. Thus, although a present day price is used for the voice transceiver, it is expected that any possible price decrease in the next 10 to 15 years would be absorbed in the cost of converting the equipment to the higher frequency band. The portion of the cost of the present voice transceiver devoted to the power amplifier would be similarly absorbed, since the power amplifier has been estimated separately.

The net result, as shown in Table 5.2-1, is that the addition of the voice communication functions to the basic surveillance and digital communication equipment adds a delta of $1250 to the selling price. This results in a total of $2500 for the surveillance, digital, and voice communication functions, excluding the surveillance and digital communication controls and displays. (The voice controls are priced with the voice transceiver.)

5.2.4 Basic Displays

The displays are one area where the technology is now available to make the required displays at a reasonable cost. The costs presented here assume extensive use of advanced forms of liquid crystal displays, of the type used on present day electronic calculators. Most of the prices for the display components were obtained directly from the Microelectronics Division of Rockwell International, one of the largest producers of electronic calculator components and finished units. These represent the typical manufacturing costs for components made in-house or purchase costs for items obtained from suppliers.

Table 5.2-2 shows the display cost estimate. Costs are estimated for the Virtual VOR (VVOR) panel, the conflict intervention display, and the communication display. The VVOR panel is that shown in Volume I of this report. Tentative configurations were postulated for the conflict intervention display (lights and arrows defining conflict sector and avoidance command) and the communication display (approximately 20 "canned" message legends, used singly or in combination).

It should be noted that the prices given in Table 5.2-2 are 1973 prices. These prices are expected to drop by the 1985-1995 time period. However, the difference could be considered absorbed in reliability and life improvements and in rating these components for the flight environment, even though the displays are a rather low-stress item compared to, for example, the transmitter power amplifiers.

The total basic displays cost is estimated at $150 with a selling price of $525, as shown in Tables 5.2-2 and 5.2-1.

Table 5.2-2. SAATMS Basic Display Cost

Number Required	Part	1973 Cost ($)	Basis
Virtual VOR Panel			
1	Keyboard	3.50	Quote: Rockwell Microelectronics Purchasing
24	Liquid Crystal Displays at $0.50 a digit	12.00	Quote: Rockwell Microelectronics Marketing
1	Toggle Switch	1.00	Typical, Allied Electronics
7	Indicator Buttons:		
	Buttons	-	Included in keyboard cost
	Legends: Liquid Crystal Displays at $0.50 each	3.50	Quote: Rockwell Microelectronics Marketing
1	"Meter" Display	3.17	$\pm$15 deg = 31 Liquid Crystal Segments at $0.07 each plus 2 legends at $0.50 each
4	Liquid Crystal Display Driver Chips at $6.00 each	24.00	Quote: Rockwell Microelectronics Marketing
1	Interface/Logic Chip	12.00	Quote: Rockwell Microelectronics Marketing
Intervention Display			
36	Light-Emitting Diodes at $0.10 each	3.60	Monsanto ad in Electronic News, June 25, 1973
5	Liquid Crystal Display Arrow Legends at $0.50 each	2.50	Quote: Rockwell Microelectronics Marketing
1	Light-Emitting Diode	6.00	Quote: Rockwell Microelectronics Marketing
1	Liquid Crystal Display Chip	6.00	Quote: Rockwell Microelectronics Marketing

Table 5.2-2. (continued)

Number Required	Part	1973 Cost ($)	Basis
Communication Display			
20	Liquid Crystal Display Message Legends at $0.50 each	10.00	Quote: Rockwell Microelectronics Marketing
2	Liquid Crystal Display Driver Chips at $6.00 each	12.00	Quote: Rockwell Microelectronics Marketing
	Case/Connectors/Power Supply	50.00	Typical
	Total Parts Cost	$149.27	
	Selling Price:	$525.00	Parts × 3.5

5.2.5 Navigation Processor

The storage requirements, program, and data for the airborne satellite navigation processor are estimated at 3100 words, including executive (see Volume III). This is for an 8-state Kalman filter. The airborne compuational requirements can therefore be handled by a computer/processor similar to the present day mini-computers. For example, the Computer Automation "Naked Mini" is a 4,000, 16-bit mini-computer on a single circuit board. It is priced now at $990 in quantities of 200 (Ref. 18). It lacks only a power supply and chassis. The necessary controls and displays are provided by the advanced displays, priced below.

The costs of mini-computers and computer components (logic and memory) have dropped drastically in the past few years. There has been, for example, a 5-to-1 reduction in the price of complete mini-computers in the past 5 years, with the "Naked Mini" the latest entry in the field.

Therefore, assuming a continuing price reduction in the cost of mini-computers in the next decade and allowing for the basic power supplies and mounting or chassis, the cost of the navigation computer/processor is estimated at $200 with a selling price of $700, as shown in Table 5.2-1.

In addition, an allowance is made for the necessary navigation signal interfacing and pre-processing circuits in the receiver. These would be primarily digital integrated circuits. Thus, the "non-common equipment" costs are increased by $30 with a selling price of $100, as shown in Table 5.2-1.

The total delta cost for the addition of the satellite navigation capability to the basic surveillance, digital, and voice communication transceiver is $230 with a selling price of $800, as shown in Table 5.2-1.

5.2.6 Advanced Displays

With the addition of the satellite navigation capability described in the previous paragraph, the user makes a significant jump in the capability and sophistication of his equipment. The advanced displays provide him with the displays and controls appropriate to the added capabilities.

For example, the basic equipment, including the basic displays, provide the low cost Virtual VOR navigation and steering. The addition of the navigation processor provides the capability for a completely self-contained (except for the satellite navigation signals) area navigation mode. At the very least, the user will want displayed his present position (latitude, longitude, altitude), velocity (ground speed), heading, ground track, destination coordinates, and destination distance, bearing, and time-to-go. In addition, he requires a navigation mode selection and indication capability (Virtual VOR or satellite navigation), course selection, update and/or initialization, route sequence, and destination or way point entry, selection, and readout. The advanced displays may also include a more sophisticated conflict intervention display and communication display. Providing displays and controls the the above capabilities is the function of the advanced displays.

A preliminary design for the advanced displays has not been made. However, it is anticipated that extensive use of advanced display components (such as liquid crystals) and digital logic devices (for display driving, interfacing, encoding, decoding, and pre-processing) will be made. A cost of $800, selling price $2800, is therefore estimated for the advanced displays which would provide the capabilities described above. These estimates are shown in Table 5.2-1.

5.2.7 Air-Air Collision Avoidance System

The cost of a simple, optional, air-air collision avoidance system which interfaces with the basic surveillance and digital communication equipment is estimated at $400 cost, $1400 selling price. This includes the necessary data processor and cockpit display and is in addition to the conflict intervention display already provided.

5.2.8 Microwave Landing System

The design and costing of the optional Microwave Landing System (MLS) which might be used with the SAATMS avionics equipment was not a part of this effort. However, an estimated price of $1600 was used, for reference, for a simplified MLS receiver/coverter/processor which interfaces with the remainder of the avionics equipment and shares equipment or displays wherever possible (see, for example, Ref. 8).

5.3 Low Cost General Aviation User

The low cost general aviation user is defined as the typical, private pilot, general aviation user who makes up the bulk of the total aviation fleet. This class carries only the minimum avionics equipment required to interface with the SAATMS. This equipment will be the lowest priced for all available avionics equipment, devoid of capabilities and extras which are not required for participation in the SAATMS. The equipment consists of:

(1) Surveillance Signal Transmitter

(2) Digital Data Transceiver

(3) Voice Transceiver

(4) Basic Displays and Controls:

 (a) VVOR Panel and Display

 (b) Communication and Conflict Display

 (c) Communication Data Entry Keyboard

 (d) Communication Control Panel

Table 5.3-1 summarizes the avionics cost for the low class user.

Table 5.3-1. Low Cost General Aviation User Avionics Costs

Cost Element	Cost Subelements	Unit Cost ($)	Number of Units Required	Cost Per Aircraft ($)	Notes
Purchase	Surveillance, Digital and Voice Communication	2500	1	2500	1
	Basic Displays	525	1	525	1
	Total Purchase Cost			3025	
Installation	Installation Cost	-	-	600	2
Maintenance	Maintenance and Repair (per yr)	-	-	300	3
	Equipment Replacement (per year)	-	-	300	3
	Total Maintenance Cost (per year)	-	-	600	

Notes:

1. Table 5.2-1.
2. Twenty percent of the equipment cost is the typical industry allowance for installation cost.
3. Ten percent of the original equipment cost per year is a typical allowance for annual maintenance costs.
4. Ten percent of the original equipment cost per year. This assumes an average equipment life of 10 years.

5.4 Sophisticated General Aviation User

The sophisticated general aviation user is defined as the general aviation user who has a larger, more expensive, better equipped, and, probably, multi-engine aircraft. Most business aircraft would be in this category as would most privately owned jet aircraft. This class user carries the same minimum avionics equipment as does the low cost general aviation user but carries two of each as well as additional equipment with added capabilities. In particular, he would include a navigation processor to receive and use the satellite navigation signals, additional displays for navigation, conflict intervention, and possible air-to-air communications, and he may carry an air-to-air collision avoidance system processor and display as optional equipment.

The sophisticated general aviation user equipment consists of the following:

(1) Surveillance Signal Transmitter

(2) Digital Data Transceiver

(3) Voice Transceiver

(4) Basic Displays and Controls

  (a) VVOR Panel and Display

  (b) Communication Display

  (c) Communication Data Entry Keyboard (also used for Navigation Data Entry)

  (d) Communication Control Panel

(5) Navigation Receiver/Processor

(6) Advanced Displays

  (a) Navigation Display Panel

  (b) Model Select Panel

(7) Air-Air Conflict Avoidance System Processor and Display (optional)

Table 5.4-1 summarizes the avionics cost for sophisticated general aviation user.

It is interesting to note that in SAATMS the general aviation user average avionics purchase cost (based on the projected percentage distribution of the low cost and sophisticated users) is $5600. This value compares to an equivalent general aviation user average avionics cost in the present system (1973) of $6365 and to the average general aviation user avionics cost for new aircraft purchased in 1972 of $9109 (see Section 2.5 of Volume VI).

5.5 Aircarrier User

The aircarrier aircraft will be equipped with the highest capability, top-of-the-line avionics. The equipment complement is identical to that carried by the sophisticated general aviation user except at least two of each component will be carried for full redundancy, and the equipment will be fully ruggedized, ARINC quality.

Table 5.5-1 summarizes the avionics cost for the aircarrier user.

Table 5.4-1. Sophisticated General Aviation User Avionics Costs

Cost Element	Cost Subelements	Unit Cost ($)	Number of Units Required	Cost Per Aircraft ($)	Notes
Purchase	Surveillance, Digital, and Voice Communication and Navigation	3300	2	6600	1
	Basic Displays	525	2	1050	1
	Advanced Displays	2800	2	5600	1
	Air-Air- CAS (Optional)	(1400)	1	(1400)	1
	MLS (Optional)	(1600)	1	(1600)	1
	Total Purchase Cost	-	-	13250 (16250)	
Installation	Installation Cost			2650 (3250)	2
Maintenance	Maintenance and Repair (per year)	-	-	1325	3
	Equipment Replacement (per year)	-	-	1325	4
	Total Maintenance Cost (per year)	-	-	2650	

Notes:

1. Table 5.2-1.
2. Twenty percent of the original equipment cost is the typical industry allowance for installation cost.
3. Ten percent of the original equipment cost is a typical allowance for annual maintenance costs.
4. Ten percent of the original equipment cost. This assumes an average equipment life of 10 years.

Table 5.5-1. Aircarrier User Avionics Costs

Cost Element	Cost Subelements	Unit Cost ($)	Number of Units Required	Cost Per Aircraft ($)	Notes
Purchase	Surveillance, Digital, and Voice Communication, and Navigation	6600	2	13200	1
	Sophisticated (Aircarrier) Displays	4200	2	8400	2
	Air-Air CAS	2100	2	4200	2
	MLS	3200	2	6400	1
	Total Purchase Cost			32200	
Installation	Installation Cost	-	-	6440	3
Maintenance	Maintenance and Repair (per year)	-	-	3220	4
	Equipment Replacement (per year)	-	-	3220	5
	Total Maintenance Cost (per year)	-	-	6440	

Notes:

1. Table 5.2-1. The table values are multiplied by 2 to arrive at the estimated cost of airline-grade avionics; 100 percent backup is also assumed.
2. The sophisticated displays (for the aircarrier) are estimated to cost 1.5 times the advanced displays listed in Table 5.2-1. They also perform the functions provided by the basic displays. The same factor is used for the Air-Air Collision Avoidance System.
3. Twenty percent of the original equipment cost is the typical industry allowance for installation cost.
4. Ten percent of the original equipment cost per year is a typical allowance for maintenance.
5. Ten percent of the original equipment cost per year. This assumes an average equipment life of 10 years.

6. POTENTIAL COST SAVINGS

The cost estimates presented thus far have been for the postulated basic SAATMS. A number of areas has been identified which have the potential of further reducing the estimated SAATMS costs or of reducing the total, combined cost of implementing the SAATMS and phasing out the GAATMS. Refer also to the discussion in Par. 8.5 of this volume.

6.1 Space Shuttle

The advent of the space shuttle has the potential of significantly reducing the satellite launching costs of the SAATMS. Satellite launches by a standard booster were assumed for the cost estimates. This results in a cost per pound in orbit ranging from $4,000 to $15,000. Launch cost estimates per pound for the shuttle are approximately $160 for low earth orbit. However, a trans-stage or "space tug" will be required to position the satellites in geostationary or geo-synchronous orbit, thus increasing the net cost per pound. The shuttle costs also assume a full load for each flight. Requiring a shuttle flight with only a partial load will increase the average costs and reduce the cost advantage of a shuttle over a single launch vehicle. Each shuttle launch is estimated to cost $11.5 million (Ref. 12) compared to the standard launch vehicle cost of approximately $28 million.

Nevertheless, if it is assumed that the shuttle flights can be optimally scheduled for full loads, thus spreading the launch costs, it seems reasonable to estimate in-orbit launch costs for the SAATMS satellites in the vicinity of $1400 per pound, including the space tug. This would result in total F&E launch costs of $16.6 million for the geostationary satellites and $9.5 million for the geo-synchronous satellites (using the estimated satellite weights shown in Table 4.2-24), resulting in a total F&E cost savings of approximately $57.8 million. This savings represents a launch cost reduction factor of approximately 3.2 times.

The space shuttle is not now scheduled to be operational until 1985. Since the satellites are among the first components of the SAATMS to be placed into service, it does not appear that the space shuttle will be fully operational in time for launching the initial complement of operational satellites. The satellites are currently planned for emplacement in the 1980-1982 time frame (see the Transition Plan, Volume VI). Therefore, with current shuttle funding and schedule plans, it is doubtful if the shuttle's full cost benefits can be realized for the initial satellite launches. The R&D satellites will still have to be launched with individual, standard, launch vehicles.

A second-order benefit of the space shuttle may be that the lower launch cost and reduced limitation on spacecraft size and weight may permit greater liberties with the design of the spacecraft, thus reducing the engineering and fabrication costs. A tradeoff between these costs may also result in an overall saving, keeping in mind the potential shuttle schedule constraints previously discussed.

6.2 Microwave Landing System

The SAATMS capabilities can impact the design requirements of the proposed MLS. While the SAATMS navigation accuracies will not provide the precision required for landing guidance to touchdown, SAATMS will enhance the capability of the user to intercept the MLS azimuth and elevation beams. This capability will permit a relaxation in the MLS azimuth, elevation, and range coverage requirements. MLS coverage may be needed only to 5 to 10 nmi from the end of the runway and over an angle of perhaps 10 to 20 deg on either side of the runway centerline, as compared to 20 to 30 nmi and 20 to 60 deg for the currently proposed MLS (see Ref. 11). The user still would have the capability for selecting linear or curved approach profiles, or combinations of these, using data provided by the SAATMS navigation function.

In addition, the requirement for missed approach MLS coverage can be relaxed because of the SAATMS surveillance and navigation coverage capability which would provide the user guidance for a repeated landing attempt (or for departure guidance upon takeoff).

The impact of the SAATMS capabilities may thus result in lower cost MLS installations. The exact sensitivity of the MLS costs to the requirements mentioned above is not yet available, but some insight into the magnitude of the cost savings can be gained by examining the estimated MLS costs and numbers of systems listed in the FAA 10-year plan (Ref. 2). The estimated MLS costs and values are presented in Table 6.2-1.

Table 6.2-1. Estimated Microwave Landing System Costs

Configuration	Number	Unit Cost ($)	Total Cost ($ Million)
Category I	709	128,000	91
Category II	209	326,000	68
Category III	44	585,000	26
Total	962		185

If it is assumed that relaxing the MLS requirements as previously described will reduce MLS costs by 20 to 30 percent, a total procurement cost saving of $37 million to $55 million could be achieved. It may also be possible to completely eliminate Category I MLS installations, based on the use of approach guidance with the VVOR service of the SAATMS. According to Ref. 2, the FAA currently envisions that 359 Category I MLS systems will be implemented after 1982. If these units were not required based on the use of VVOR approach guidance, a cost savings of $46 million would result.

6.3 Remote Airports

Remote airports are defined as those airports which do not have the quality of surveillance coverage available in the major terminal areas. SAATMS will provide essentially the same surveillance coverage and accuracy for all airports, regardless of distance from major traffic centers. Therefore, it will not be necessary to install additional surveillance radars to provide adequate coverage at the remote airports should increased operations at these airports make the improved coverage desirable in the future. The cost savings, while obvious, are difficult to quantify. However, some insight into the potential savings can be gained by using the data in the FAA 10-year plan (Ref. 2).

A new airport surveillance radar (ASR/ATCRBS) now costs approximately $1.9 million. The 10-year plan projects 92 such new radars in the 1973-1982 time period or approximately 9 per year. It is further planned to refurbish the old radars which are replaced by the new ASR/ATCRBS installations and move them to more remote locations. If SAATMS eliminates the need for such improvements or permits the postponement of these improvements in anticipation of the installation of SAATMS, an approximate savings of $17 million per year could be realized.

7. SYSTEM COST COMPARISONS

This section presents the results of several comparisons of the estimated costs of the SAATMS with the proposed GAATMS. All SAATMS cost data are taken directly or derived from the data in the preceding sections. The GAATMS data are obtained from Ref. 1, Volume 3, or Ref. 2 of this volume.

7.1 Controller Backup

The SAATMS control concepts are based upon centralized conflict intervention (two RCC's), centralized controller backup (at the CCC), and a high degree of data mobility to permit the transference of real time aircraft control from an RCC to the CCC during an overload or emergency situation. These concepts result in a significantly fewer number of required controllers than a control concept which employs a large number of control centers, with very limited data mobility, and provisions for transfer of control. Essentially, the latter concept requires 100 percent controller backup; i.e., the system needs two controllers for each function to provide the needed backup. The SAATMS concept places the backup controller at the CCC, with the capability of standing in for the corresponding controller at either RCC. Thus, only 1.5 controllers are required, on the average, for each control function.

Figure 7.1-1 plots the costs of the two concepts against the number of controlled aircraft per center. The costs are based upon data in Section 4.3. The 40-aircraft-per-sector value is the nominal chosen by TSC direction for the SAATMS costing effort. The number of controllers necessary for the SAATMS is a function of both the degree of centralization and the automation philosophy selected. The use of fail-safe control and interchangeable surveillance and navigation data should allow a different, more efficient, automation philosophy to be utilized. The 10-aircraft-per-sector value represents the higher bound of typical, present day numbers of controlled aircraft per sector, while the 80-aircraft-per-control-sector is probably the achievable limit within the present philosophy assuming full automation aids. This point is discussed again in a later section.

The cost advantage of the SAATMS backup concept is clear from Fig. 7.1-1. The cost savings translate directly into annual O&M costs and are the more significant because the controller costs represent the major portion (70 to 80 percent) of the total system O&M costs.

7.2 Comparison of SAATMS and GAATMS Life Cycle Costs

7.2.1 SAATMS Costs

Figure 7.2-1 presents a plot of the SAATMS total annual expenditures as well as the R&D, F&E, and O&M portions of the total. Table 7.2-1 presents these data in tabular form. The F&E and O&M costs are divided into those associated with the Surveillance, Navigation, and Communications (SNC) functions and those associated with only the control function.

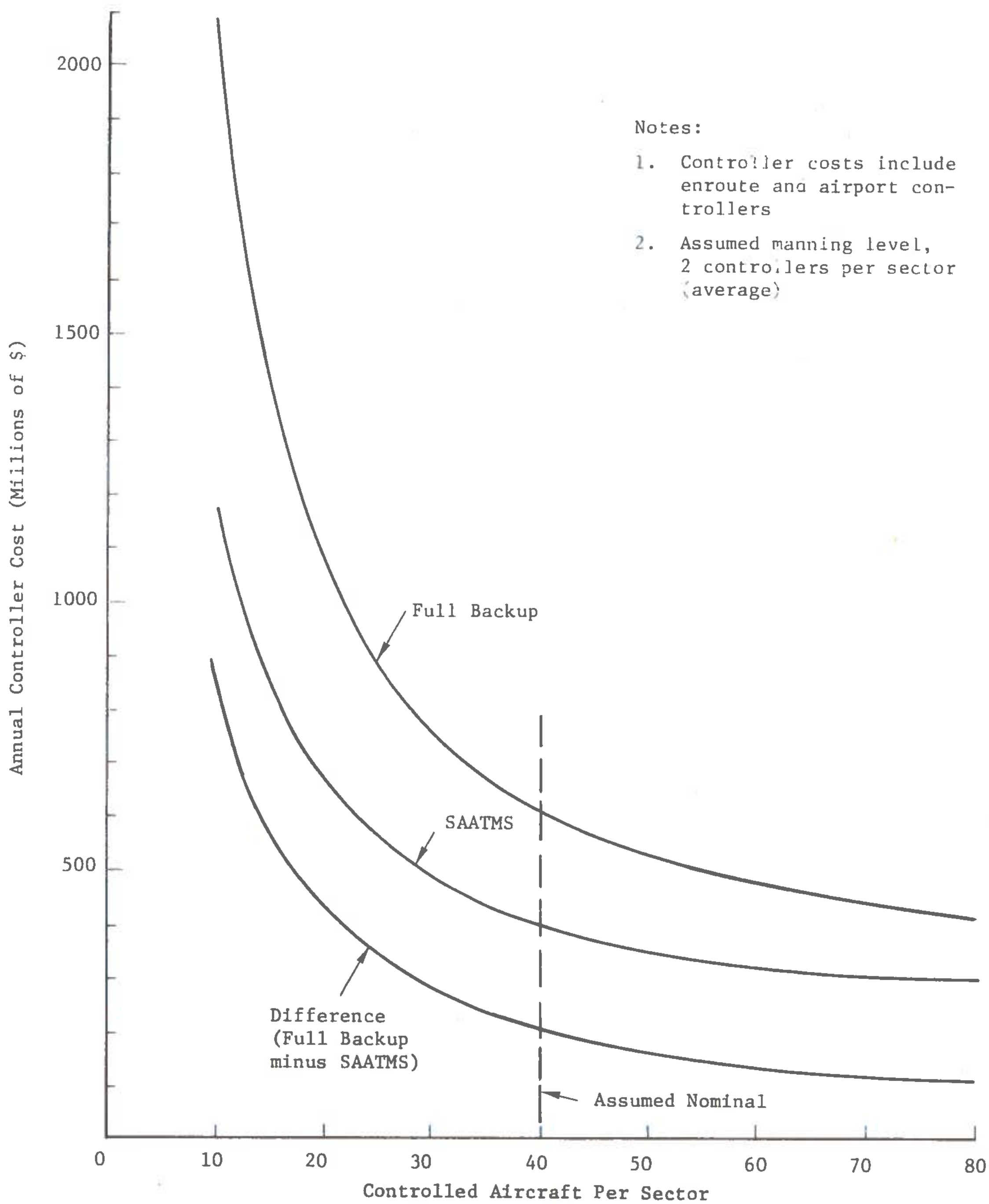


Figure 7.1-1. Annual Controller Cost Vs. Controlled Aircraft Per Sector

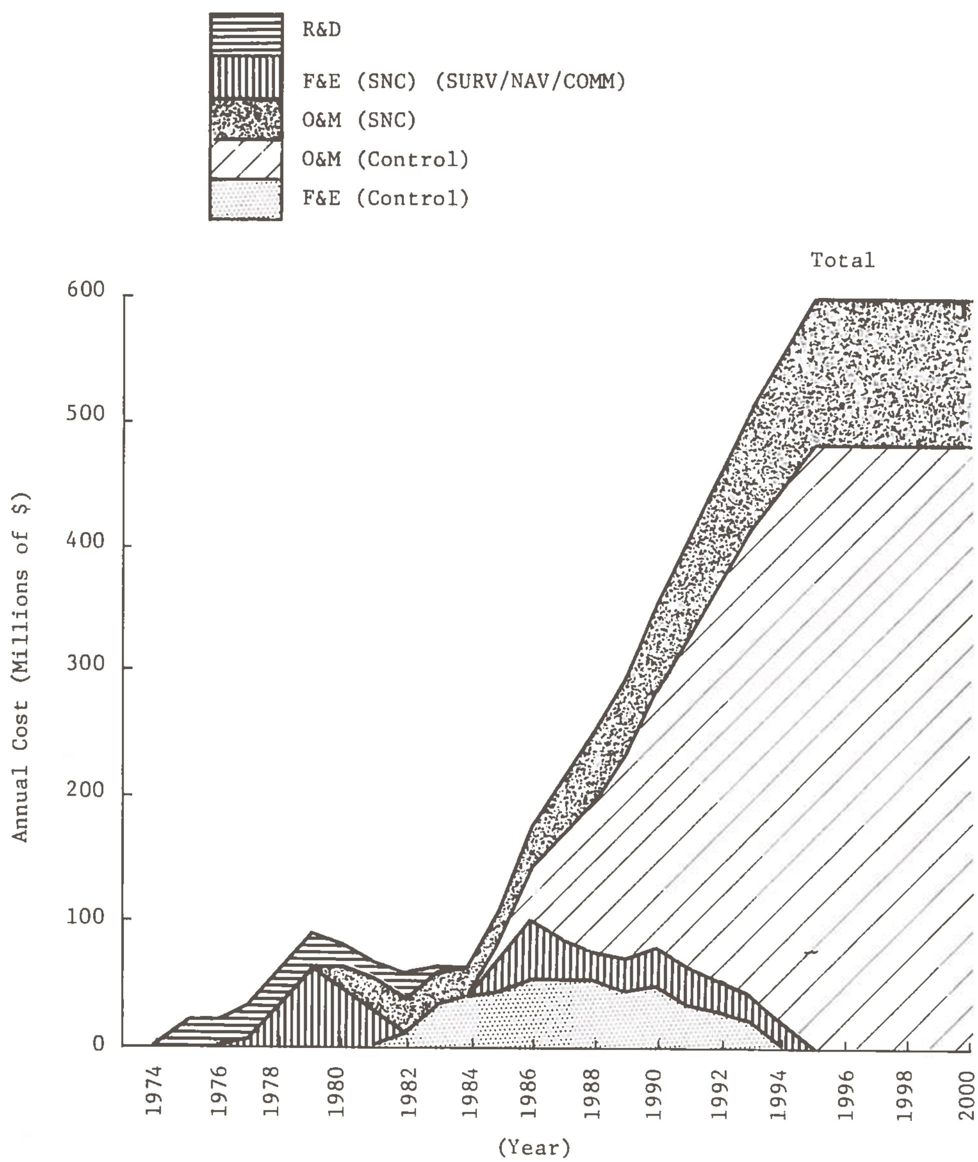


Figure 7.2-1. SAATMS ANNUAL COSTS (Year 1995 Implementation)

TABLE 7.2-1 SAATMS ANNUAL COSTS (YEAR 1995 IMPLEMENTATION)

Year	R&D	F&E			O&M			Annual Total	Cumulative Total
		Control	SNC	Total	Control	SNC	Total		
1975	22							22	22
1976	22							22	44
1977	27		14	14				41	85
1978	29		39	39				68	153
1979	25		67	67		4	4	96	249
1980	18		44	44		21	21	83	332
1981	12		29	29		26	26	67	399
1982	20	10	1	11		27	27	58	457
1983	3	30		30		27	27	60	517
1984		40		40		27	27	67	584
1985		45	30	75	16	27	43	118	702
1986		50	55	105	44	34	78	183	885
1987		50	40	90	83	47	130	220	1105
1988		45	20	65	122	55	177	242	1347
1989		45	25	70	165	63	228	298	1645
1990		40	30	70	208	71	279	349	1994
1991		35	25	60	263	80	343	403	2397
1992		30	25	55	318	90	408	463	2860
1993		22	20	42	373	100	473	515	3375
1994		10	10	20	428	110	538	558	3933
1995					479	121	600	600	4533
1996					479	121	600	600	5133
1997					479	121	600	600	5733
1998					479	121	600	600	6333
1999					479	121	600	600	6933
2000					479	121	600	600	7533
Totals	178	452	474	926	4894	1535	6429	7533	7533

Note: All costs in millions of dollars

The time phasing of the expenditures is based upon the transition schedule and concepts described in Volume VI, Section 3. The proposed schedules and phasing for the year 1995 phase-in of SAATMS are reproduced here in Tables 7.2-2 and 7.2-3.

7.2.2 GAATMS Costs

In order to provide a comparison of the estimated annual SAATMS costs with the GAATMS, the phased, annual costs for the latter system were developed. The GAATMS R&D and F&E costs and time phasing were obtained from the Rand report (Ref. 3), although these estimates are very similar to those shown in the previous study report (Ref. 1). These data are plotted in Fig. 7.2-2 and are tabulated in Table 7.2-4. As the latter reference cautions, the division between the GAATMS R&D and F&E expenditures is somewhat arbitrary and it is most meaningful to consider the sum of the two when comparing system concepts. The indicated R&D and F&E expenditures assume the GAATMS will evolve to essentially a "mature" configuration by 1985 and all subsequent expenditures will be those for O&M.

In order to keep the comparisons on an equivalent basis as much as possible, the GAATMS O&M costs were reestimated to eliminate non-applicable costs (such as the Flight Service Stations, etc). The FAA 10-year plan (Ref. 2) contains estimates of the number of controllers required through 1982. These estimates assume a controller productivity increase of 5 percent per year (after 1977) based upon (1) completion and operational implementation of the basic Third Generation ATC System which consists of ARTS and NAS Stage A and (2) the introduction of the GAATMS with such refinements as metering, spacing, and conflict prediction and resolution.

With these improvements, the required number of controllers increases only slightly in the post-1977 time frame, in spite of the increase in active aircraft. The FAA's rate of increase was assumed to hold and was projected through the year 2000 for the purposes of the comparisons here. In order to eliminate the effects of inflation (salary increases), a constant average controller salary of $20,000 was used for the GAATMS, as was assumed for the SAATMS cost estimates. The controller costs in Table 7.2-4 are the result.

Similarly, the maintenance personnel costs were reestimated. A constant $20,000 average salary for maintenance personnel was also assumed. A fixed cost of $50 million was added to account for miscellaneous other non-personnel O&M expenses (utilities, supplies, equipment replacement, etc). The sum of the maintenance and the miscellaneous costs are listed under "other O&M" in Table 7.2-4.

TABLE 7.2-2. SURVEILLANCE/COMMUNICATION/NAVIGATION FACILITIES TRANSITION SCHEDULE (YEAR 1995 IMPLEMENTATION)

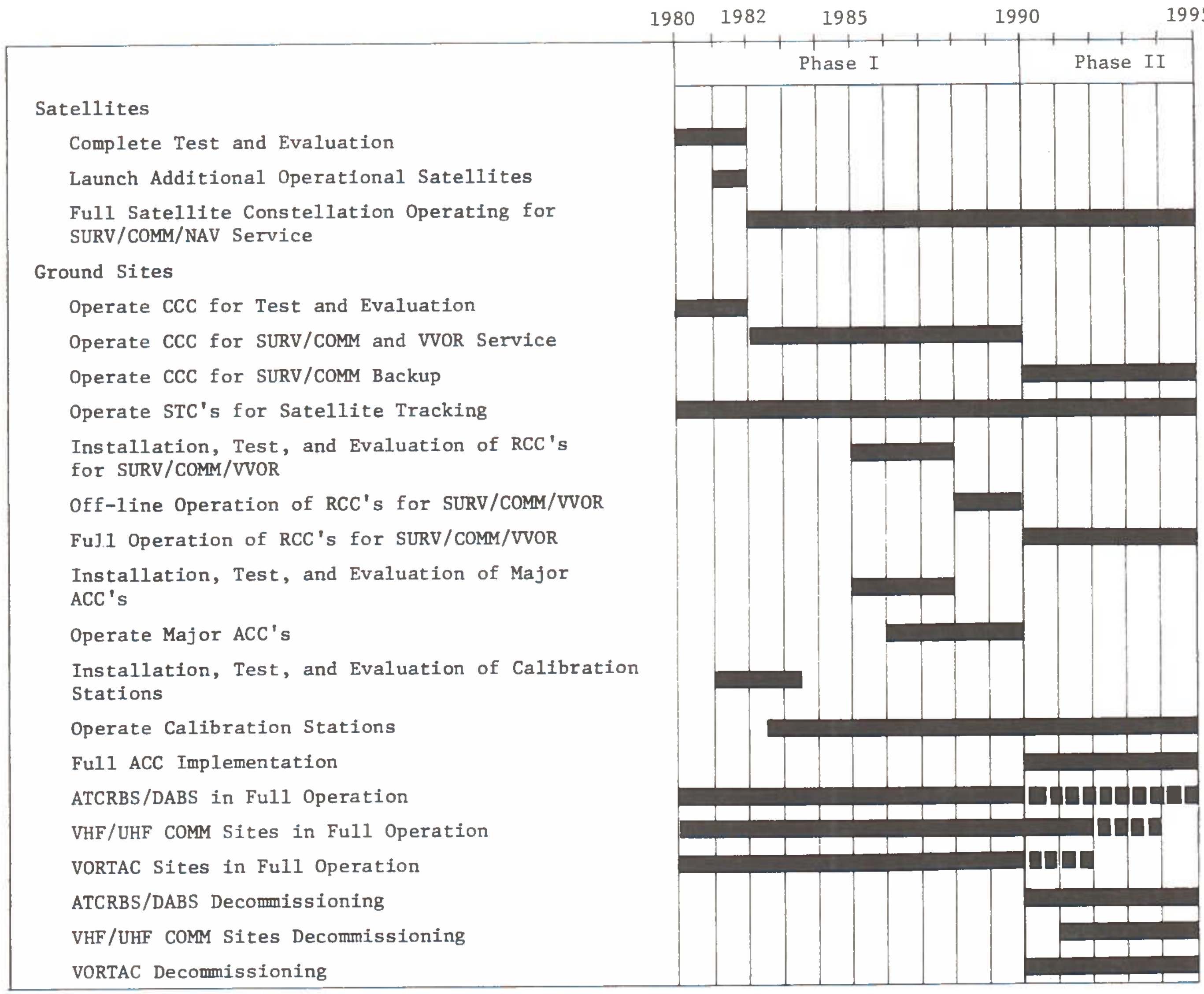
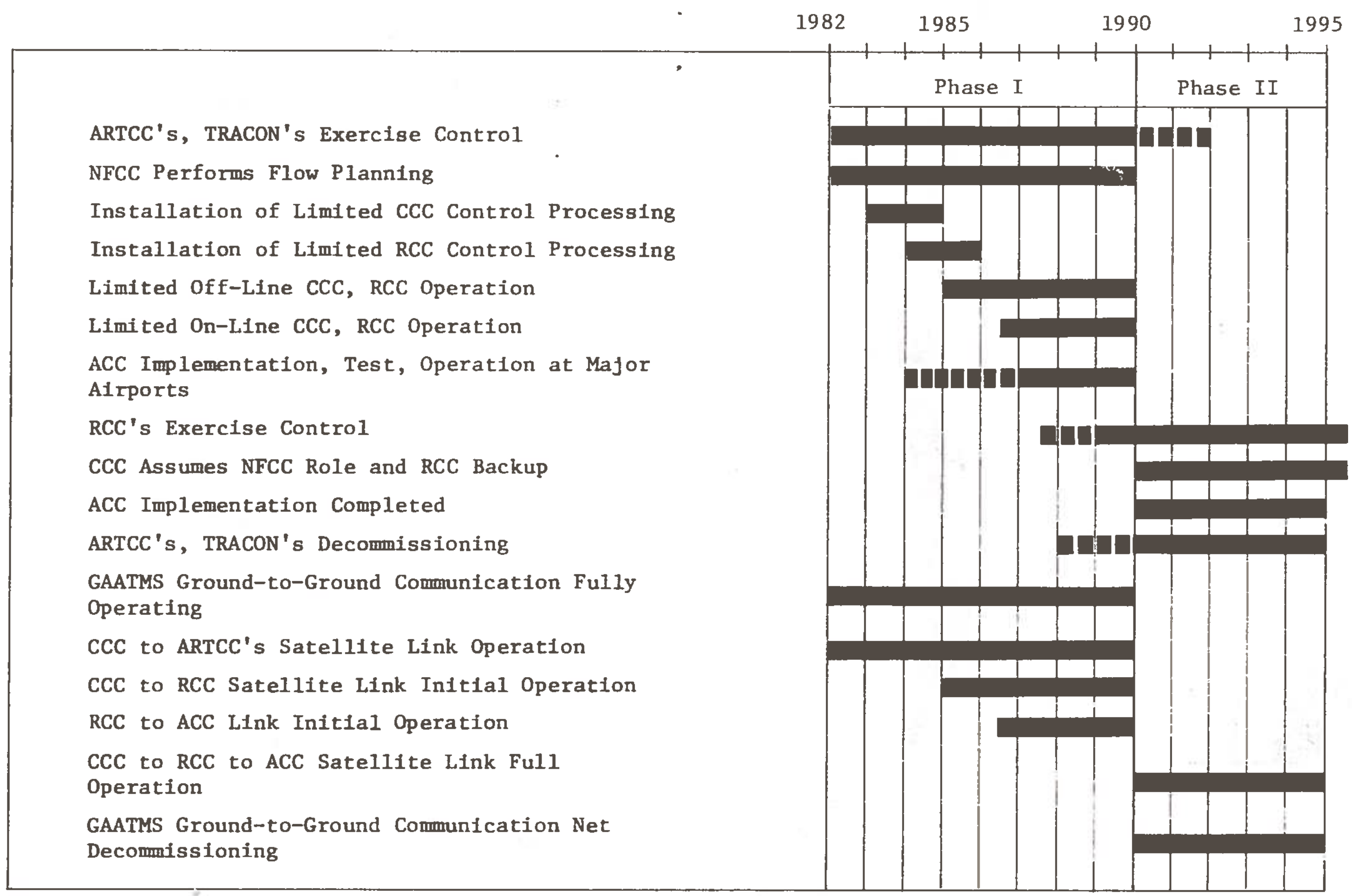


TABLE 7.2-3. CONTROL PROCESSING AND GROUND-TO-GROUND COMMUNICATION TRANSITION SCHEDULE (YEAR 1995 IMPLEMENTATION)



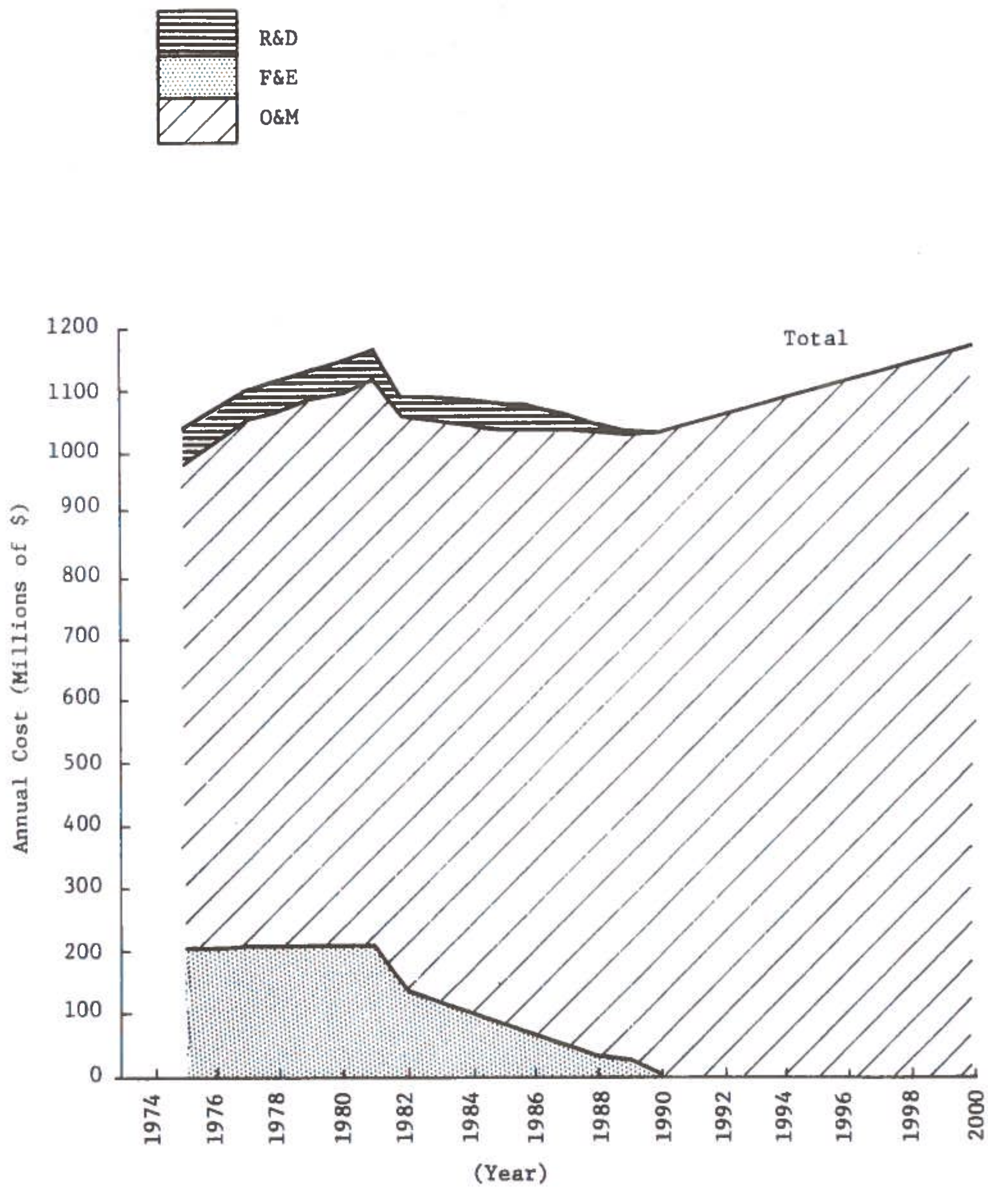


Figure 7.2-2. GAATMS Annual Costs

7.2.3 Combined System Costs

Figure 7.2-3 presents a plot of the total annual expenditures of both systems. The difference between the two systems is most noticeable after 1995, where the costs are entirely O&M costs. The GAATMS requires an estimated $1100 million for O&M, while the SAATMS requires $600 million, a difference of $500 million per year. Since the O&M costs are almost entirely controller and maintenance personnel costs, the difference reflects the lower number of controllers estimated to be required for the SAATMS and the lower number of maintenance personnel required to service and maintain the SAATMS. The concentrated nature of the SAATMS facilities (no enroute facilities, remote radars, navigation aids, etc) should enhance the maintainability of the system facilities and contribute to reduced maintenance.costs.

The total cost of implementing the SAATMS, given the "in-being" GAATMS, can be estimated by superimposing the costs for the SAATMS and the GAATMS according to the Transition Plan in Volume VI. As the SAATMS facilities reach operational capability and can assume control of portions of the airspace, the equivalent control facilities can be decommissioned. However, all GAATMS surveillance, communication, and navigation facilities must remain active during most of the transition phase, even though the control function has been assumed by SAATMS facilities and controllers, until all user aircraft in the region have converted to SAATMS avionics. Thus, the GAATMS maintenance expenditures will be required until the transition is complete. Table 7.2-5 presents the GAATMS costs if the SAATMS is phased-in. Figure 7.2-4 is a plot of these costs. The total is also shown in Fig. 7.2-3 (lower dashed curve) for comparison. Table 7.2-6 presents a tabulation of combined costs, based upon the data in Tables 7.2-1 and 7.2-5. The major portion of the transition occurs between 1990 and 1995. The SAATMS is assumed to be fully operational in 1995 and only SAATMS O&M expenditures are required after 1995. Figure 7.2-5 shows the combined annual expenditures including the R&D, F&E, and O&M breakdowns. The total is also shown in Fig. 7.2-3 (upper dashed line) for comparison.

The selected transition plan, which spreads the facilities transfer over a number of years (1986-1995), has the effect of eliminating an expenditure and manpower "peak" which would result from a total or nearly total parallel operation of the two systems. As each increment of the SAATMS control facilities is constructed and becomes operational, the corresponding GAATMS facility is decommissioned and the controllers thus freed will begin training on the next SAATMS facility.

TABLE 7.2-4. GAATMS ANNUAL COSTS

Year	R&D*	F&E*	O&M			Annual Total	Cumulative Total
			Controller	Other	Total		
1975	60	206	464	310	774	1040	1040
1976	55	206	479	331	810	1071	2111
1977	47	208	495	348	843	1098	3209
1978	47	208	503	357	860	1115	4324
1979	47	208	513	362	875	1130	5454
1980	47	208	520	366	886	1141	6595
1981	46	208	534	371	905	1159	7754
1982	37	137	541	375	916	1090	8844
1983	37	119	551	380	931	1087	9931
1984	37	100	560	384	944	1081	11012
1985	37	80	570	389	959	1076	12088
1986	37	62	579	393	972	1071	13159
1987	27	45	590	398	988	1060	14219
1988	14	29	599	402	1001	1044	15263
1989	6	14	608	407	1015	1035	16298
1990			618	411	1029	1029	17327
1991			627	416	1043	1043	18370
1992			637	420	1057	1057	19427
1993			646	424	1070	1070	20497
1994			656	429	1085	1085	21582
1995			665	433	1098	1098	22680
1996			675	438	1113	1113	23793
1997			685	443	1128	1128	24921
1998			694	447	1141	1141	26062
1999			704	451	1155	1155	27217
2000			713	456	1169	1169	28386
Totals	581	2038	15426	10341	25767	28386	28386

*Rand Estimates (Reference 3)

Note: All costs in millions of dollars

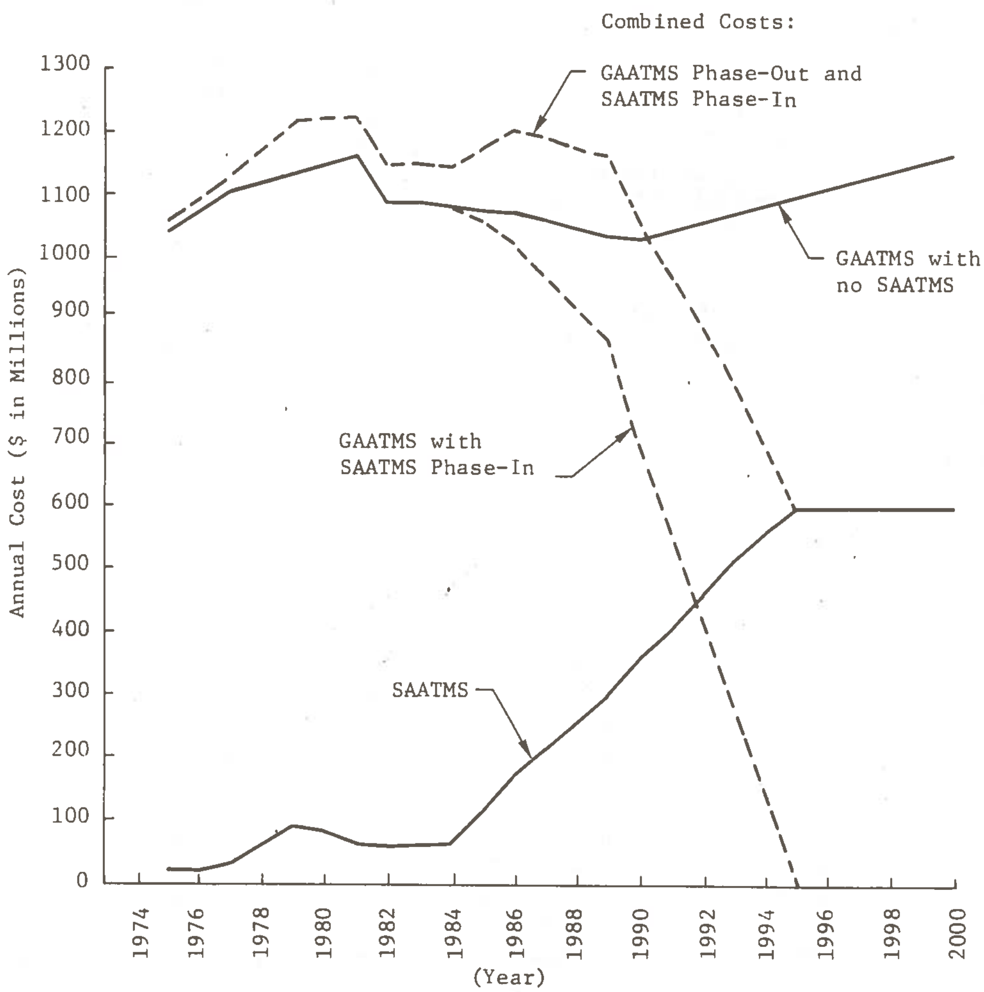


Figure 7.2-3. Total Annual Costs of SAATMS and GAATMS ATC Approaches (Year 1995 Implementation)

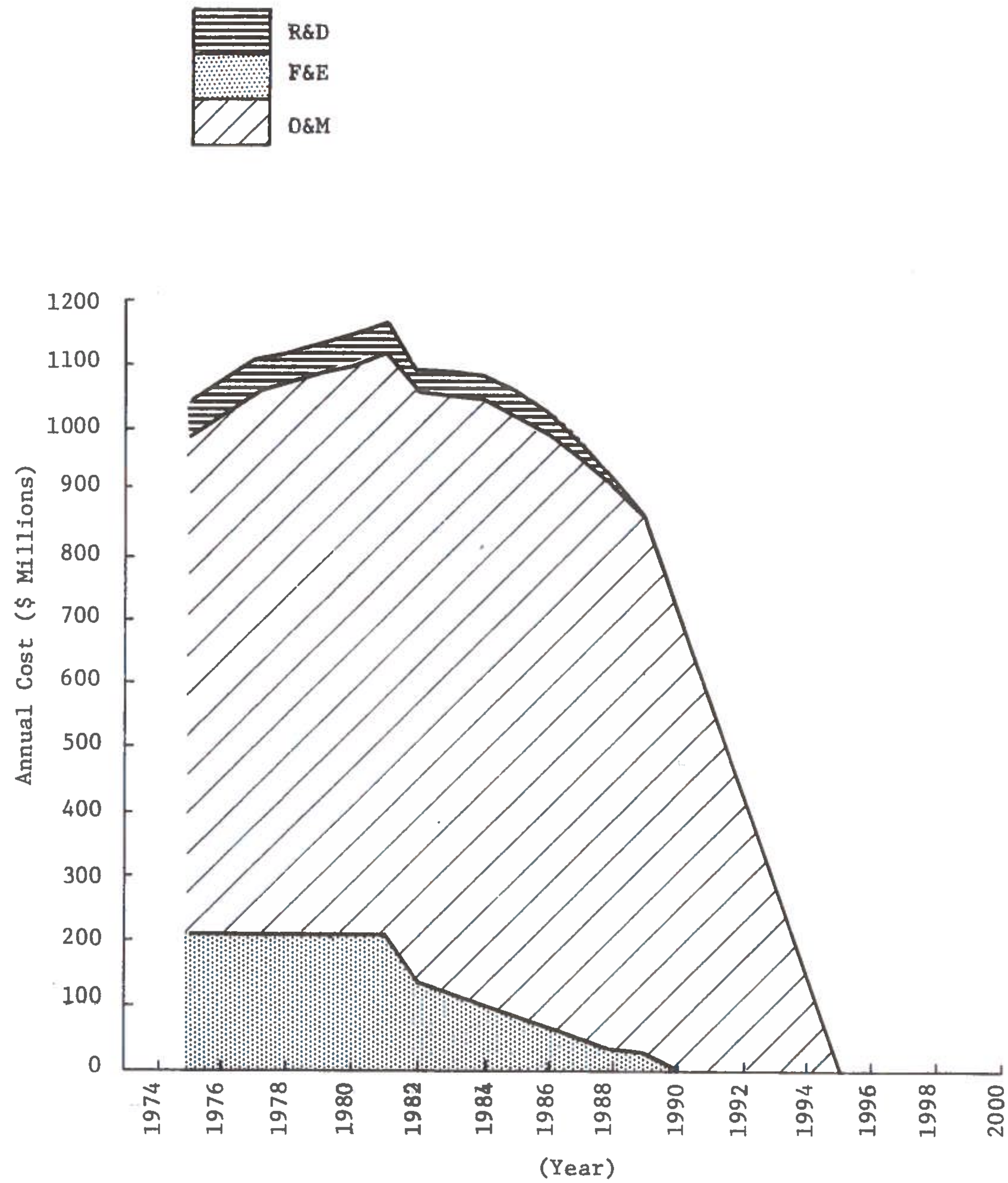


Figure 7.2-4. GAATMS Annual Costs with SAATMS Phase-In
(Year 1995 Implementation)

TABLE 7.2-5. GAATMS COSTS WITH SAATMS PHASE-IN
(YEAR 1995 IMPLEMENTATION)

Year	R&D	F&E	O&M			Annual Total	Cumulative Total
			Controller	Other	Total		
1975	60	206	464	310	774	1040	1040
1976	55	206	479	331	810	1071	2111
1977	47	208	495	348	843	1098	3209
1978	47	208	503	357	860	1115	4324
1979	47	208	513	362	875	1130	5454
1980	47	208	520	366	886	1141	6595
1981	46	208	534	371	905	1159	7754
1982	37	137	541	375	916	1090	8844
1983	37	119	551	380	931	1087	9931
1984	37	100	560	384	944	1081	11012
1985	37	80	554	389	943	1060	12072
1986	37	62	535	393	928	1027	13099
1987	27	45	507	398	905	977	14076
1988	14	29	477	402	879	922	14998
1989	6	14	443	407	850	870	15868
1990			370	340	710	710	16578
1991			300	270	570	570	17148
1992			230	200	430	430	17578
1993			140	150	290	290	17868
1994			50	100	150	150	18018
1995							
1996							
1997							
1998							
1999							
2000							
Totals	581	2038	8766	6633	15399	18018	18018

Note: All costs in millions of dollars

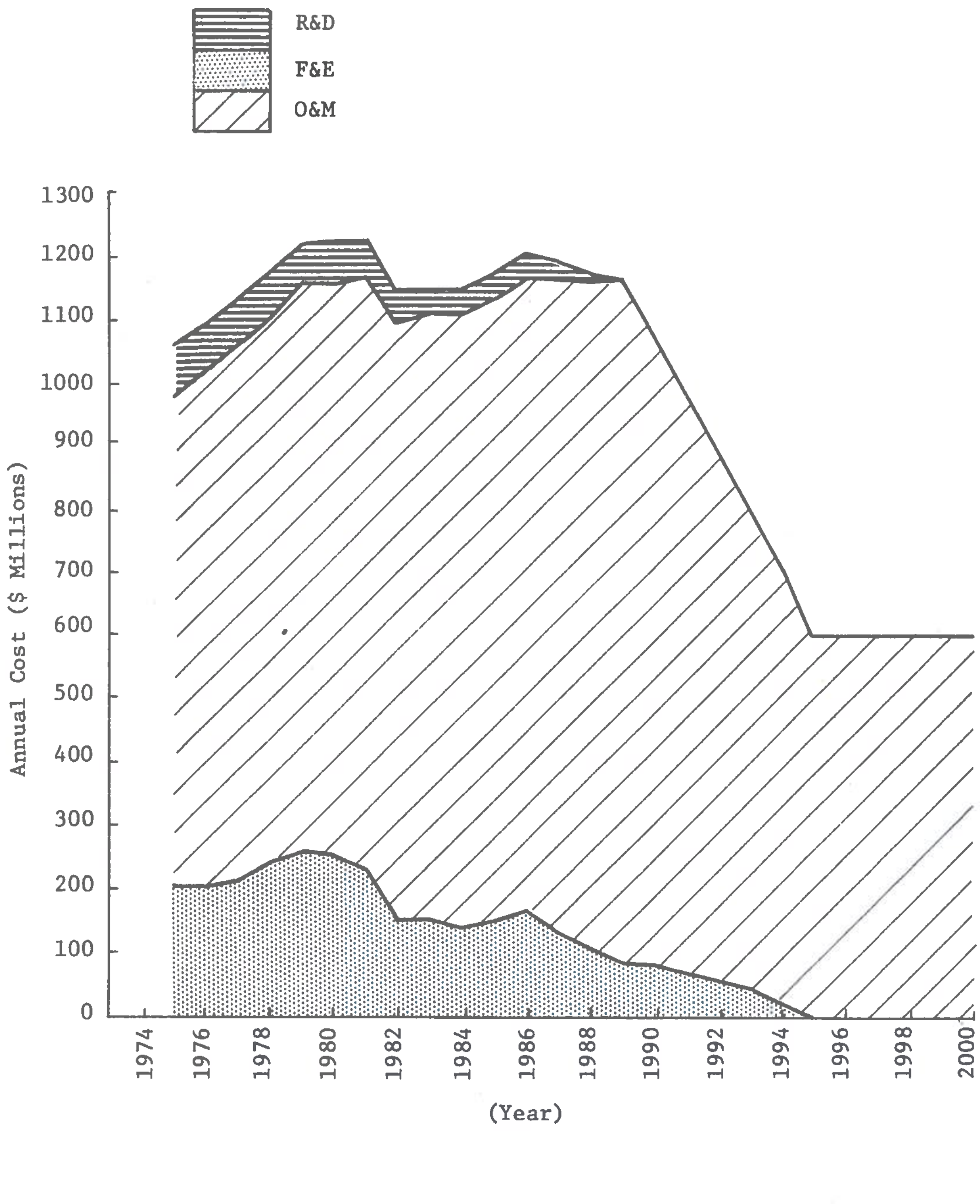


Figure 7.2-5. Combined Costs of GAATMS Phase-Out and SAATMS Phase-In (Year 1995 Implementation)

TABLE 7.2-6. COMBINED COSTS-GAATMS PHASE-OUT AND SAATMS PHASE-IN (YEAR 1995 IMPLEMENTATION)

Year	R&D	F&E	O&M	Annual Total	Cumulative Total
1975	82	206	774	1062	1062
1976	77	206	810	1093	2155
1977	74	222	843	1139	3294
1978	76	247	860	1183	4477
1979	72	275	879	1226	5703
1980	65	252	907	1224	6927
1981	58	237	931	1226	8153
1982	57	148	943	1148	9301
1983	40	149	958	1147	10448
1984	37	140	971	1148	11596
1985	37	155	986	1178	12774
1986	37	167	1006	1210	13984
1987	27	135	1035	1197	15181
1988	14	94	1056	1164	16345
1989	6	84	1078	1168	17543
1990		70	989	1059	18592
1991		60	913	973	19545
1992		55	838	893	20438
1993		42	763	805	21243
1994		20	688	708	21951
1995			600	600	22551
1996			600	600	23151
1997			600	600	23751
1998			600	600	24351
1999			600	600	24951
2000			600	600	25551
Totals	759	2964	21828	25551	25551

Note: All costs in millions of dollars

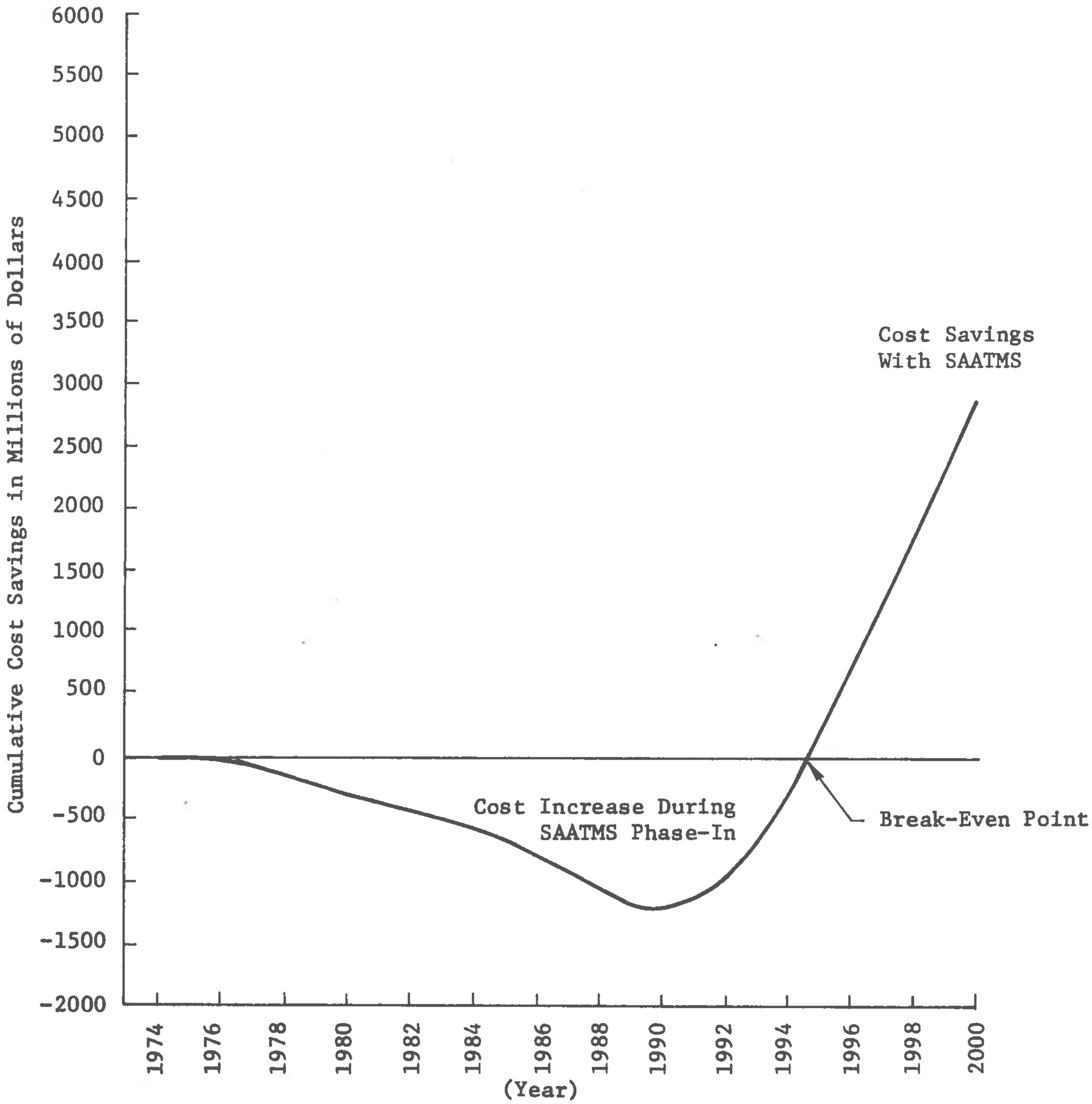


Figure 7.2-6. Cumulative Cost Savings of SAATMS Over GAATMS (Year 1995 Implementation)

7.2.4 SAATMS Implementation Cost Savings

The estimated costs shown in Fig. 7.2-2 and 7.2-5 are based upon the currently formulated plans for implementation of the GAATMS as reflected in Ref. 2. Any actions taken to introduce some of the advanced concepts into the GAATMS program to further ease the transition between the two systems and to realize some of the cost benefits earlier will alter the costs shown. However, some insight into the implementation costs and the cost savings realizable from implementing the SAATMS can be gained by referring to Fig. 7.2-6. The plot shown was obtained by subtracting the cumulative cost of implementing the SAATMS from the cumulative cost of implementing and retaining only the GAATMS. Table 7.2-7 presents the results of this computation.

It is seen that the curve in Fig. 7.2-6 is negative (added expenditures) prior to 1995 but rapidly becomes positive, representing the large cost savings achieved. The accumulated cost savings continue to increase after 1995, reaching a value around $6 billion by the year 2005. The added expense for SAATMS R&D and F&E can thus be recovered in a few years through savings in the reduced O&M costs of the SAATMS.

TABLE 7.2-7. CUMULATIVE COST SAVINGS OF SAATMS OVER GAATMS (YEAR 1995 IMPLEMENTATION)

Year	GAATMS Only*		Combined Costs**		Cumulative Savings
	Annual	Cumulative	Annual	Cumulative	
1975	1,040	1,040	1,062	1,062	-22
1976	1,071	2,111	1,093	2,155	-44
1977	1,098	3,209	1,139	3,294	-85
1978	1,115	4,324	1,183	4,477	-153
1979	1,130	5,454	1,226	5,703	-249
1980	1,141	6,595	1,224	6,927	-332
1981	1,159	7,754	1,226	8,153	-399
1982	1,090	8,844	1,148	9,301	-457
1983	1,087	9,931	1,147	10,448	-517
1984	1,081	11,012	1,148	11,596	-584
1985	1,076	12,088	1,178	12,774	-686
1986	1,071	13,159	1,210	13,984	-825
1987	1,060	14,219	1,197	15,181	-962
1988	1,044	15,263	1,164	16,345	-1,082
1989	1,035	16,298	1,168	17,543	-1,245
1990	1,029	17,327	1,059	18,592	-1,265
1991	1,043	18,370	973	19,545	-1,175
1992	1,057	19,427	893	20,438	-1,011
1993	1,077	20,504	805	21,243	-739
1994	1,085	21,589	708	21,951	-362
1995	1,098	22,687	600	22,551	+136
1996	1,113	23,800	600	23,151	+649
1997	1,128	24,928	600	23,751	+1,177
1998	1,141	26,069	600	24,351	+1,718
1999	1,155	27,224	600	24,951	+2,273
2000	1,169	28,393	600	25,551	+2,842

All costs in millions of dollars

*From Table 7.2-4

**From Table 7.2-6

8. SAATMS TRANSITION STUDIES

This section presents the results of a series of studies of various SAATMS transition schedules and their resulting costs. The studies were undertaken to gain some insight into the sensitivity of the total system costs to the year in which full implementation was achieved. All costs are computed for the 25-year time period, 1975 to 2000. Four dates were assumed for the year in which the SAATMS would be fully operational: 1986, 1990, 1995, and 2000. The schedule and costs for the 1995 implementation date were those presented earlier in this report. The 1995 schedule and costs were then used as the basis for computing the costs for the other implementation years.

Also considered was the controller staff requirement. Estimates were made of the costs for a 15-aircraft-per-sector assumption, for a revised staff estimate based upon a direct task analysis, and for the originally assumed 40-aircraft-per-sector staffing level.

Finally, consideration was given to the cost savings which would result if presently projected ATC system improvements were not undertaken in favor of an early transition to the SAATMS.

8.1 Assumptions and Bases

The assumptions used for all cost analyses are the same as those given previously in this report. It should be especially noted that all costs are in constant 1973 dollars. No corrections have been made to account for the effects of inflation.

The cost base developed for the nominal 1995 SAATMS implementation schedule is used as the starting point for all the estimates presented here. The yearly expenditure estimates for the 1995 schedule are those presented earlier in this report. Except as specifically noted, the same total system costs, R&D, F&E, and annual O&M (after full implementation), are assumed no matter the year of complete transition. Differences arise because of the length of the transition period and the speed with which the existing equipment is decommissioned. The system is assumed sized to meet the nominal 1995 demand, for all cases. From these 1995 cost bases, the costs for other implementation years are developed by synthesis of the individual costs or by differences (deltas) from the base year costs. The time period assumed in all cases are the years 1975 through 2000. The total costs incurred for this period are computed.

The GAATMS estimates used are those given in Par. 7.2.2 of this volume. These were obtained by projecting the FAA 10-year plan estimates to the year 2000 and discounting the effects of inflation. Figure 7.2-2 is a plot of the GAATMS annual expenditures assuming no transition to SAATMS.

The 1995 transition/phasing schedules used as the bases are those given in Vol. VI and are reproduced here as Tables 7.2-2 and 7.2-3. Compressed or stretched versions of these schedules were used for the other implementation years but the basic phasing of events was not changed.

In all the discussions here, the implementation year is defined as the year of first full operation of the SAATMS, with the transition and decommissioning of the existing system completed. The implementation year can be viewed as the first year that only SAATMS O&M costs are incurred.

8.2 Transitions With Nominal Controller Staff

All of the transition cost estimates developed in this section assume the nominal 40-aircraft-per-enroute control sector, two controllers per sector, and staffing level used for the costs already presented. The total number of enroute controllers required are as follows (refer to Table 4.3-7).

	Controllers	Supervisors	Managers	Total Each	Total
RCC (2)	3231	269	5	3505	7010
CCC (1)	3231	269	5	3505	3505
				Total	10515

In addition, there is a total of 8000 airport (ACC) controllers and supervisors, for a total control staff of 18515.

8.2.1 Year 1995 Implementation

The year 1995 is the year assumed for all cost and transition studies already reported in detail in Par. 7.

8.2.2 Year 2000 Implementation

The required annual expenditures for an assumed year 2000 implementation were computed. It was assumed that the SAATMS would be fully implemented by the year 2000 and the GAATMS fully decommissioned. However, the 1995 demand level was assumed for these computations, even though there may be some nominal cost increase for SAATMS if it is sized for the year 2000 demand level rather than the year 1995.

It was further assumed that the same relative transition schedule would be used for this case, except that the start of implementation would be delayed by five years; i.e., no stretchout of the various phases, except for the R&D effort. The R&D activities were maintained at a low level for the "intervening" five years, resulting in a slight increase in the total SAATMS costs. The F&E cost total was assumed unchanged. The extra time for R&D might well result in a more efficient system design and thus justify the assumption of no cost increase for year 2000 demand. Tables 8.2-1 and 8.2-2 show the revised implementation schedules.

Figure 8.2-1 plots the SAATMS annual costs for the year 2000 implementation, from which the stretchout in R&D can be seen in comparison to Fig. 7.2-1. Only the total combined annual costs for the SAATMS and the GAATMS were plotted for this case. In Fig. 8.2-2, the curve labeled "Year 2000 Phase-In" shows these combined costs in comparison to the other implementation years.

Finally, the cumulative cost savings of implementing the SAATMS in the year 2000 over retaining the GAATMS was computed and plotted in Fig. 8.2-3 (the curve labeled "Year 2000 Phase-In"). As the curve shows, the break-even point is barely reached by the year 2000. Thus, there is little or no cost advantage to implementing the SAATMS by the year 2000 when considering the costs over the 1975 to 2000 time span only.

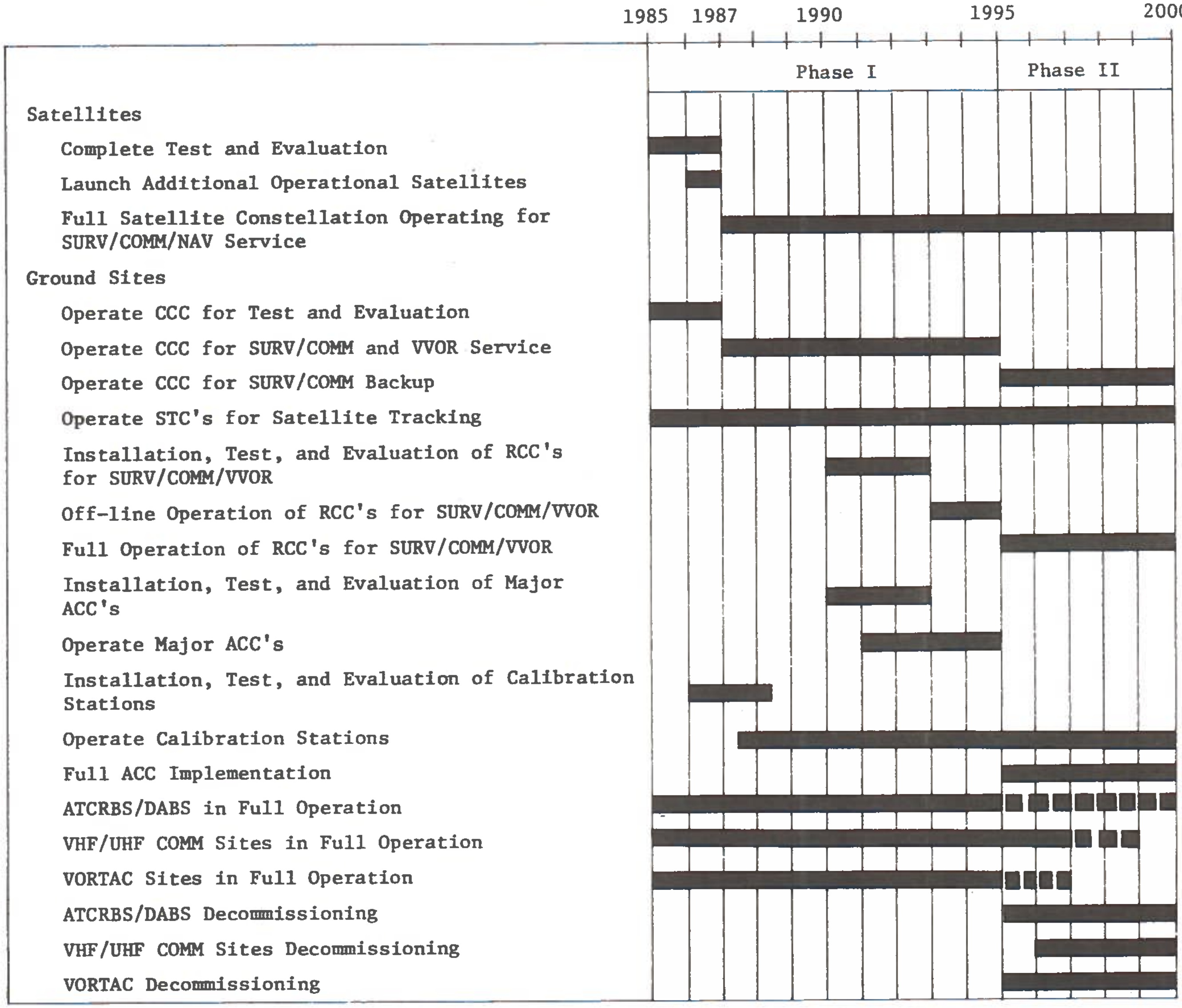
8.2.3 Year 1990 Implementation

The required annual expenditures for an assumed year 1990 implementation were computed. It was assumed that the SAATMS would be fully implemented by the year 1990 and the GAATMS fully decommissioned. The system is assumed sized to meet the 1995 demand level so that the F&E and O&M costs in the fully implemented system are the same as those used for the nominal year 1995 implementation schedule. However, the R&D cost total was more than doubled to reflect the schedule speedup and the fact that there may not be time to take advantage of test programs of other agencies (see Par. 4.1 in this volume). The required data would have to be obtained by test programs funded independently by DOT/FAA.

Tables 8.2-3 and 8.2-4 show the revised implementation schedule for the year 1990 implementation. As shown, the Phase I and Phase II transition periods have been compressed to 8 and 4 years, respectively, compared to the 10 and 5 years previously allotted (Tables 7.2-2 and 7.2-3). The schedule compression is necessary because less time is available in which to accomplish the transition.

Figure 8.2-4 plots the SAATMS annual costs for the year 1990 implementation. The effect of the acceleration in the schedule and the increased R&D costs are seen in the "bulge" in the R&D and F&E costs, particularly in the 1974 to 1980 time span. The increased annual expenditures during the transition can also be seen in the plot of the total combined costs (SAATMS and GAATMS) shown in Fig. 8.2-2 (the curve labeled "Year 1990 Phase-In"). Prior to approximately 1985, the combined annual costs are greater than those required for the more leisurely implementation schedules. After about 1985, some of the SAATMS facilities come on-line and advantage can be taken of the lower operating costs for the SAATMS by decommissioning corresponding GAATMS facilities.

TABLE 8.2-1. SURVEILLANCE/COMMUNICATION/NAVIGATION FACILITIES TRANSITION SCHEDULE (YEAR 2000 IMPLEMENTATION)



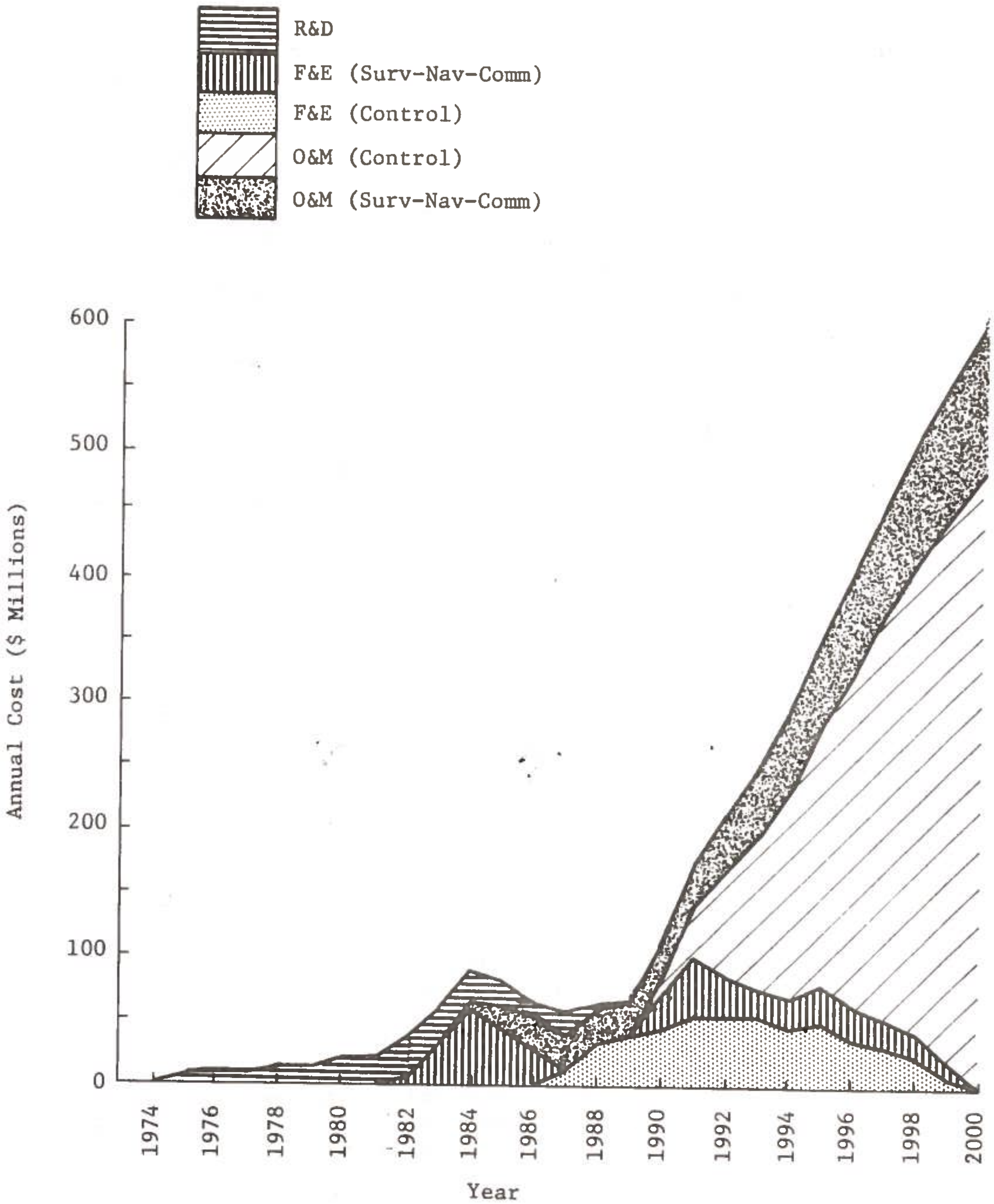
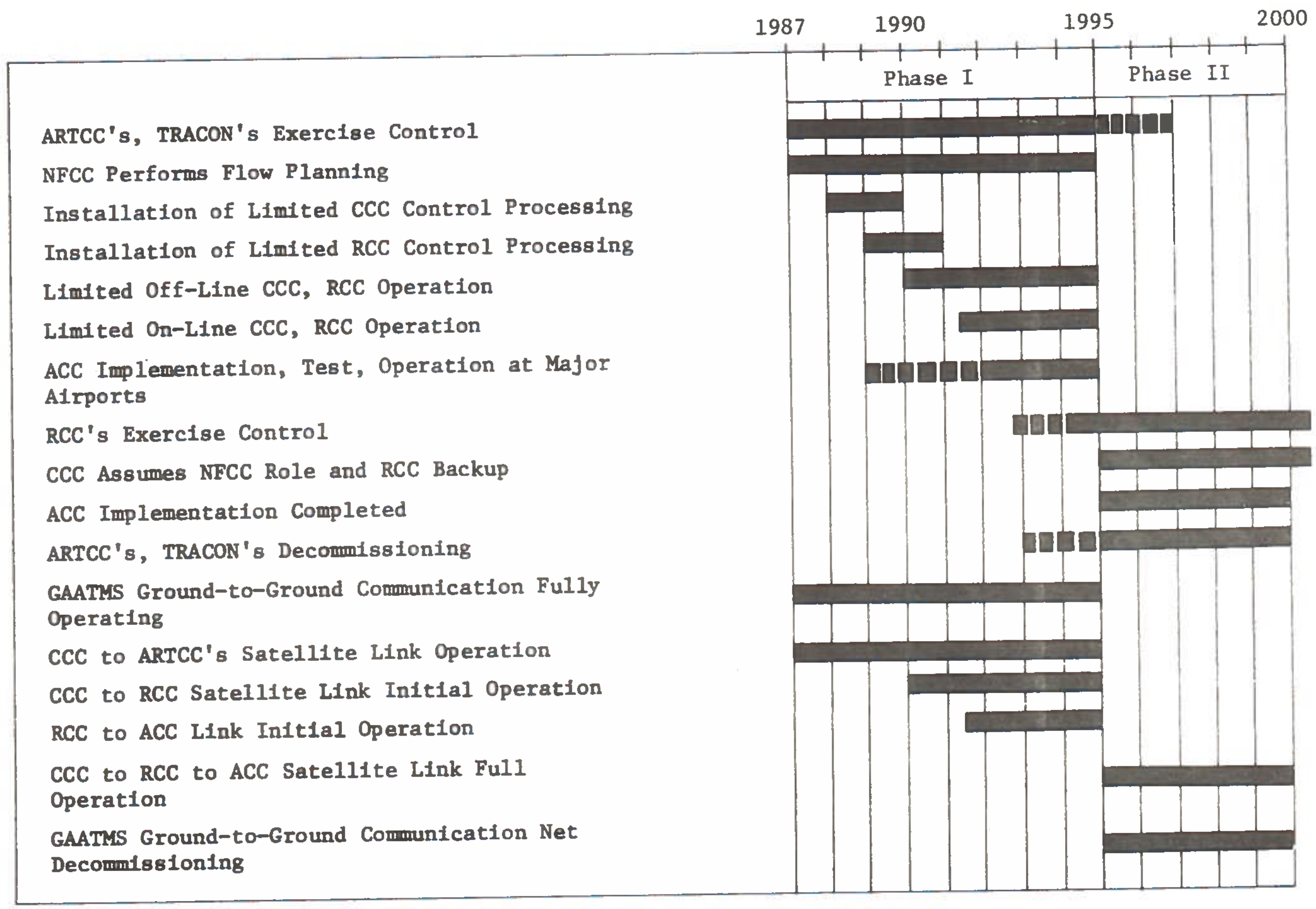


Figure 8.2-1. SAATMS Annual Costs (Year 2000 Implementation)

TABLE 8.2-2. CONTROL PROCESSING AND GROUND-TO-GROUND COMMUNICATION TRANSITION SCHEDULE (YEAR 2000 IMPLEMENTATION)



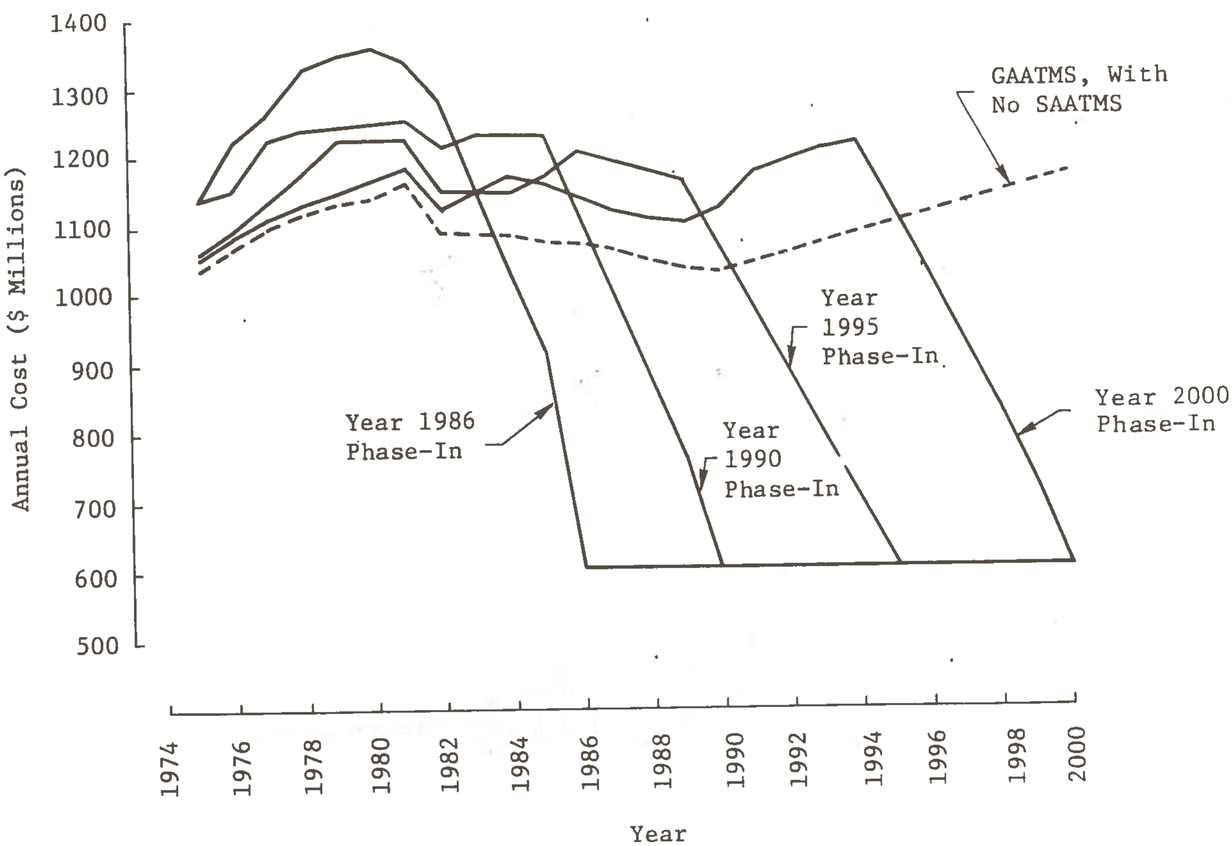


Figure 8.2-2. Total Annual Costs of GAATMS With and Without SAATMS Phase-In

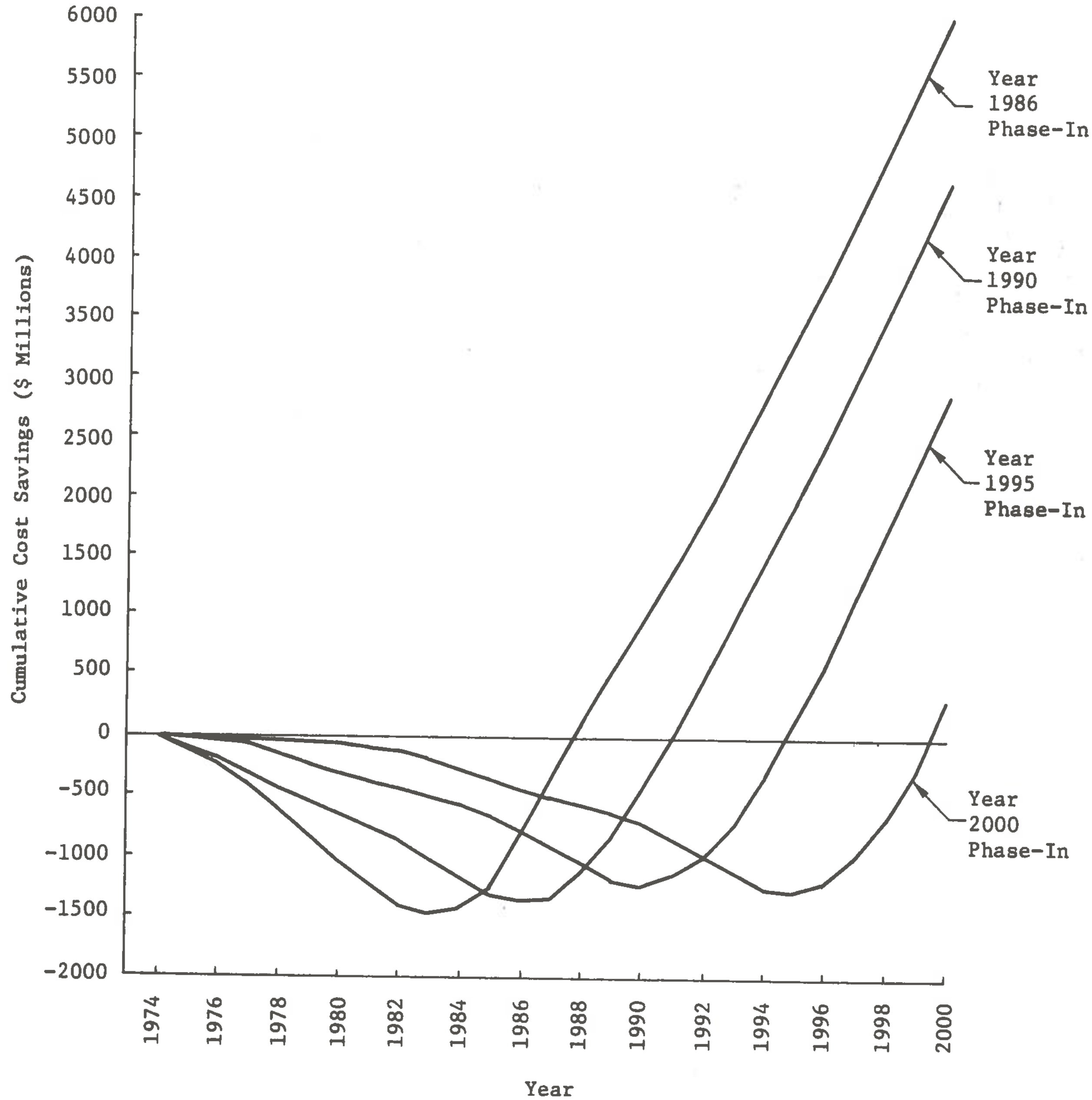


Figure 8.2-3. Cumulative Cost Savings of SAATMS Phase-In Over GAATMS With No SAATMS

TABLE 8.2-3. SURVEILLANCE/COMMUNICATION/NAVIGATION FACILITIES TRANSITION SCHEDULE (YEAR 1990 IMPLEMENTATION)

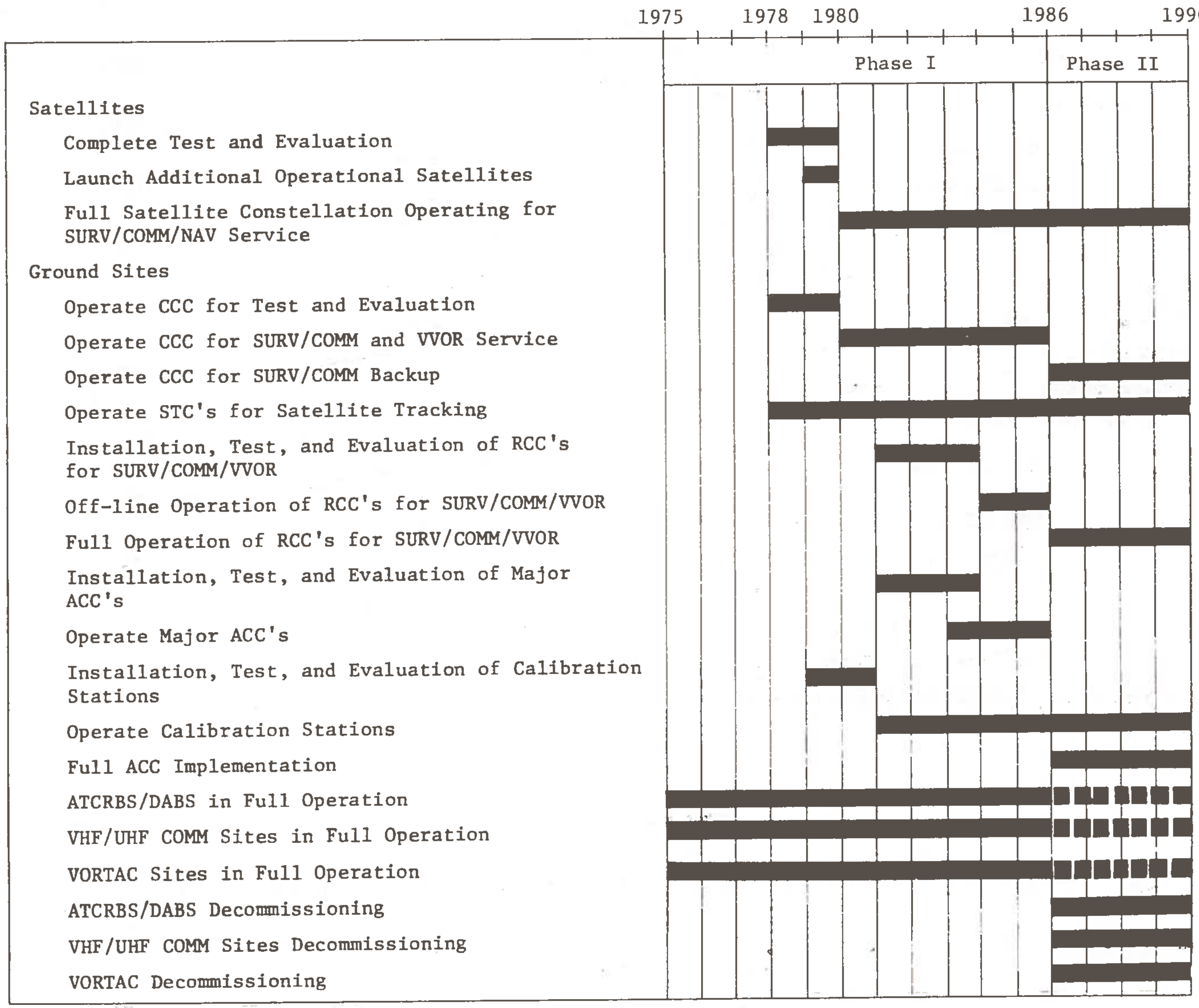
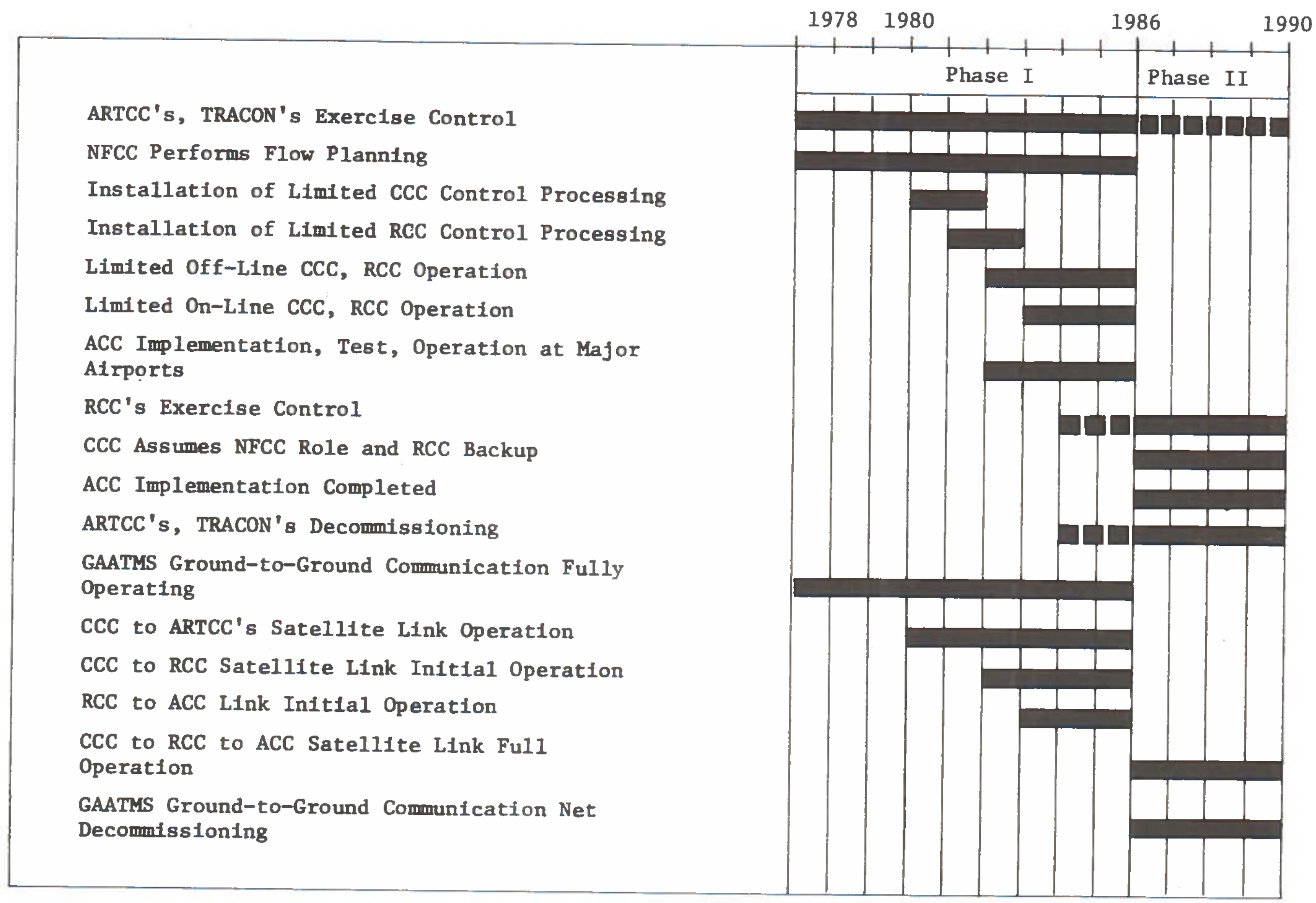


TABLE 8.2-4. CONTROL PROCESSING AND GROUND-TO-GROUND COMMUNICATION TRANSITION SCHEDULE (YEAR 1990 IMPLEMENTATION)



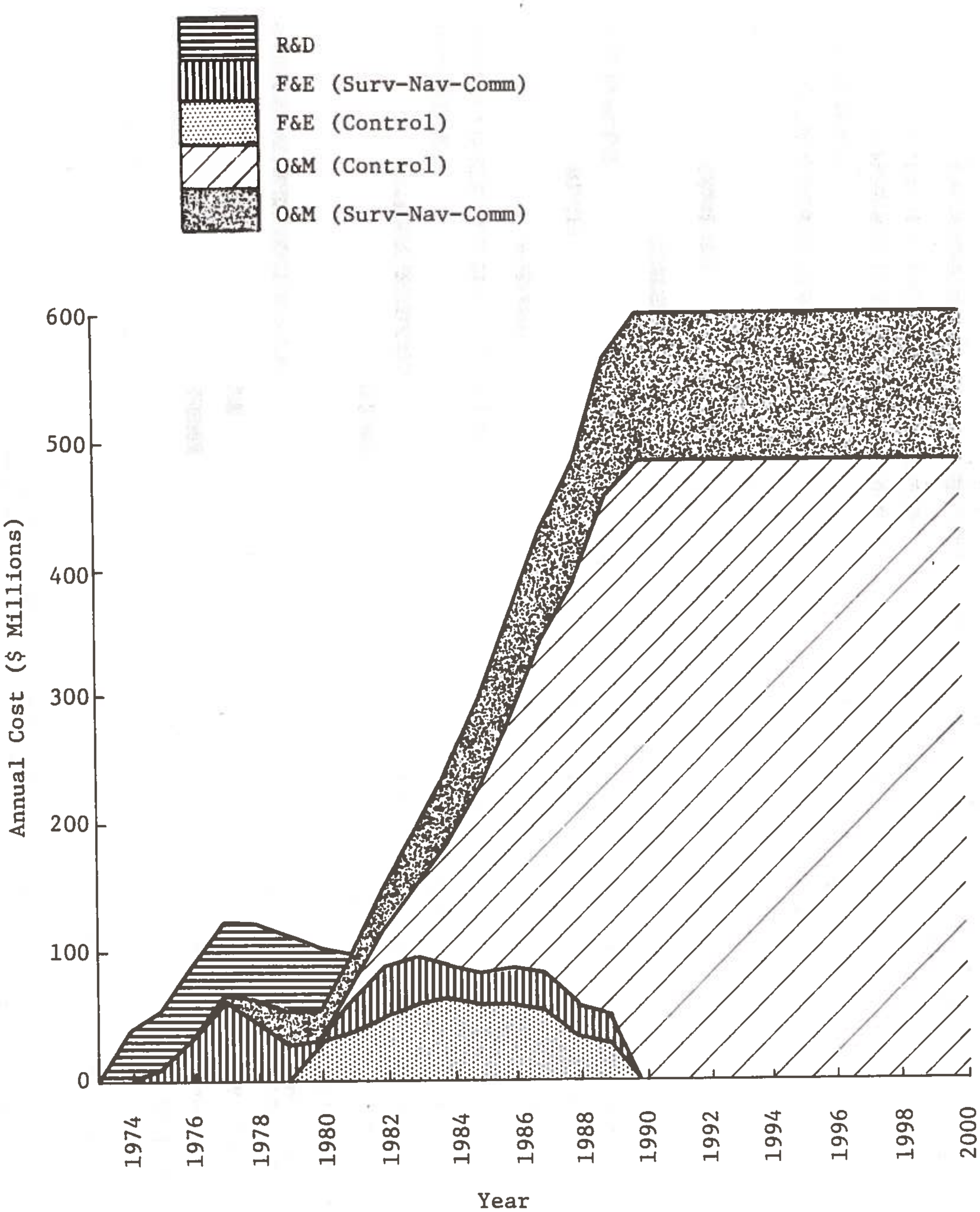


Figure 8.2-4. SAATMS Annual Costs (Year 1990 Implementation)

Finally, the cumulative cost savings of implementing the SAATMS in the year 1990 over retaining the GAATMS was computed and plotted in Fig. 8.2-3 (the curve labled "Year 1990 Phase-In"). As expected, the net cost savings of SAATMS over GAATMS are greater by the year 2000 simply because the SAATMS will have been in full operation longer, with its lower operating costs. The break-even point in this case is around the year 1991. The slightly later break-even point occurs because of the need to amortize the increased R&D costs, because the transition is more rapid, and as great an advantage cannot be taken of the lower SAATMS O&M costs during the transition.

8.2.4 Year 1986 Implementation

The required annual expenditures for an assumed year 1986 implementation were computed. These were not computed in as great detail as the previous cases but was done to get a feeling for the costs if a supreme, all-out effort were mounted to implement the SAATMS. As before, the system is assumed sized to meet the 1995 demand level so that the F&E costs and O&M costs for the fully implemented system are the same as those used for the nominal year 1995 implementation schedule. As for the 1990 schedule, the R&D cost total was more than doubled to reflect the schedule speedup and the fact that there may not be time to take advantage of test programs of other agencies.

Figure 8.2-5 plots the SAATMS annual costs for the year 1986 implementation. The effect of the compressed schedule is even more pronounced for this case and can be observed very clearly in Fig. 8.2-2 (the curve labeled "Year 1986 Phase-In"). The combined total costs (SAATMS and GAATMS) are greater than for the other transition schedules in the early years until around 1982 when the advantage of the lower SAATMS O&M costs begins to become noticeable.

As would be expected, the net cumulative cost savings of implementing the SAATMS in 1986 are greater by the year 2000 simply because of the longer operating time for the SAATMS with its lower O&M costs, as shown in Fig. 8.2-3. The break-even point in this case is still later than the full implementation data, occurring around 1988 because of the need for the heavy initial funding and the inability to fully realize the SAATMS operating savings during the foreshortened transition period.

It should be emphasized again that achieving a 1986 implementation data for SAATMS implies an immediate all-out commitment. It also implies that no unusual research and/or development problems or delays will occur to impede a smooth transition within the available time.

8.2.5 Summary

Table 8.2-5 summarizes the data presented above and Fig. 8.2-6 is a plot of these data. The table shows the cumulative cost totals, in $ billions, for the various SAATMS operational dates for the period 1975 to 2000. Note again that the GAATMS costs include the total GAATMS R&D and F&E costs as well as the GAATMS O&M costs incurred prior to and during the transition (see, for example, Fig. 7.2-4). Similarly, the SAATMS costs include the total SAATMS R&D and F&E costs as well as the SAATMS O&M costs incurred during and after the transition (see, for example, Fig. 7.2-1).

The net savings by the year 2000 represents the difference in cost to the government between keeping the GAATMS until the year 2000 or transitioning to the SAATMS by the indicated date. Since the SAATMS O&M costs are estimated to be significantly lower than the GAATMS, an early transition to SAATMS is shown to result in greater overall cost savings.

One possibility of inducing early user transition to SAATMS avionics is for the federal government to partially or fully reimburse the civil avionics costs. For reference, Table 8.2-5 shows the cost (purchase and installation) of converting the existing civil aviation fleet to SAATMS equipment by the indicated implementation date. All new aircraft purchased after the implementation date would already be equipped with SAATMS avionics. Even if the government reimbursed these costs 100 percent, a net saving results for SAATMS implementation dates of 1995 or earlier.

8.3 Reduced Automation Capability

As stated, all of the cost estimates presented in the preceding section were based on the nominal 40-aircraft-per-enroute-control-sector, two controllers per sector, staffing level. Furthermore, the CCC was capable of fully backing up either RCC. All of these costs were reestimated using a 15-aircraft-per-enroute-control-sector automation level, no backup capability, and with all other assumptions unchanged. This automation level is nearly that of the present system or will be when the balance of the currently planned automation equipment is installed. The total number of enroute controllers, therefore, becomes (refer to Table 4.3-7):

Total Enroute IAC: 32,675 (year 1995)

Total Number of Required Control Sectors: 32,675/15 = 2178

Total Day Shift: At 2 controllers per sector, 2 × 2178 = 4356 controllers

Total Controller Staff: With leave and shift factors,
4356 × 1.58 × 2.5 = 17,206

Supervision (Average One Per 12.5 Controllers): 17,206/12.5 = 1376

Total Control Staff: 17,206 + 1376 = 18,582

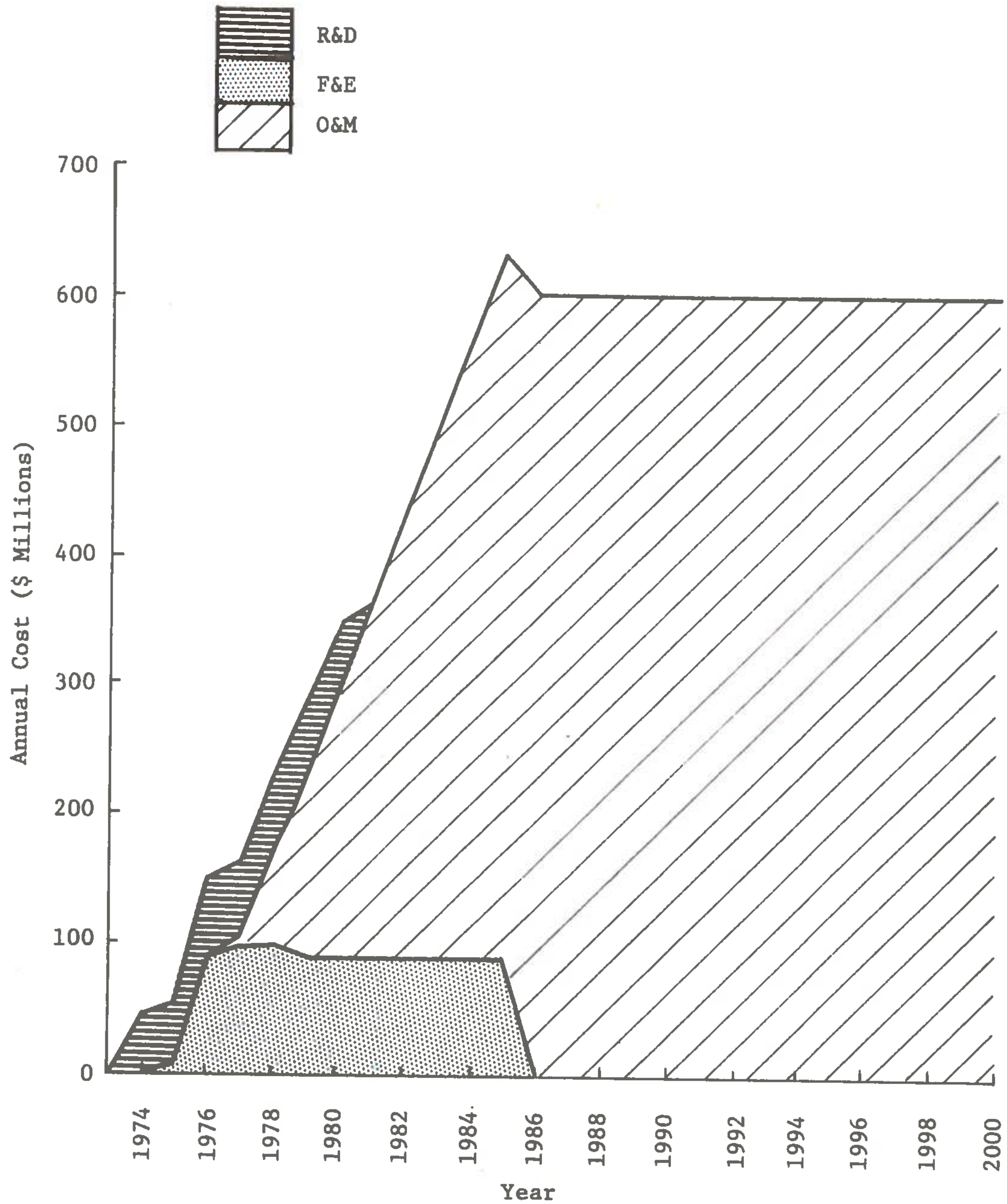


Figure 8.2-5. SAATMS Annual Costs (Year 1986 Implementation)

TABLE 8.2-5. TOTAL ATM SYSTEM COSTS FOR VARIOUS SAATMS IMPLEMENTATION DATES, FIRST COMPUTATION

Cost Element	Total Costs for Period 1975 to 2000 For SAATMS Fully Operational Date ($ Billions)				
	1986	1990	1995	2000	No SAATMS
GAATMS System (FAA Plan Extended)	9.6	13.6	18.0	23.5	28.4
SAATMS (As Proposed)	12.8	10.1	7.5	4.6	-
Savings If Certain Planned GAATMS F&E Costs Are Not Incurred (e.g., DABS, Radar Improvements, etc)	-0.8	-0.8	-	-	-
Total R&D, F&E, O&M	21.6	22.9	25.5	28.1	28.4
Net Savings By the Year 2000	6.8	5.5	2.9	0.3	0
Cost of Converting All User Avionics By SAATMS Implementation Date	1.8	2.1	2.5	3.1	-

Note: SAATMS System as proposed
(40 A/C per sector, CCC Backup)

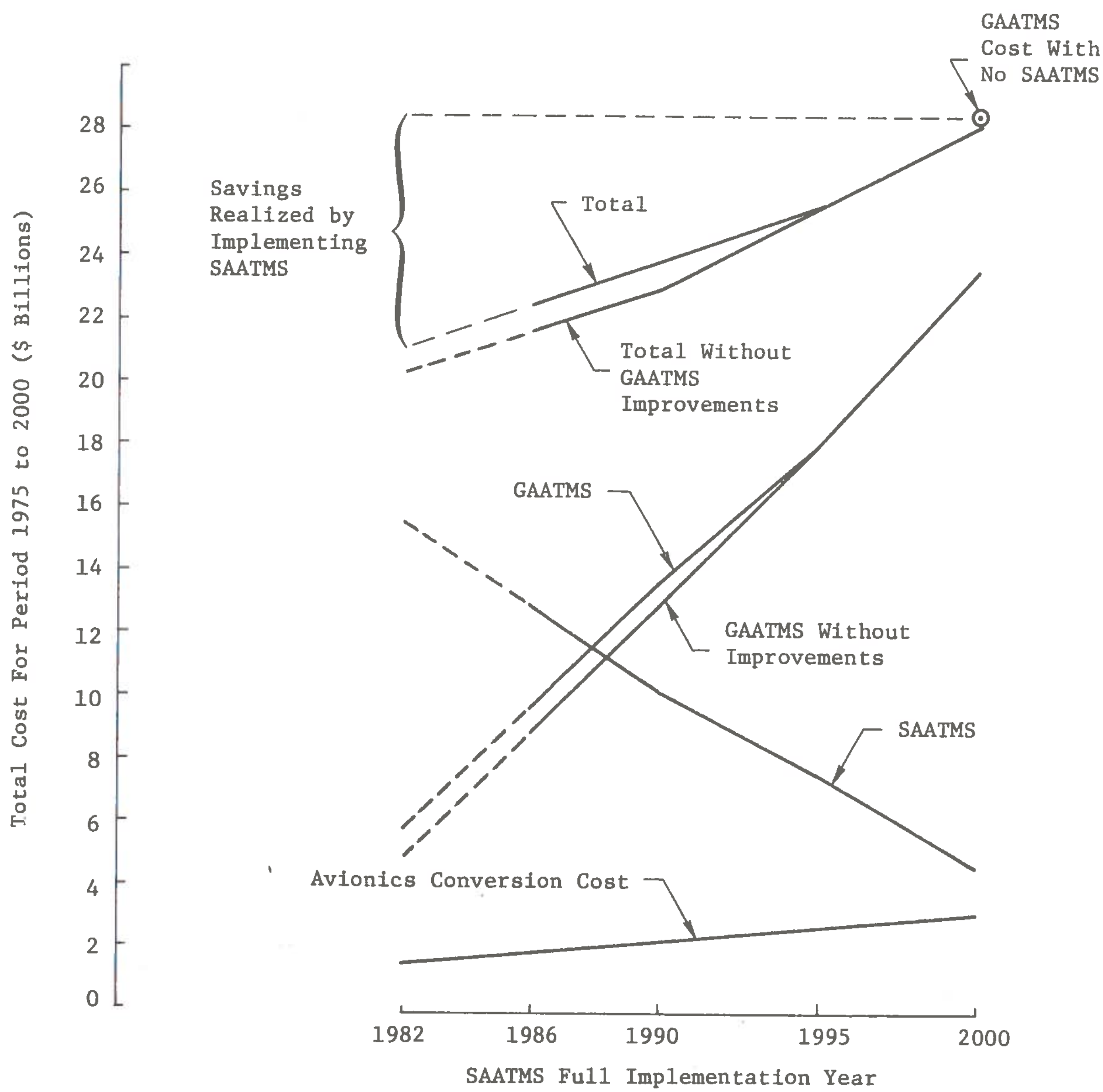


Figure 8.2-6. Total ATM System Costs (1975 to 2000) For Various SAATMS Implementation Dates, First Computation

Furthermore, the total number of terminal controllers in 1973 was 10,788 for 394 towers, or an average of 6.9 controllers per tower per day shift. However, this total includes the TRACONS whose functions are absorbed by the RCC's. The previous estimate (Table 4.3-8), for the ACC's was 3.3 controllers per tower, average. If this value is doubled to 6.6 controllers per ACC per day shift, to reflect a reduced automation capability and greater (more nearly present day) load on the tower controllers, the total number of terminal controllers becomes 16,000. The total control staff is, therefore, 18,582 + 16,000 = 34,582. Since the previous control staff estimate was 18,515, this represents an increase of 16,067 controls or approximately $320 million per year additional operating costs, ignoring any required increases in facilities and equipment needed for the larger number of controllers. The total O&M for a fully operational SAATMS is therefore $920 million per year, not very much less than the GAATMS O&M estimate (Fig. 7.2-2).

All of the annual costs were recomputed using the higher SAATMS O&M cost. The results are presented in Table 8.3-1.and Fig. 8.3-1. As expected, the cost advantage of the AATMS becomes significantly less than before (see Table 8.2-5) due to the higher operating cost. A clear advantage of SAATMS over GAATMS is, in fact, evident only for the earlier implementation dates (1986 or 1990). The nominal 1995 implementation date is essentially the break-even date. In no case could 100 percent of the avionics costs be reimbursed from the net savings.

8.4 Revised Controller Requirements

Recent work, described elsewhere in this report (see Volume IV), has derived the number of controllers required by examining the tasks the controllers must perform, estimating the length of time required to perform these tasks, and estimating the rate at which these tasks must be performed. The control philosophy assumed was one where all routine communication and control tasks are handled automatically. The controller does not "monitor" the traffic. He only handles unusual situations, emergencies, and random (non-canned) voice communication. The frequency of such situations, and the time required to handle them, determines the minimum number of controllers required.

8.4.1 Controller Estimates

The derivation of manpower required to perform the required functions is presented below and summarized in Table 8.4-1. The frequency of events which is used for this analysis presented in Volume II of this report.

(1) Flow Advisories - From the RCC to Specific Aircraft - These advisories consist of predicted delays and available alternates. It is estimated that 700 such advisories per peak hour CONUS-wide will occur, with each advisory occupying a controller for three minutes. Therefore, controllers will be occupied for 2100 minutes per hour, which equals 35 controllers CONUS-wide or 18 controllers per RCC.

TABLE 8.3-1. TOTAL ATM SYSTEM COSTS FOR VARIOUS SAATMS IMPLEMENTATION DATES, SECOND COMPUTATION

Cost Element	Total Costs for Period 1975 to 2000 For SAATMS Fully Operational Date ($ Billions)				
	1986	1990	1995	2000	No SAATMS
GAATMS System (FAA Plan Extended)	8.6	13.0	17.4	22.8	28.4
SAATMS (15 Aircraft Per Control Sector and Present Backup Philosophy)	18.9	14.9	10.9	6.4	-
Savings If Certain Planned GAATMS F&E Costs Are Not Incurred (e.g., DABS, Radar Improvements, etc)	-0.8	-0.8	-	-	-
Total R&D, F&E, O&M	26.7	27.1	28.3	29.2	28.4
Net Savings By the Year 2000	1.7	1.3	0.1	-0.8	0
Cost of Converting All User Avionics By SAATMS Implementation Date	1.8	2.1	2.5	3.1	-

Note: SAATMS with 15 A/C per sector and present backup philosophy

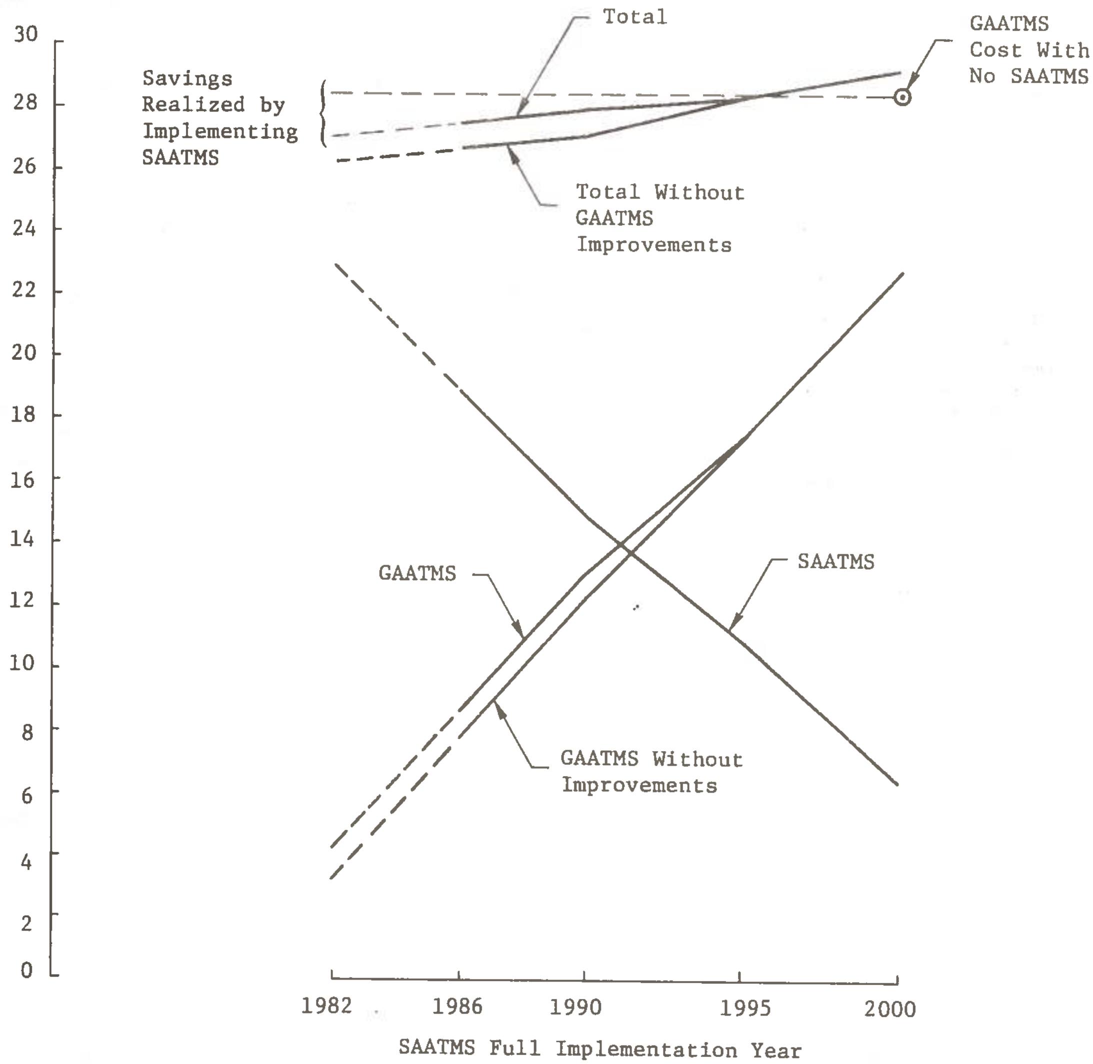


Figure 8.3-1. Total ATM System Costs (1975 to 2000) for Various SAATMS Implementation Dates, Second Computation

TABLE 8.4-1. DERIVATION OF REVISED CONTROLLER MANPOWER REQUIREMENTS

Function	Analysis (CONUS-Wide)	Requirements Per RCC
Flow Advisories	3 min/advisory × 700/hr = 2100 min/hr = 35	18
Request for Advisories	20 sec/advisory × 100/hr = 2000 sec/hr = 1	1
Traffic Advisories	20 sec/advisory × 2000/hr = 40,000 sec/hr = 12	6
Flight Plan Modification Request	5 min/mofification × 750/hr = 3750 min/hr = 63	32
Coop Aircraft Request to Fly in Controlled Airspace	2 min/request × 25/hr = 50 min/hr = 1	1
Emergencies	20/day = 1	1
Manual Handoff	1 min/handoff × 350/day; 1 day = 16 hr; 22 min/hr = 1	1
Boundary and Conflict Intervention	1% of automatic mode = 4/hr	2
Clearances	1% of automatic mode = 100/hr; 10 sec/clearance = 1	1
Metering and Spacing	1% of automatic = 18/hr at 1 min/metering and spacing = 1	1

Total per RCC	64
Overload Factor (2 ×)	64
	128
Supervisors (one for every 10 to 15 controllers)	10
Total Day Shift Controller Staff	138
7-Day and Leave Factor*	×1.58
	218
Shift Factor*	× 2.5
Total Controller Staff/Center	545
Managers	5
Total Staff/Center	550
Number of Centers (2 RCC's and 1 CC)	× 3
Total Controller Requirements	1650

*Factors taken from Table 4.3-7.

(2) Requests for Advisories - From Aircraft to the RCC - These consist of traffic, weather, and delay information requests. It is estimated that 100 such requests per peak hour will occur, with each request occupying a controller for 20 seconds. Therefore controllers would be occupied for 2000 seconds per hour, which equals one controller CONUS-wide or one controller for each RCC.

(3) Traffic Advisories - From the RCC to Specific Aircraft - These advisories consist of aircraft type, location, and direction of flight. While these messages could be given automatically over the digital link to aircraft equipped with a situation display, it is assumed for this analysis that all such advisories will be issued manually over the voice link. It is estimated that 2000 such advisories per peak hour will occur, with each advisory occupying a controller for 20 seconds. Therefore, controllers would be occupied for 40,000 seconds per hour, which equals 12 controllers CONUS-wide or 6 controllers per RCC.

(4) Flight Plan Modification Requests - From Controlled Aircraft to the RCC - These consist of route change and/or altitude change requests. Responses to these requests are either in the form of flow advisories already covered under item (1) or discrete clearance messages issued over the digital link. It is estimated that 750 such requests per peak hour will occur, with each request occupying a controller for 5 minutes. Therefore, controllers would be occupied for 3750 minutes per hour, which equals 63 controllers per RCC.

(5) Cooperative Aircraft Request Clearance to Fly in Controlled Airspace - From Cooperative Aircraft to the RCC - These consist of intent messages. Such requests can occur at any time and the system will attempt to accommodate each aircraft if possible. However, requests will only be granted if there is room for the aircraft, which implies that peak hours are not in effect. It is estimated that 25 such requests per hour will occur, with each request occupying a controller for 2 minutes. Therefore, controllers will be occupied for 50 minutes per hour, which equals one controller per RCC.

(6) Emergencies - From Aircraft to the RCC - These consist of MAY DAY, lost, and assistance needed messages. It is estimated that 20 such emergencies will occur CONUS-wide per day. Therefore, one controller would be needed per RCC to handle all emergencies. Should a given emergency occupy a controller for an inordinate length of time, supervisory or backup personnel can be employed to handle new emergencies that may occur.

(7) Manual Handoffs - From RCC to Aircraft - These consist of voice commands to contact an adjacent RCC or ACC over a specified frequency. This is a backup to the automatic mode. It is estimated that 350 manual handoffs per day, will occur, with one "day" equalling 16 hours and one handoff occupying a controller for one minute. Therefore, controllers would be occupied for 22 minutes per hour, which equals one controller per RCC.

(8) Boundary and Conflict Intervention Backup - From RCC to Aircraft - These occur when aircraft do not respond to the automated intervention commands. It is estimated that the rate of manual commands equals 1 percent of the total number of interventions, or 4 per hour CONUS-wide. Assuming that one controller is required for each manual intervention results in 4 controllers needed CONUS-wide, or 2 per RCC.

(9) Clearance Backup - From RCC to Aircraft - These occur in the event of digital communications avionics failures. It is estimated that the rate of manual clearances equals 1 percent of the total clearance rate, or 100 clearances per hour. If each clearance occupies a controller for 10 seconds, controllers will be occupied for 1000 seconds per hour. Therefore, one controller per RCC is required.

(10) Metering and Sequencing Backup - From RCC to Aircraft - These occur when there is a digital communications failure. It is estimated that the rate of manual metering and sequencing equals 1 percent of the automatic rate or 18 per peak hour. If the manual function occupies a controller for 1 minute, controllers will be occupied for 18 minutes per hour. Therefore, one controller per RCC is required.

Summing up the requirements for all these functions results in a requirement for 64 controllers per RCC per day shift. Adding factors as indicated in Table 8.4-1 brings the total controller requirement, CONUS-wide, to 1650.

In addition to controller personnel, the centers require computer operators, programmers, maintenance personnel, and administrative staff. These people support the operation of the ATM system but are not directly involved in its functioning. For this reason, the SAATMS automation philosophy has little impact on the manning requirements for these support functions. Therefore, the analysis summarized in Table 4.3-8 can be used to obtain the manpower level in these areas. The total personnel requirement for two RCC's, one CCC, seven STC's, and 50 calibration stations is 431. This brings the total enroute staff requirements to 2081. To this number must be added personnel requirements for the planning functions located in the CCC to obtain the total, non-airport, SAATMS manpower requirements.

All communications involved in the planning function can be via digital data link with the exceptions of pilot weather reports (PIREPS). The data flow out of the CCC is largely canned and initiated in most cases by either requests from the FSS or as programmed events. Therefore, a human is not required in the CCC to initiate planning messages.

Communications received from the RCC, ACC, and National Weather Service will also be in digital format. They will consist of status and weather information plus flight plan revisions. These messages constitute updates to existing data files and as such can be entered directly into computer memory without the need for human intervention.

Therefore, the only voice information being received by the CCC planning center is PIREPS. It is assumed that 700 such messages would be sent during the peak hour. This assumption is based upon the demand Level 2 peak enroute IAC of 26,000 aircraft. This IAC consists roughly of 4500 aircarriers, 2000 military aircraft, and 19,500 GA aircraft. It is further assumed that during the peak hour, 10 percent of the aircarrier and military aircraft would issue PIREPS while only 0.25 percent of the GA aircraft would issue such reports, hence, the number 700.

Assuming that each PIREP transmission takes approximately 1 minute, the peak volume would average 12 PIREPS per minute. These reports would automatically be recorded on tape. At periodic intervals, say each hour, a human stenographer/keypunch operator would be required to extract the information from the tapes and enter it into the planning computers to update the weather data bank. Assuming a human efficiency factor of 50 percent, 24 such personnel would be required to transcribe one hour's worth of data in one hour. Assuming a 1.58 7-day factor and that only two shifts would be required, a total of 76 planning personnel would be required. No additional computer operators, programmers, or maintenance personnel would be needed over and above those required for other CCC functions.

The functions performed at the ACC include assignment of runways and taxi routes, providing clearances to taxi, takeoff, and land, waving off arriving traffic, and providing traffic advisories. In the present system, these functions are performed manually by ground and local controllers. Usually one local controller will service all traffic on a pair of runways while one or two ground controllers will handle all airport ground traffic. The number of men required at the airport is dependent upon the number of active runways rather than the demand at the airport. Automation developments at airports are more in the nature of improving surveillance and taking the bookkeeping load off of the controller. It is expected that the human controllers will still be required to supervise the traffic pattern and movement of aircraft on the ground.

The number of personnel required at the 700 ACC's projected for the 1995 time period is shown in Tables 4.3-7 and 4.3-8 in this volume. A total of 12,800 people are required, 62 percent or 8000 of which are controllers. The remaining 4800 people consist of programmers, technicians, maintenance, security, and administrative personnel.

8.4.2 Cost Summary

The results of the above analyses are summarized in Table 8.4-2. The total manpower required to implement the SAATMS automation philosophy described above and in Volume IV is 15,057, compared to the previous estimate of 23,746. This results in a reduction of approximately $180 million per year in operating costs, ignoring any possible decreases in facilities and equipment permitted by the reduced staff. The total O&M for the fully operational SAATMS is therefore $420 million per year compared to the original estimate of $600 million per year.

Table 8.4-2. Summary of Revised SAATMS Manpower Requirements

Site	No. Required	Personnel Type	Total
RCC	2	Controllers and Supervisors	1100
		Maintenance and Administrative	336
CCC	1	Controllers and Supervisors	550
		Maintenance and Administrative	168
		Planners	76
ACC	700	Controllers and Supervisors	8000
		Maintenance and Administrative	4800
STC	7	Maintenance	14
Calibration Station	50	Maintenance	13
		Total SAATMS Personnel	15057

All of the annual costs were recomputed using the lower SAATMS O&M cost. The results are presented in Table 8.4-3. As expected, the cost advantage of the SAATMS is considerebly greater than for the nominal case (Table 8.2-5) due to the reduced operating cost. Figure 8.4-1 presents a plot of the data in Table 8.4-3.

The conclusion to be drawn is obvious: If at all feasible, fully automate the system and implement it as early as possible. The cost savings to be gained can be enormous and far more than ample to recover the investment costs required.

Note: SAATMS System with revised CCC/RCC Controller Staff estimates

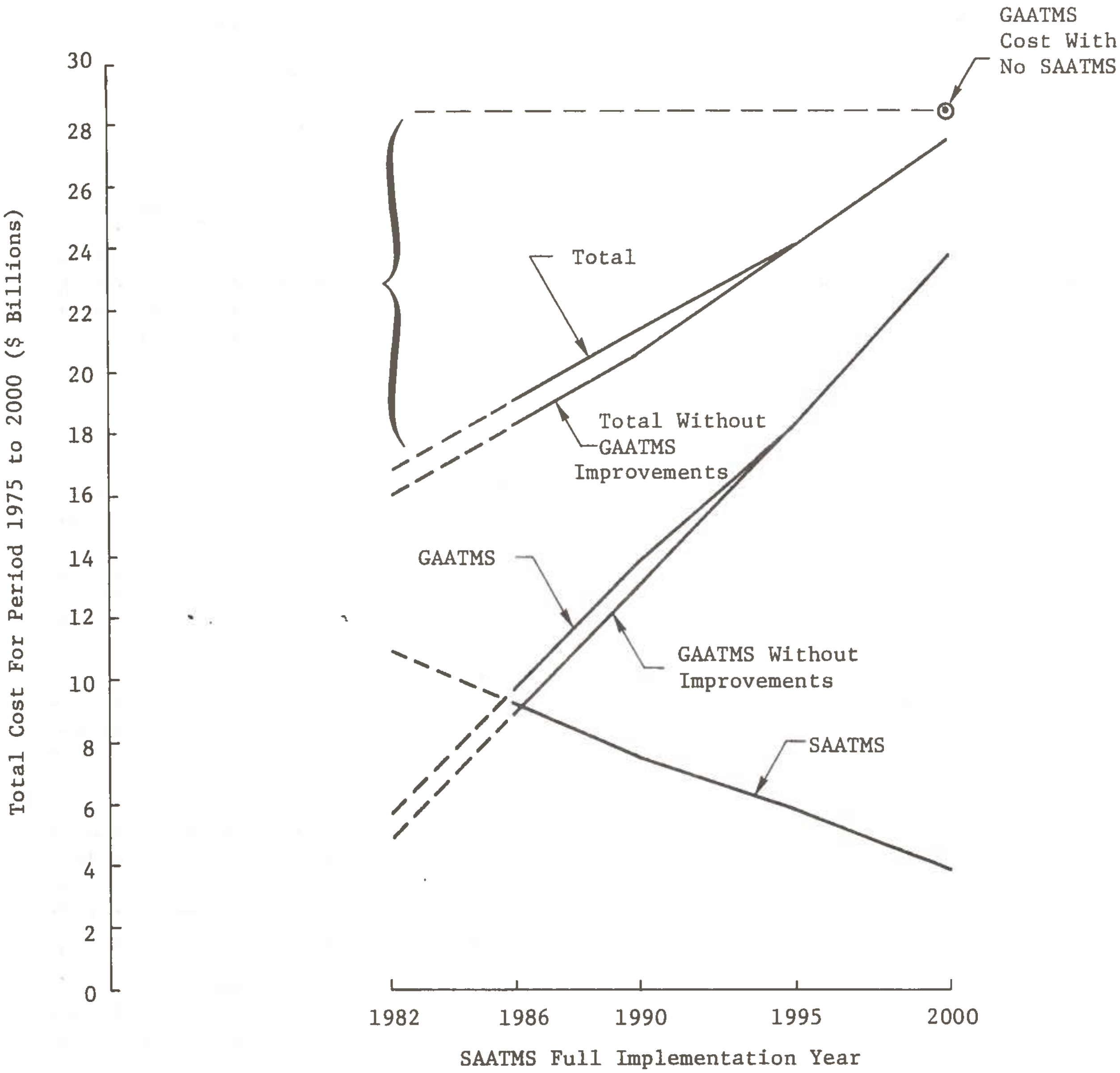


Figure 8.4-1. Total ATM System Costs (1975 to 2000) For Various SAATMS Implementation Dates, Third Computation

TABLE 8.4-3. TOTAL ATM SYSTEM COSTS FOR VARIOUS SAATMS IMPLEMENTATION DATES, THIRD COMPUTATION

Cost Element	Total Costs for Period 1975 to 2000 For SAATMS Fully Operational Date ($ Billions)				
	1986	1990	1995	2000	No SAATMS
GAATMS System (FAA Plan Extended)	9.7	13.8	18.2	23.7	28.4
SAATMS (With Revised Controller Manpower Requirements)	9.3	7.5	5.8	3.8	-
Savings If Certain Planned GAATMS F&E Costs Are Not Incurred (e.g., DABS, Radar Improvements, etc)	-0.8	-0.8	-	-	-
Total R&D, F&E, O&M	18.2	20.5	24.0	27.5	28.4
Net Savings By the Year 2000	10.2	7.9	4.4	0.9	0
Cost of Converting All User Avionics By SAATMS Implementation Date	1.8	2.1	2.5	3.1	-

8.5 No GAATMS Improvements

One other cost factor was examined and that was an estimate of the savings which would result if certain presently planned ATC expenditures were omitted or programmed in favor of early SAATMS implementation. One obvious area is the planned phase-in of DABS. Other areas would include various enroute radar and navigation aid improvements, terminal area expansion, etc. Table 8.5-1 lists these items and their estimated costs, as taken from the recent FAA 10-year plan (Ref. 2, Tables 3-2, 4-2, and 7-2). A total of $830 million of planned F&E costs appear to be avoidable if the SAATMS will be available early.

The assumption made was that these expenditures are for facilities and equipment which would be replaced or superceded by SAATMS. The full costs of these facilities may not be amortized if the facilities were installed and the SAATMS implemented soon after. Thus, it may be possible to "make do" with old equipment (i.e., not replace or modernize) and not install advanced facilities and equipment (e.g., DABS if it is known that the SAATMS will be implemented shortly. The costs which are thus avoided are additional cost savings attributable to SAATMS.

Tables 8.2-5, 8.3-1, and 8.4-3, and Fig. 8.2-6, 8.3-1, and 8.4-1 show the effects of this cost savings. It was assumed that the savings would be applicable to only the 1986 and 1990 AATMS implementation dates. The later dates would provide sufficient time to fully amortize the new facilities and equipment and would require "making do" with old equipment for an unreasonable period, not to mention such considerations as safety, effects on capacity, and operating costs.

14. Communications from General Electric Market Development and Applications Engineering, Owensboro, Kentucky, January 31, 1973, and February 14, 1973.

15. "L-Band Transistor Amplifier Dishes Out 1 KW," Microwaves, December 1972, page 9.

16. "Printed Circuit TWTs Developed," Aviation Week and Space Technology, February 5, 1973, page 53.

"Traveling Wave Tubes Advance," Electronics, May 10, 1973, page 74.

Communications from Varian to Autonetics Division of Rockwell International, dated February 1, 1973, with brochure.

"Low Cost Microwave Tubes for Airborne Phased Array Radar Application."

17. Fourth Generation Air Traffic Control Study, Autonetics Division of Rockwell International, C71-61/301, Volume IV, pages E-1, E-2, E-3.

18. Electronics, May 10, 1973, page 154, and June 7, 1973, page 109.

19. Radio Technical Commission for Aeronautics, SC-117, Report No. 148, A new Guidance System for Approach and Landing, December 18, 1970.

9. REFERENCES

1. DOT-TSC-304-1 (Autonetics C71-61/301), Fourth Generation Air Traffic Control Study, Final Report; Volume III, Appendix D, dated June 1972.

2. The National Aviation System Plan, Ten Year Plan, 1973-1982, No. 1000.27, Appendix 2, Department of Transportation, Federal Aviation Administration, dated March 1972.

3. WN-7834-DOT (DOT-TSC-344-1) Advanced Air Traffic Management Systems; A Cost Model and Comparative Analysis, Prepared by Rand Corporation, dated May 1972.

4. AD 813807, Department of Defense, Rule-of-Thumb Pricing Guide for Estimating Costs of Military Communication and Electronic Systems, Second Edition, June 1, 1966. (Note: Since this document is about seven years old, it was used primarily as a guide for estimating costs. In most cases, the cost estimates from the document were increased by a factor of 1.5 to account for approximately six percent annual price inflation since 1966.)

5. TN-8181-73-2, Capacity and Control Staff Estimates Corresponding to a Particular Set of Assumptions for a Hypothetical Fourth Generation Enroute ATC System, by J. O. Williams and R. S. Ratner, Stanford Research Institute Technical Note, dated August 4, 1972.

6. MTR-6110 Controller Productivity Study, The Mitre Corporation November 1971.

7. Aviation Week and Space Technology, March 5, 1973, page 20.

8. Aviation Week and Space Technology, March 12, 1973, page 43.

9. Aviation Week and Space Technology, February 19, 1973, page 64; February 26, 1973, page 19; March 5, 1973, page 14.

10. Advanced Air Traffic Management System Data Formats Specification-TSC, October 18, 1972.

11. MTP-138, Satellite Systems Planning Costs, by B. M. Hadfield, The Mitre Corporation, October 1972.

12. TSC Memo, Launch Vehicle Payloads and Costs for AATMS, from R. H. Reck, to D. E. Lev, dated April 13, 1973, plus Addendum No. 1, dated April 16, 1973.

13. Advanced Air Traffic Management System Program Requirements Specification, The Mitre Corporation, Draft, dated December 29, 1972, Table 2.1.3.5.1-1.

14. Communications from General Electric Market Development and Applications Engineering, Owensboro, Kentucky, January 31, 1973, and February 14, 1973.

15. "L-Band Transistor Amplifier Dishes Out 1 KW," Microwaves, December 1972, page 9.

16. "Printed Circuit TWTs Developed," Aviation Week and Space Technology, February 5, 1973, page 53.

"Traveling Wave Tubes Advance," Electronics, May 10, 1973, page 74.

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18. Electronics, May 10, 1973, page 154, and June 7, 1973, page 109.

19. Radio Technical Commission for Aeronautics, SC-117, Report No. 148, A new Guidance System for Approach and Landing, December 18, 1970.