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CONCEPT FOR A SATELLITE-BASED ADVANCED AIR TRAFFIC MANAGEMENT SYSTEM

Volume VI. Development and Transition Plans

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16. Abstract

This volume presents the plans for implementing the Satellite-Based Advanced Air Traffic Management System (SAATMS) described in Volumes II, III, and IV. Two plans are presented: an RDT&E plan and a transition plan. The RDT&E plan is presented as a series of task descriptions which delineate the activities that must be performed to generate requirements and to develop the hardware and software that comprise the various components of the system. The plan also describes those management tasks necessary to document and control the orderly development of the system. Development schedules and associated costs are also presented.

The transition plan presents a two-phase, 13-year program for transition from the in-being system to the SAATMS. The plan describes how the facilities, services, equipment, and rules governing operation in the SAATMS are phased in and the in-being system is phased out. The plan is designed to minimize user costs and avoid federal government budget peaks. A schedule of various regulations governing the installation of SAATMS avionics equipment in user aircraft is also presented.

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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

This volume presents the plans for implementing the SAATMS as described in Volumes II, III, and IV of this report. Two plans are presented: an RDT&E plan and a transition plan. Section 2 describes the plan for developing the SAATMS and consists of the research, development, test, and evaluation (RDT&E) activities needed to bring the SAATMS from the conceptual phase to an operational system. The RDT&E plan is presented as a series of task descriptions which delineate the activities that must be performed to generate requirements and to develop the hardware and software that comprise the various components of the system. The tasks are broken down into five areas: air traffic management processing and control, satellites, airports, avionics, and a management area which describes the system integration, documentation, and procedures required to control the SAATMS configuration, parameters, and interface. Included in this last section are those tasks needed to develop specifications and test and evaluation plans. The RDT&E plan also presents a schedule for accomplishing each task and an estimate of the associated costs.

Section 3 presents the plan for transitioning from the in-being system to the SAATMS. The transition plan consists of a two-phase program covering a 13-year period. The plan describes how the facilities, services, equipment, and rules governing operation in the SAATMS are phased in and the in-being system is phased out. The plan was designed to provide for a gradual and evolutionary introduction of the SAATMS operational and functional concepts. In so doing, care was taken to minimize user costs by not requiring dual avionics to be carried during the transition period and to minimize government budget peaks. The plan features a single control authority for all users during the transition period. This enhances safety and facilitates coordination of traffic control for users of both the in-being system and SAATMS. Another feature of the transition plan is the employment of tax benefits and cost rebates as incentives for users to transition to the SAATMS at an early date. The plan further describes the schedule by which various regulations governing the installation of SAATMS avionics will be implemented.

2. RESEARCH, DEVELOPMENT, TEST AND EVALUATION (RDT&E) PROGRAM

2.1 Introduction

The evolutionary development of a Satellite-Based Advanced Air Traffic Management System (SAATMS) requires an orderly program of research, technical development, test, and evaluation. The goal of the RDT&E program is to gather the knowledge required to initiate a low-risk implementation program of a SAATMS which will satisfy the air transportation demands in the 1990 time period. This program must span all activities from initial concept formulation, through concept definition and system development, to the beginning of the system implementation program to ensure continuity of efforts and a minimization of costs. A list of the RDT&E tasks is presented in Table 2.1-1.

The RDT&E activities for developing SAATMS requirements, testing, evaluating techniques, and equipment have been organized to take maximum advantage of the scheduled DOD/NASA satellite tests. A flow of the RDT&E activities is presented in Fig. 2.1-1.

Initial efforts are concerned with establishing satellite test planning, developing the necessary equipments, and determining system and subsystem requirements. These requirements are refined during the early test phases, and high risk development begun. As the requirements become better defined, the hardware and software specific to the SAATMS are developed and again evaluated. Finally, a limited operational SAATMS is developed and detailed operational testing initiated.

Several of the later system testing tasks require use of prototype SAATMS equipments. For example, the final SAATMS testing scheduled for 1981-1982 makes use of a prototype version of a limited CCC and 6 to 10 SAATMS satellites. The operational use of these subsystems extends beyond the R&D phase and into the implementation and transition phases. Since their use extends far beyond the testing phase, their cost has not been included in the RDT&E costs.

2.2 The RDT&E Plan Provides a Comprehensive Vehicle for SAATMS Development

The RDT&E plan is a management document that is designed to control the orderly performance of those activities required to develop a SAATMS. This plan defines a course of action over the next decade which will supplement the FAA 10-year plan and which is sensitive to the planned efforts of the Department of Defense and the National Aeronautics and Space Administration.

The plan provides an understanding of the RDT&E Program by relating future elements of the program to past and continuing programs, their guidelines and rationale, and their R&D products. It describes the RDT&E program in terms of the activities, their end products, their purpose and scope, and the funds required.

Table 2.1-1 (Continued)

AVIONICS
Avionics Requirements
Surveillance Control and Displays
*DABS/SAATMS Compatibility Requirements
Air-to-Air Collision Avoidance System (CAS)
*Communications Avionics Requirements
*Navigation Avionics Requirements
Avionics Hardware Development
*Frequency Generator
*L-Band Amplifier
*Antennas
*Displays
*Integrated Surveillance and Communications Equipment
*Navigation Equipment
SAATMS DEVELOPMENT
Subsystem Integration
Parameter Control Document
Signal Interface Control Document
Test Plan and Procedures
Software
Hardware
Hardware/Software
Subsystem Test and Evaluation
Subsystem Specification Development
Administrative Specification
Subsystem Specifications

*Specific to SAATMS

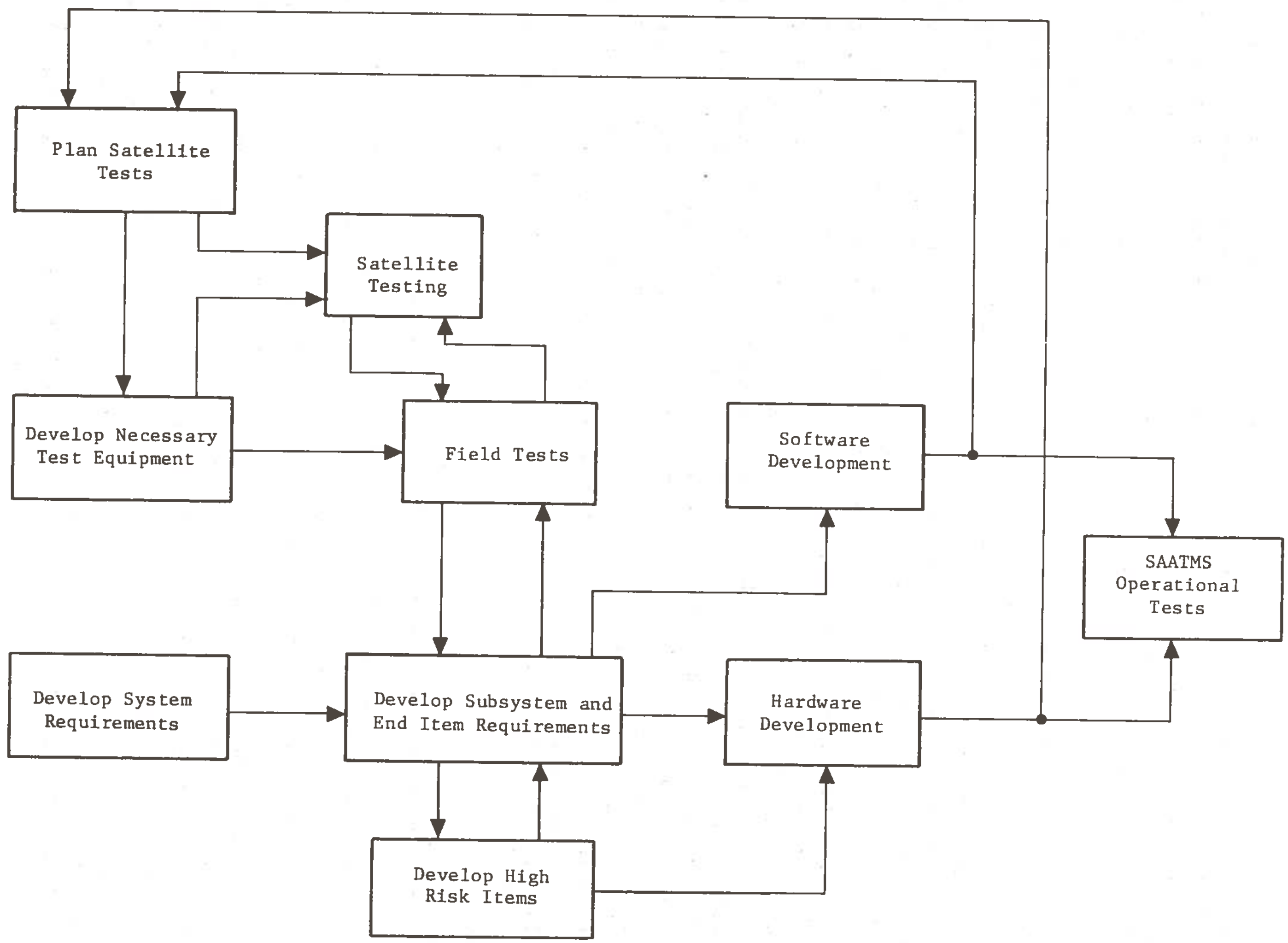


Fig. 2.1-1 RDT & E Activities

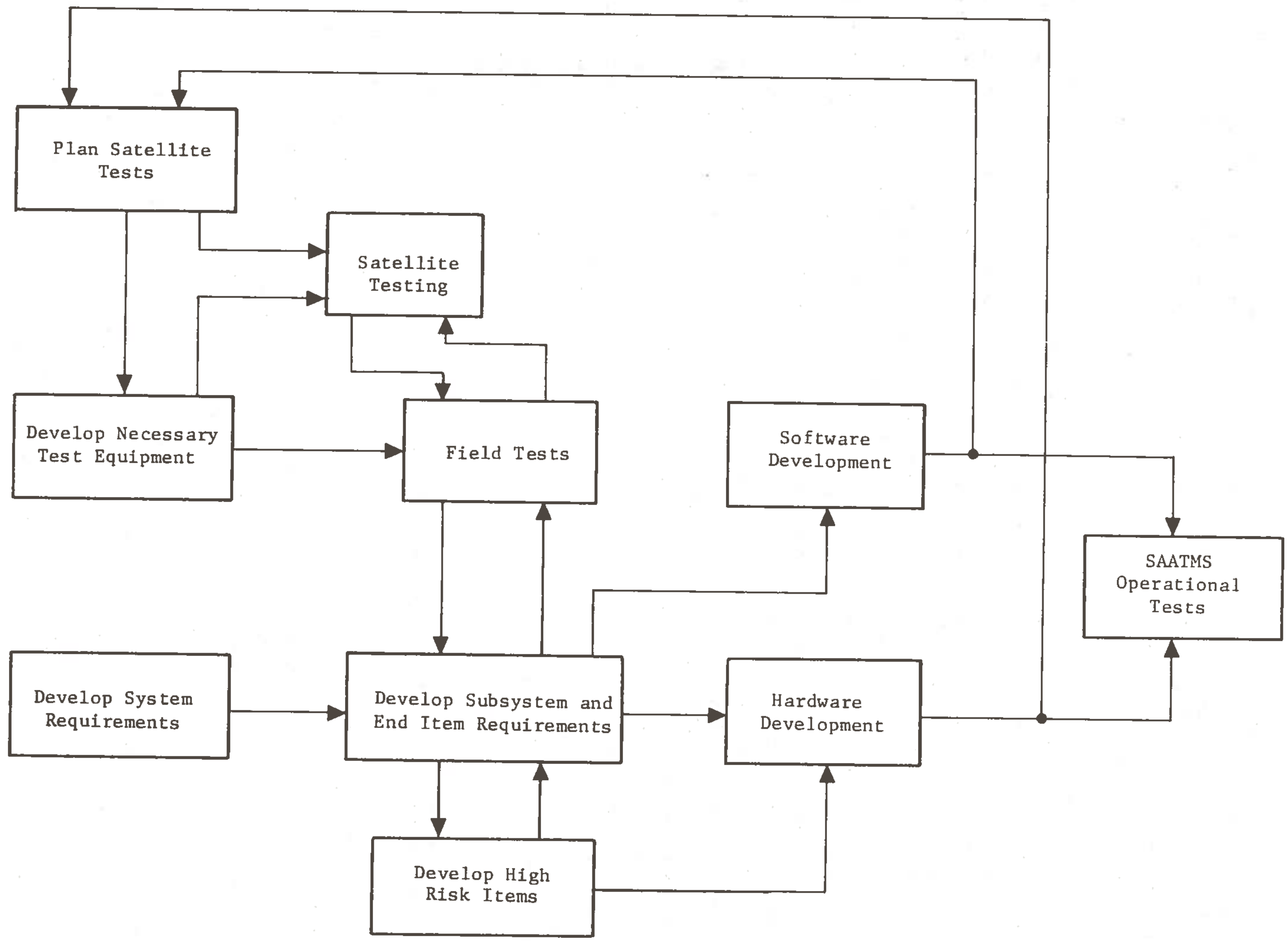
As the RDT&E program progresses, technology will change and, as activities are completed, knowledge of the concept feasibility will increase. This may well alter the initial baseline SAATMS concept and will require changes in the RDT&E program. The intent of the RDT&E plan is to control the comprehensive test and evaluation program geared to validating the behavior of the system, and to alter the baseline SAATMS concept on the basis of the knowledge gained during the program.

To insure that the goal of the RDT&E program is achieved, the planning for control of the activities must begin prior to the start of the system development cycle. The development cycle consists of three major phases as shown in Fig. 2.2-1. The requirements phase is concerned with the development of the system and subsystem functional requirements, establishing the feasibility of the system concepts at both the equipment and technique levels, optimizing the techniques to obtain maximum system performance, specifying the critical items with high technical risk, and developing preliminary system and subsystem performance specifications. The design and development phase covers activities from the hardware and software design through the building of breadboard, brassboard, and prototype items. Each of the hardware and software items must be tested for performance and reliability to assure that they satisfy their specifications. The end items must be integrated into specific subsystems which must also be tested against the subsystem performance specification. A high degree of control must be maintained during this phase to insure satisfying the performance requirements at a minimum cost. The final phase of the system development cycle is the system integration phase. During this phase, the prototypes of the individual subsystems are integrated to operate as a system. The system must be tested to determine if the performance specification has been met. If adequate control has been maintained during the prior phases of the cycle the system integration phase can readily provide the procurement specifications at the hardware, software, subsystem, and system levels. If adequate control is lacking, an iteration of the cycle may be required to achieve full system integration and satisfactory performance.

2.3 System Development Cycle Requires a System Management Approach

The number and complexity of the interfaces involved in a SAATMS require a formalized systems management approach to control its orderly and economical development. A system manager should be chosen to manage and control the design and development, to integrate the numerous end items into subsystems and ultimately into a complete system, and to develop the performance of the subsystem and system through tests and evaluations. A system of this complexity warrants a minimum of two associate system integrators, one for software and one for equipment and facilities. Each of these associates should operate under the direction of a central government agency whose responsibility would be to monitor the integration, performance, operation, and cost of the RDT&E activities. Each of the associate integrators would be responsible for the selection of the hardware or software contractors, with concurrence from the responsible government agency. The system manager and the associate integrators would be responsible for the development of the control documentation required to assure that the specifications are met.

The control documents which are of primary importance are the parameter control, signal interface, and physical interface documents. These allow the system integrators to trace how equipment parameters affect other equipment,



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REQUIREMENTS PHASE

Objectives and Requirements

- System Objectives
- System Requirements
- Subsystem Requirements

Concept Development

- Operational Concepts
- Mechanization Concepts
- Software Concepts
- Performance Measures
- Technical Performance Parameters
- Cost Data

Tradeoff Analysis

- Performance of Alternate Concepts
- Cost of Alternate Concepts
- Performance vs Objectives and Requirements

Feasibility Analysis

- Technique
- Software
- Operational Concept
- Technical Risk

Modeling, Simulation, and Experiments

- Operational Concepts
- Software Concepts
- Man/Machine Interfaces
- System Performance

Outputs

- Concept Definition
- Preliminary System Performance Specification
- Required Technical Development Areas
- Subsystem Performance Specification

DESIGN AND DEVELOPMENT PHASE

Subsystem Definition

- Software Specifications
- End Item Specifications
- Design Specifications
- Cost Estimates

System Control

- Accuracy Control Documents
- Specification Diagram
- Signal Interface Control Documents
- Physical Interface Control Documents
- Schedule Estimates
- Personnel and Training Requirements
- Program Management Plans
- Program Development Plans
- Reliability and Maintainability Programs
- Cost Reduction Programs

Selection of System Developers

- System Manager
- System Integration Contractors
- End Item Contractors
- Software Contractors

Modeling, Simulation, and Experiments

- Prove Design Feasibility of High Risk Items
- Software Programs and Computer Organization

Design and Development

- Prototype End Items
- Prototype Software Items
- Subsystem Prototypes
- Operating Personnel
- End Item, Software, and Subsystem Procurement Specifications
- Supporting Equipment

Testing and Evaluation

- End Item Performance
- Software Performance
- Subsystem Performance
- Reliability

SYSTEM MANAGEMENT PHASE

- System Integration
- System Procurement Specification
- Subsystem Procurement Specification
- End Item Procurement Specification
- Software Procurement Specification
- Supporting Equipment
- Certification Procedures
- Cost Reduction Programs

Fig. 2.2-1 System Development Cycle

subsystem performance, and system performance. In the event that an individual specification cannot be met, these documents allow the integrator to determine the impact on performance and the specification adjustments which can be made and still maintain acceptable performance.

A strong system manager, a comprehensive RDT&E plan, and a complete set of control documents are mandatory requirements for a successful, minimum-cost system development cycle.

The major responsibilities of the System Manager are

(1) Insuring the integrity of the SAATMS

(2) Coordinating and interfacing the development activities of the subsystem and end item contractors

(3) Defining the interaction of the SAATMS with other systems.

The System Manager's job is implied within all the tasks of the RDT&E plan.

The major functions of the SAATMS System Manager will be as follows:

(1) To integrate the various SAATMS end items and subsystems for acceptance testing and evaluation

(2) To perform the SAATMS tests and evaluations

(3) To develop the procurement specifications for the SAATMS end items

Although the exact details of the manager's tasks will be specific to each individual subsystem, these functions will be performed throughout.

2.4 The Satellite-Based Advanced Air Traffic Management System RDT&E Plan

This section presents a comprehensive RDT&E plan, which, when coupled with a strong systems engineering and management organization, can provide the leadership for the SAATMS development cycle. The plan covers the activities, schedule, and estimates of the required funding for each of the four subsystems and for the overall system. The four subsystems are as follows:

(1) Air Traffic Management

(2) Satellites

(3) Airports

(4) Avionics

The requirements for the system management tasks are also presented in this section. Each of the subsystem RDT&E activities are presented and discussed using an identical format. The two areas of activities presented are (1) requirements and (2) design and development. The activities in the areas of integration, test and evaluation, and specifications will be discussed in general in the presentation of the System Management tasks. These tasks will be performed in each development program by the System Manager. The details of these activities should be developed by the System Manager and the associate contractors under the direction of the government agency responsible for the control of the RDT&E program.

2.4.1 Air Traffic Management (ATM)

The Air Traffic Management subsystem includes the equipment and software that are physically located at the Continental Control Center (CCC), the Regional Control Center (RCC), and the Airport Control Center (ACC). ATM includes all of the functions performed by the CCC and RCC's, with the exception of those performed by the satellite ground tracking stations. It also includes the remote surveillance functions performed at the ACC's. The major functions to be performed in the ATM subsystem include the following:

(1) Flow planning and flight planning

(2) Aircraft surveillance acquisition and tracking

(3) Conflict prediction and resolution

(4) Transition and arrival control of aircraft

(5) VVOR navigation

(6) Data display

(7) Communications

The performance of these functions is dependent on the interface between the ATM, satellites, and airport activities. The RDT&E plan has scheduled the ATM activities so that the development, test, and evaluation can proceed independent from the development of the satellite and airports.

The primary cost benefits of the SAATMS are derived from the centralization of the control facilities and the automation of the air traffic control functions. Centralization of the control facilities will reduce the Facilities and Equipment (F&E) costs while automation reduces the Operations and Maintenance (O&M) costs.

The ability to centralize the SAATMS control facilities is derived from the use of satellites. Because satellites provide CONUS-wide coverage, fail operational and fail safe surveillance, navigation, and communication are possible with a small number of centers. The most crucial function performed with the use of satellites is the acquisition and tracking of the asynchronous surveillance signals transmitted by each aircraft using the SAATMS. The equipment and software item that is critical to establishing the feasibility of performing the acquisition and tracking of the surveillance signal (and hence to centralization of control) is the high speed surveillance signal processor. The analysis of requirements for this processor should be given priority to establish the feasibility of centralization.

Automation of specific functions should also be given high priority because of potential cost benefits. The application of automation will be impacted by the use of satellites. Satellites provide down-to-ground coverage and range independent position accuracies throughout CONUS. These features, coupled with more precise surveillance and navigation accuracies, permit the development of new operational concepts which will impact system performance, centralization of control, and the level of automation which can be achieved. During the requirements phase, the feasibility of the operational concepts will be established. These concepts will then be evaluated, and the optimal operational concept will be determined. Once this optimal concept has been selected, the application of automation can be developed. At this point the effect of that automation level on the SAATMS performance measures of capacity, safety, and delay can be determined. Other planned automation activities include: (1) the design, development, and testing of the software necessary to implement the selected level of automation, (2) the design and development of the controls and displays for the man/machine interface, (3) the integration of the software and hardware, and (4) the evaluation of the total automation concept.

Although the details of the automation software and hardware configuration are impacted by the operational concept that is ultimately selected, the approach to automation can be developed and its feasibility established earlier. The final configuration cannot be completed until the optimal operational concept has been fully defined.

The schedule and estimated cost of the RDT&E activities for the requirements, design and development, integration, and the test and evaluation of the ATM activities are presented in Fig. 2.4-1.

2.4.1.1 ATM Requirements

The activities involved in establishing the requirements for the ATM activities are presented in two parts. The first area concerns the development of the optimal operational concept. The second area concerns the development of the remainder of the software and hardware requirements which will permit a cost effective development of ATM subsystem prototype equipment.

2.4.1.1.1 Operational Concepts

An operational concept has three major elements: an airspace structure, a management concept, and a set of rules and procedures. The requirements for each of these elements must be established and then the concept must be evaluated to determine its impact on system performance. Three techniques were considered for evaluating the operational concept, viz, field tests, real time simulation, and digital simulation models. Field tests provide the greatest realism but are expensive, difficult to implement, and have limited evaluation flexibility. Real time simulations are realistic but are also expensive and do not provide complete flexibility. Digital simulations offer limited realism but are less expensive than field tests or real time simulations. They are the most flexible and can readily be adapted to represent different test conditions. Therefore, the plan stresses the use of digital simulations to initially evaluate the proposed operational concepts, to obtain sensitivities of system performance to variations in operational concepts, and to select the concepts that provide the desired performance. The selected concepts will then be evaluated using real time simulations with a more detailed representation of the interaction between the concept and system performance. The surviving concept then will be evaluated in detail with field tests.

Item	Fiscal Year													
	72	73	74	75	76	77	78	79	80	81	82	83	84	85
Requirements				$2 Million										
Design, Development, and Fabrication					$15 Million									
Integration					$8 Million									
Procurement Specifications						$8 Million								
Test and Evaluation					$14 Million									

Fig. 2.4-1 ATM RDT & E Schedule and Funding Allocations

There are eleven activities or tasks, as itemized below, involved with the development of the operational concept. The first two activities are the formulation of a system concept and a definition of that system. These activities have already begun and are included to provide a complete and consistent RDT&E plan.

Item 1. <u>System Concept Formulation</u>

Based upon the comments and requirements specified by TSC, the FAA, and ATCAC, the application of advanced technology to a fourth generation air traffic system was developed. Using this technology, the trade-off data among viable system alternatives was developed, and based upon government objectives, different SAATMS concepts were formulated. Results of these studies included: SAATMS concept formulation, SAATMS concept trade data, and a SAATMS concept recommendation. This task is complete.

Item 2. <u>System Concept Definition</u>

Based upon the recommendations of the concept formulation studies, the SAATMS was further defined. Trade-off data for the alternative subsystem mechanization approaches and the subsystem and system performance data were developed. The SAATMS concept was described with a system specification, an RDT&E plan, and a transition plan. Results from this task included a SAATMS concept definition, system and subsystem performance, a SAATMS system specification, and RDT&E and transition plans. Further and more detailed definition of specific subsystems is required.

Item 3. <u>Model Requirements and Availability</u>

Several operational concept candidates have been developed and a limited evaluation has been completed. The preliminary results indicate a significant impact on system performance and subsystem requirements.

This task will develop the detailed requirements and sensitivities for the models necessary to perform the analyses and evaluations of the different operational concepts. It will also determine the usability of presently developed models. This task will also develop the details of the operational concepts and their interaction with a SAATMS as well as developing the modeling structure used for concept evaluation. The task outputs are as follows:

Operational concept definitions and description

Interaction of the operational concepts and system tasks

Operational concept sensitivities definition

Model requirements

Model availability

Model architecture

Model development plan

Item 4. Develop System Measures and their Relationship to SAATMS

Previous DOT studies have established the fundamental relationships between various subsystem parameters and capacity and safety. This task will review the past work and extend it to cases of specific interest, develop more detailed relationships, and prepare methods for normalizing the models to known data points. The results of these studies will be used as the basis of the capacity and safety models to be developed in this subsystem.

SAATMS capacity and safety are affected by the performance of various subsystems and equipment. To fully understand the impact of the operational concept on the SAATMS performance, the relationship of these system measures to subsystem performance must be understood. This will allow a more detailed definition of the models and modeling structure and will insure incorporating the proper sensitivities into the models. This task will include the effects of both wake turbulence and noise abatement requirements on capacity and safety and will define the following:

Capacity and safety

Quantitative relationship of system performance and runway capacity

Quantitative relationship of system performance and aircraft safety

Capacity and safety relationships for the following:

Runways

Airports

Terminal Areas

Enroute Airspace

Total System

Item 5. Develop Demand Model

As a result of previous DOT work, the sensitivities of system and subsystem performance to demand projections have been established. To avoid future problems in comparison evaluations and to allow DOT to make decisions based upon proper input data, a set of universal demand projections and a model describing these projections will be required.

This task will develop a demand model capable of generating variable aircraft mixes, interarrival times, aircraft characteristics, and demands. This model will be based upon demand projection studies carried out by DOT and will be used to provide a universal demand projection for all future efforts. This model will develop the aircraft demands for different airports under different operating conditions and will be used to support the input data required to run the evaluation models. Task results shall be in the form of the following:

Demand projections

Demand generator model

User's manual

Item 6. Develop Evaluation Models

This task will result in the development of the operational concept evaluation models and will use the previous work sponsored by TSC, e.g., Autonetics Requirements Analysis, as well as the work accomplished under this task. These models will be used to develop subsystem and system level sensitivity relationships as well as performance.

Models of the various SAATMS elements (area models) and the different SAATMS users will be developed. The area models will be used to represent the runways, airports, terminal, and enroute areas and will show sensitivities as required to depict variations in operational concepts. This will include the airspace structures, rules and procedures, and the control concept. The user models will describe the dynamics of different aircraft and the flight characteristics of different user classes, i.e., controlled and cooperative. The data necessary to initiate and validate the flight models will be developed from actual measurement programs. When completed, these models will represent the flight of aircraft within the SAATMS in compliance with the proposed operational concept and SAATMS subsystem elements. Results of this task will include the following:

Data collection and measurement plan

Data measurements

Description of user flight

Model development plan

Area models

Aircraft flight models

Operational concept evaluation plan

Item 7. Validate Evaluation Models

To provide a realistic base from which to derive future system and subsystem performance, the area models developed in previous tasks must be normalized to some known baseline. The operating ATC system provides a good source of information and will be used as the baseline reference source.

The task will provide a basis for validating and normalizing the evaluation models. To achieve this calibration, a measurement program must be initiated and data must be gathered for sample scenarios. These scenarios will then be evaluated with the performance models and a calibration factor obtained. The outputs from this task will be as follows:

Measurement program plan

Data collection

Operating system performance

Test scenarios

Normalization factors

Item 8. Operational Concept Evaluation

The digital modeling evaluation of the candidate operational concepts will be performed in this task. The data necessary to perform a trade-off of the concept benefits, performance, and penalties will be developed. The study will also be concerned with the impact of the operational concept on the subsystem requirements. Typical results will be as follows:

Operational concept performance

Subsystem requirements as related to operational concepts

Selected promising operational concepts for more detailed evaluation

Item 9. Simulation Plan

Once the most promising operational concepts have been determined, a more detailed evaluation must take place. This evaluation of system performance must take into account human performance, both pilot and controller, as well as the man/machine/system interface. To accomplish this in a realistic manner, real time simulation is recommended. This task will develop the simulation requirements by reviewing each of the operational concepts and determining its impact on the various subsystems. The availability of real time simulators will be determined. A design plan for developing and testing the necessary simulations will then be developed. This study will result in the development of the following:

Simulation requirements

Simulation availability

Simulation design plan

Simulation test plan

Item 10. Simulator Development

Based upon the design plan, the simulator required for operational concept evaluation will be designed, developed, and integrated. The simulator is expected to be a full scale mockup of both the ground and airborne stations and will include displays, controls, control loops, and a simulated environment and route structure. The specific control algorithms necessary for the simulator implementation will be developed. Primary outputs include the following:

Simulator hardware

Simulator software

Control algorithm requirements

Simulation test plan

Item 11. Simulation Evaluation of Operational Concepts

The operational concepts showing the most promise as a result of the model evaluation will be evaluated in a detailed real time simulation. Simulated real time scenarios will be run to test the effects of human performance characteristics, different subsystem parameters, and different operational concepts on system performance. As a result of this evaluation, a recommended operational concept consisting of an airspace structure, rules and procedures, and management and control concepts will be described. This concept will then be operationally evaluated in the SAATMS. Task results will include the following:

Simulation test results

Operational concept description

Impact of operational concept on subsystem requirements

Sample control algorithms

Sample flow planning algorithms

2.4.1.1.2 Software Requirements

Some requirements for the design and development of the software algorithms and programs involved in the ATM control functions will be developed during the operational concepts activities. The digital and real time simulation activities will include simulation of the flow planning, acquisition and tracking, conflict prediction and resolution, and transition and arrival control software programs. These programs include algorithms for metering, sequencing, merging, scheduling, and spacing of aircraft. The operational concept RDT&E activities will provide program and algorithm requirements documents as outputs. In some areas, the simulation may involve activities of such detail that the output will be an algorithm or program description document which describes a specific mechanization. The design and development activity for that algorithm or program could then be deleted. The design and development activities are presently scheduled in the RDT&E plan since the specific details of the information that will be provided from the operational concept activities are not known. Software requirements must be established for the communications and data processing end items. The RDT&E plan includes studies in these areas as well as studies to determine the impact of satellites on automation applications and the impact of automation on personnel training. The software requirements are itemized as follows.

Item 1. <u>Ground-to-Ground Communications Trade Studies</u>

This task will develop the cost-effectiveness tradeoffs for transmitting data between ground sites, i.e., ACC-RCC, RCC-RCC, CCC-RCC, and CCC-ACC. The data can be transmitted via three means:

(1) Satellites

(2) Ground relays

(3) Land lines

The analysis will consider the data rates, distance, and modulation technique and develop cost effectiveness relationships illustrating the impact on the SAATMS of a specific communications netting. Results will be in the form of ground-to-ground communications cost-effectiveness relationships.

Item 2. <u>Site Location Studies</u>

The purpose of this task is to determine the most effective location for the CCC and the RCC's. The site location analysis should consider satellite constellation visibility, the applicability of present facilities, and present data communication networks. In addition, the availability of operating personnel must be considered. Results will be in the form of cost trade-off data for the proposed RCC and CCC site locations.

Item 3. <u>Data Processing Requirements</u>

The objective of this task is to develop the quantitative requirements for the individual data processing tasks concerned with the performance of the control functions by the CCC, RCC's, and the primary ACC's. The requirements will include the following:

(1) Processing speed (instructions/second)

(2) Main memory size

(3) Auxiliary memory size

(4) Auxiliary memory access time (μsec)

(5) Input/output rate (words/sec)

The output of this task will be a data processing requirements document for the CCC, RCC's, and ACC's.

Item 4. Impact of Satellites on Automation Applications

The purpose of this task is to determine the impact of satellite features (e.g., remote area coverage, down-to-ground coverage, and range independent surveillance and navigation accuracy) on the application of automation to the functions, subfunctions, and tasks performed by the ATM subsystem. The relationships between the measures of system performance (i.e., capacity, safety, and delay) and the level of automation will be determined. Results will include a definition of SAATMS functions to be automated.

Item 5. Impact of Automation on Training Procedures

The application of automation will result in roles that are different for SAATMS personnel than for personnel in the present system. Training of personnel to function effectively in this new role will have a large impact on system performance. The purpose of this task will be to establish the requirements for equipment and software to accomplish the training of the SAATMS operating personnel. This task will also establish the procedures for training these personnel. Results will be in the form of the following:

Requirements for training equipment and software

Documentation of training procedures

2.4.1.1.3 Hardware Requirements

The requirements which lead to the preliminary design of the ATM hardware will be established in part from the activities concerning the operational concepts and from the software studies previously outlined. The functional interface between the software and the hardware will provide insight into what special functions will be required of the hardware. The hardware requirements studies are itemized as follows:

Item 1. Ground Processing Hardware Requirements

The objective of this task is to determine requirements for the ground processing subsystem design and development. The system level studies will define the number, location, and duties of each ground control center. This task will involve examining the functions performed by the automation subsystem in each of these centers to identify data acquisition, storage, processing, and control requirements. In addition, demand data will be examined to determine the subsystem capacity and speed requirements. The basic outputs of this task will be

A ground processing hardware specification which will include:

- Memory
- Speed
- Access time
- Accuracy
- Data source definition
- System information flows
- Interface and interconnect requirements

Item 2. Control Console Requirements

Requirements for the ATM subsystem control consoles will be developed in this task. Controls are required for two main purposes. The first permits a human controller to interface with the ATM equipment for the purpose of selecting operating modes, overriding automatic operation, taking over in emergencies or unusual situations, and generally supervising the operation of the ATM subsystem. The other is for the purpose of programming, testing, and maintaining the ATM equipment. These controls are needed for turning the equipment on and off, making adjustments, gaining access to test points, and for controlling checkout tests.

This task will be concerned with identifying the man/machine interface requirements. Human performance criteria consisting of parameters such as range, accuracy, frequency of performance, and feedback will be established based upon human engineering design criteria. Human channel capacity and bandwidth will also be specified to determine how many control actions can be performed by the operator within the time and performance constraints. These will be related to job requirements to determine how many controller stations are needed for each function.

The output of this task will be a man/machine control interface requirements document which will include:

- Job requirements
- Frequency of occurrence
- Performance accuracy
- Error effects
- Data input characteristics

Item 3. Display Hardware Requirements

The objective of this task is to determine the information required by a human to enable him to monitor and control the operation of the ATM subsystem. A second objective is to translate the information requirements into requirements for formatting and displaying the data to the human operator.

The human's role in the system will be obtained from the automation applications study. Once information requirements are established, an analysis will be made to determine the best means or format for presenting the information to the human. Techniques such as printed output, audio displays, pictorial TV type displays, alpha/numeric displays, and lighted discrete transilluminated displays will be considered. Also, the content of the displayed message will be determined.

Human engineering requirements for displays will also be established. These will include resolution, brightness and contrast, flicker, update rate, and color requirements for each data item. The relationship between the controls and displays will also be established, e.g., time lag between control input and display output.

The output of this task will include the following:

. Display information requirements:

Range

Resolution

Update rates

Display format

Human engineering requirements for each end item

Item 4. Communications Requirements and Message Analysis

The ATM subsystem will be required to communicate with users by both digital and voice links. In the case of voice communications, the interface between the user and the automation equipment may be a human; while in the case of digital communications, an encoder/decoder and processor will provide the interface. The purpose of this task is to develop requirements for communications hardware that will link the user to the ATM subsystem.

An analysis of the communications messages will be performed. The message analysis will include message content, bit rate, duration, and frequency as a function of demand level. Based upon this analysis, processor, encoder, and decoder requirements will be established for digital messages; and audio control requirements for voice communications will be established. A human engineering analysis will be performed to determine how many voice communication stations will be necessary. This analysis will be based on the amount and frequency of expected voice messages and the human's ability to handle voice communications traffic.

The output of this task will be as follows:

Message lists

Communications hardware requirement document

2.4.1.2 Automation Development

A major goal of the National Aviation System Plan is "to meet the demands of increased traffic without proportionate increases in the personnel required to control this traffic." Therefore, the plan shows the desired evolution of air traffic control "generations" from the manual "labor intensive" direction by the controller through the radar assisted "labor intensive" controller direction of today. The goal for the SAATMS is given as "machine intensive" and monitored rather than directed by a controller.

To achieve these goals, the present plan establishes the hardware and software to relieve the controller, provide the controller with complete situation and computation status knowledge, and provide the means for the controller to make intelligent decisions. These capabilities will be provided by automation.

2.4.1.2.1 Software Development

Based upon the operational concept and software requirements developed earlier, algorithms can be developed, hardware concepts selected, and general operational routines established. In the case of SAATMS, maximum utilization will be made of the current automation plans that are described in the FAA 10-year plan. However, since the SAATMS concept implies several major changes in sensors and in functional equipment, many of the detailed software items will require a completely new set of programs. New control, display, data acquisition, and communication programs will also be required in several areas. It is desirable that the development of the third generation and SAATMS automation be coordinated. Such coordination will extend the useful life of equipment to the benefit of the user and will minimize cost.

2.4.1.2.1.1 Communications Software

Item 1. Communications Processing

The user aircraft transmits communication messages (using pseudo-noise pulses) via satellites to the CCC and RCC's. These pulses are first processed in a special purpose hardware processor. Algorithms are required to decode the digital signal output from the pulse processor and to code and decode the messages.

During this task the communications algorithms specific to the SAATMS will be developed, simulated, and operationally coded. The outputs from this task will be as follows:

Algorithm description document

Listings and tapes for air-to-ground and ground-to-air communications

2.4.1.2.1.2 Control and Display Software

Item 1. Transition and Arrival Control

During the transition and arrival phases of flight to primary aircarrier airports, the ATM subsystem will perform several control functions. These functions include: merging, sequencing, metering, and spacing. The purpose of this task is to develop, simulate, and operationally code programs for transition and arrival control, including the algorithms for merging, sequencing, metering, and spacing. This program will also define display outputs and inputs to the algorithms from the control console. The major results of this task are as follows:

Transition and arrival control program description documents

Algorithm descriptions

Listings and tapes

Functional interface descriptions between programs and control and display end items

Item 2. Conflict Prediction and Resolution

The SAATMS provides separation assurance for all aircraft in the system. The conflict prediction and resolution algorithms necessary to provide separation assurance will be developed, simulated, and operationally coded in this task. This task will also describe the functional interface between these algorithms and the control and display end items.

The outputs of this task will be as follows:

Conflict prediction and resolution algorithm description documents

Listings and tapes

Functional interface descriptions

Item 3. Intrusion Prediction and Avoidance

The purpose of this task is to develop, simulate, and operationally code the software for the storage of airspace boundaries including the following:

(1) Airspace restricted for national security

(2) Controlled airspace

(3) Uncontrolled airspace

(4) Cooperative airspace

(5) TCA flight corridors

(6) Airports

The algorithms for prediction of intrusion into restricted airspace and for avoiding intrusions will also be developed in this task as will the program for the interface between these algorithms and the control and display equipment. The outputs of this task include the following:

Intrusion prediction and avoidance algorithm description documents

Listings and tapes

Boundary data file organization description

Functional interface descriptions

Item 4. Controls and Displays

The interface at the control console allows the operating personnel to interact with the data processing equipment to control the functions of the ATM subsystem. Data from the computer equipment must be displayed so that personnel can monitor the control activities and the status of the data processing equipment. The purpose of this task is to develop, test, and operationally code the software program required to achieve the specified man/machine interface. The programs to drive the specific displays provided for the operating personnel will also be developed. The task outputs are as follows:

Program description documents for the display software

Listings and tapes

Control console/central computer interface program description documents, listing, and tapes

2.4.1.2.1.3 Surveillance Software

The ATM subsystem must know the position of each aircraft in order to perform the air traffic control functions. The critical activities concerned with aircraft surveillance are acquisition of the aircraft's surveillance signal, determination of the aircraft's position, and the maintenance of a track file on each aircraft. The acquisition of surveillance signals is a hardware function; the calculation of position and the continued tracking of aircraft is a software function. Surveillance software development tasks are as follows.

Item 1. Aircraft Tracking

The purpose of this task is to develop, simulate, and operationally code the algorithms and programs required to compute the position of, establish, and maintain a track file on each aircraft.

The outputs of this task include the following:

Program description document

Listings and tapes for the position computation and aircraft track file algorithms

Item 2. Virtual VOR (VVOR)

The purpose of this task is to develop, simulate, and operationally code the algorithm needed to generate cross-track deviation from desired flight path and range from the designated grid point for all aircraft. This algorithm will make use of aircraft surveillance data to provide an RNAV capability for GA aircraft. The outputs of this task will be as follows:

VVOR algorithm description document

Listing and tape

Item 3. Data Storage Organization

The purpose of this task is to develop the organization of the data files, the access methods for storage and retrieval of information, the means for updating access keys, and the methods of reassigning locations containing old data. The files requiring organization include the following:

(1) Active aircraft file which contains the position, velocity, and status data on each aircraft

(2) File of restricted airspace and the jurisdictional control boundaries

(3) Flow plan file

(4) Weather information files

(5) Flight plan files

(6) NOTAMS

The task outputs include the following:

Data file organization document

File access document

2.4.1.2.1.4 Automation Management Processing

The CCC is responsible for the national flow planning of all aircraft filing flight plans. It provides to users information on weather, enroute and terminal traffic conditions, system status, and expected delays or conflicts. A large software program is required to keep track of all flight information, confirm reservations, approve flight plans, and disseminate information. The management processing software for the flow planning must be developed for the CCC. In addition, the operations, maintenance, and training software must be developed, not only for the CCC but also for the RCC's. The elements of this processing are itemized as follows.

Item 1. Flow Planning

The objective of this task is to develop, test, and operationally code the flow planning program and algorithms for providing flight information to all user aircraft requesting such service. The factors to be considered in the program and algorithms include the following:

(1) Weather data, both short- and long-term

(2) Aircraft flight plans

(3) Short- and long-term traffic densities

(4) RNAV routes

(5) Terminal capabilities

(6) Airport status

The task output will include the following:

Flow planning program description document

Listings and tapes

Item 2. Operation and Maintenance Software

The purpose of this task is to develop the software programs for determining system status, locating the elements of the subsystem that are functioning improperly, and displaying this information.

The task outputs include the following:

Program description documents

Listings and tapes for testing and checkout of all subsystem elements

Failure mode program description document

Item 3. Training Software

The purpose of this task is to develop, test, and code the off-line and on-line software programs for the training of operating personnel. These programs may utilize simulations external to the operating system or may utilize the actual system elements during nonstressed conditions.

The task output consists of a training program description document.

2.4.1.2.2 Hardware Development

The hardware development for the ATM activities must be closely coordinated with the software development to insure compatibility and to minimize subsystem integration costs. The primary hardware items involved are the ground based special processors and the general purpose processors. The ability of the SAATMS to centralize the system functions is dependent on the feasibility of the equipment design and development. These development activities should be given priority. The other hardware items requiring development include the controls and displays and the operating, maintenance, and training equipment. The hardware development tasks are itemized as follows.

Item 1. Ground Processing Equipment

The ground processing equipment includes general purpose computers and special purpose processors. Both of these items are planned to be developed as part of the total ground processor. The special purpose processors will be used to process the acquired surveillance signals, to identify the aircraft of origin, and to provide the time of arrival of each surveillance signal to the software program that determines aircraft position. The general purpose computer provides the capability for performing the software programs involved with the planning and scheduling of aircraft, the real time control of aircraft, the display of data to operating personnel, and the testing of hardware to insure proper operation. The development of the ground processing equipment may include the use of off-the-shelf general purpose digital components and associative processors as well as special purpose processors designed specifically for the automation subsystem. The purpose of this task is to develop the total prototype ground processing equipment and will include the hardware and software integration activities.

The task outputs include the design of the following:

Prototype special purpose processors

Prototype general purpose processors

Prototype ground processor

Preliminary procurement specification for the ground processor

Item 2. Control Console

The control console permits the operating personnel to interface with the ground processor and to influence its operation. The control console has two major interface requirements. The first involves those controls which permit the operating personnel to select operating modes, override automatic operation, and intervene directly in the performance of the system functions. This type of activity involves a direct interface with the subsystem software. The second involves turning equipment on and off, making adjustments, and controlling checkout, operational, and maintenance tests. The purpose of this task is to develop the control console equipment to provide the man/system interface. The development of this equipment must be controlled to insure compatibility of the hardware and software. The control console must interface directly with the display equipment. This task must develop the signal and physical interface to aid in the development of the display equipment.

The task outputs consist of the following:

Control console prototype

Preliminary procurement specification

Signal and interface documentation for the control console/ computer and control console/display interfaces.

Item 3. <u>Displays</u>

The display equipment is similar to the control console in that it permits personnel to interface with the ATM subsystem for operational checkout, and maintenance purposes. The objective of this task is to develop the display equipment prototypes that provide data to the operating personnel. The design techniques and the prototype development will be based on the human factors and display requirements developed earlier in the program. This task will involve an interface with the software programs used to provide the data being displayed and an interface with the control console.

The task results include the following:

Prototype display equipment for subsystem operation

Checkout and maintenance procedure

Preliminary display procurement specification

Item 4. <u>Training Equipment</u>

Equipment must be developed to train operating personnel in the use, checkout, and maintenance of the ATM subsystem. The purpose of this task is to develop the hardware required to provide on-the-job training of operating personnel and to evaluate their performance. This task will also be used to determine whether the training equipment should be an integral part of the ATM subsystem or a separate end item.

The task outputs include the following:

Prototype training equipment

Preliminary training equipment procurement specification

2.4.2 Satellite Subsystem

The SAATMS satellite R&D activities will be fully coordinated with other government agencies both to minimize direct DOT costs and to maximize availability of test data. This plan is based, to a large extent, upon use of existing DOT/DOD planned programs for preliminary feasibility assessment of SAATMS techniques.

Specifically, a program similar to The Boeing Aircraft Company/FAA tone ranging experiments should be conducted with pulsed pseudo-noise analog matched filter waveforms using satellites. Although the satellite payload is well defined and most experiments have been allocated for ATS-F, the L-band channel is sufficiently flexible so that a wide range of communications, surveillance, and navigation experiments can be accommodated. With a single satellite, two dimensional position fixing is not possible, but the experiments will provide sufficient data to assess the feasibility of alternate SAATMS techniques, e.g., multipath and link tests can be performed. These data will be particularly important in providing preliminary estimates of the magnitude and characteristics of these major satellite system error sources and will provide a basis for planning future and more detailed testing.

The ATS-F launch is scheduled for 1974 and, if the SAATMS program is to profit by it, plans and specific hardware fabrication must begin in 1973. To delay action past the beginning of FY-74 would jeopardize obtaining the SAATMS objectives from this test program.

The most promising candidates, as concluded from the initial ATS-F tests, can be included in the wideband Aerosat experiment program. With two satellites available, limited position fixing for surveillance and navigation is possible. Evaluation of alternate control concepts can be accomplished under operational conditions with test military and aircarrier aircraft. Additional signals and waveforms can be generated by ground test equipment to evaluate the signal handling capacity of a simulated CONUS system.

With the data gathered from the ATS series of experiments, simulations, and analyses, signal waveforms and avionics hardware mechanizations can be selected which would be compatible with the SAATMS satellite system objectives. The preoperational and experimental Aerosat programs will extend over the 1975-1980 time frame. The RDT&E tasks, aimed toward meeting the test dates, are indicated in the schedule.

Perhaps the most promising areas for satellite preoperational testing is the DOD Defense Navigation Development Program. Several satellites will be launched in 1977, and wideband L- and C-band channels are planned. Coordination with DOD must begin early to insure inclusion of TSC/DOT SAATMS objectives in the test and associated equipment design. Using these satellites, a more detailed and complete evaluation of the SAATMS waveforms and techniques can be accomplished, and the use of DNDP is preferred. The SAATMS surveillance, navigation, and communication techniques can be evaluated using these satellites. In addition, more detailed multipath, ionosphere, and link effects studies can be performed. A significant amount of SAATMS test data can be developed using these satellites. Examples of the experiments applicable to each of the satellite programs are illustrated in Table 2.4-1.

To insure meeting the objectives of the total satellite testing, DOT can outfit a SAATMS test aircraft specifically to support the satellite and ground tests. This will insure equipment and aircraft availability when required.

Although the satellite tests are important to the SAATMS R&D program, supplementary tests can be performed without satellites. These include both laboratory simulations and field tests. The effects of multiple access noise and multipath can be determined, and code optimization can be performed with both laboratory and field tests. The use of the SAATMS test aircraft will facilitate the scheduling and performance of these tests.

Concurrent with the testing program, analysis and development of the SAATMS satellite components will begin. Specifically, design, development, and evaluation of the satellite antennas and transmitters should be started early, since these items are key to the SAATMS design. In particular, increasing the reliability and lifetime of the L- and C-band transmitters must be considered a major objective of the satellite R&D activities.

The satellite R&D activities will culminate with the development and test of a prototype satellite subsystem. The detailed testing and evaluation of the subsystem equipments should include new satellite launches. The satellite constellation should be specific to the SAATMS needs and will serve to demonstrate the full SAATMS technical objectives. In addition, the constellation will serve a dual purpose by being used during the SAATMS transition phase. Thus, launches will be performed during the 1980-1982 time period.

The overall schedule and costing of the satellite R&D tasks are shown in Fig. 2.4-2.

2.4.2.1 Satellite Requirements

A great deal of experience has been gained over the past 20 years in the design, development, test, and operation of earth satellite systems. In the planned RDT&E program, maximum utilization will be made of this information by close coordination with past, present, and future satellite systems. The tasks that are described below are oriented toward development of SAATMS system requirements within the objectives of these test programs, extrapolation of data to the SAATMS system, development of design analysis, and test programs to investigate areas not yet fully substantiated.

Item 1. Orbit and Constellation Analyses

A detailed model for the analysis of the interaction of the satellite orbit and constellation geometry with the surveillance, navigation, and communications functions will be developed. The model will account for

Table 2.4-1 Satellite Experiment Program

ATS-F Tests and Experiments	Aerosat* Tests and Experiments	DNDP Tests and Experiments
Initial Multipath Experiments	Detailed Multipath	Multipath Experiments
TOA Measurement Techniques	TOA Measurement Techniques Evaluation	Link Characterization
Link Characterization (Partial)	Link Characterization	TOA Measurement Techniques
Aircraft Antenna Pattern Experiments	Aircraft Antenna Patterns	Aircraft Antenna Patterns
Preliminary Multi-access Noise	Navigation Waveform	Navigation Waveform
Satellite Tracking	Surveillance Waveform	Surveillance Waveform
	Communication Waveform	Communications Waveform
	Multi-access Noise	Multi-access Noise
	Preliminary Surveillance Mechanization	Asychronous Acquisition and Tracking
	Preliminary Operational Concept Evaluations	Surveillance Mechanization
	Satellite Tracking	Navigation Mechanization
		Communication Mechanization
		Operational Concept Evaluation
		Control Software Evaluation
		VVOR
		Satellite Tracking
		Limited SAATMS Operational Tests
		Integrated Avionics Evaluation

*The short evaluation time planned for the Aerosat satellites prior to its operational phase will impose limits on these tests.

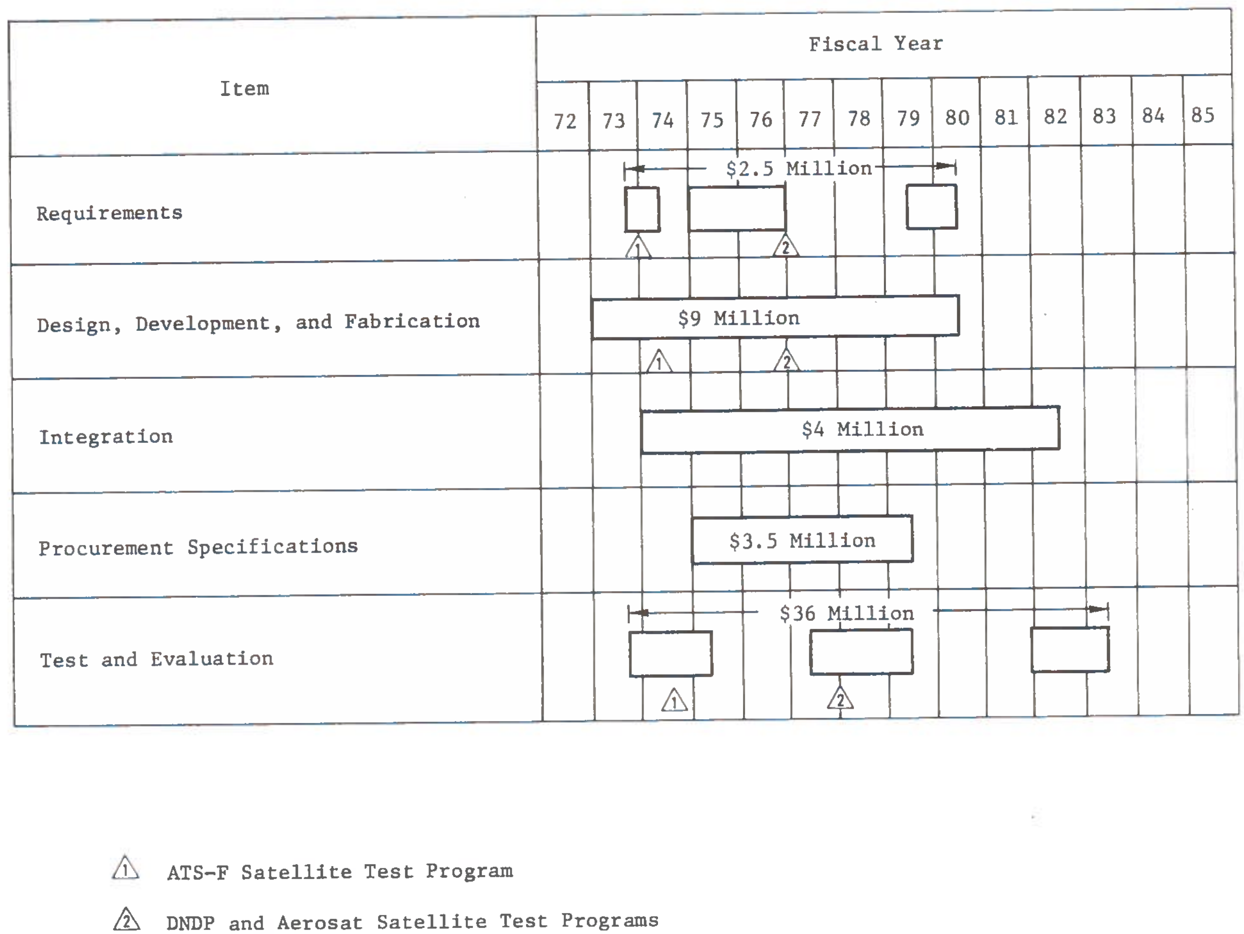

Fig. 2.4-2. Satellite RDT & E Schedule and Funding Allocations

aircraft/satellite effects such as antenna patterns, received signal energy, platform stabilization, and look angles. In addition, satellite/space effects such as multiple body gravity, nonspherical earth, and solar pressure will be accounted for. The major outputs will include the following:

Satellite constellation and surveillance and navigation accuracies relationships

Satellite visibility relationships

Effects of aircraft antenna patterns and maneuvers

Degraded user effects

Avionics requirements

Satellite requirements

Satellite lifetime

Constellation lifetime degradation

Item 2. <u>Satellite Launch Vehicle Study</u>

To determine the most cost effective means of launching and inserting the SAATMS satellites into orbit, the interaction of the space shuttle and the satellites shall be investigated. The task outputs include the following:

Cost effectiveness relationships for launching and inserting SAATMS satellites into orbit

SAATMS/space shuttle interaction

Item 3. <u>Satellite Attitude Control</u>

The activities in this task are geared toward the development and demonstration of the satellite attitude stabilization subsystem. The attitude control requirements for the synchronous satellites are not expected to be severe since they are designed to be pointing at their subsatellite points. However, the geostationary satellites are required to maintain a pointing angle consistent with their location, the selected antenna patterns, and the final constellation geometry. The task outputs will be as follows:

Attitude stabilization requirements

Attitude stabilization subsystem development specification

Exploratory development of the attitude stabilization subsystem

Test plan

Attitude stabilization performance

Design specification

Item 4. <u>Satellite Link Characterization</u>

This task consists of a study to characterize and develop a model for the effects of the ionosphere and troposphere. The model will determine the characteristics of errors introduced into the satellite due to the ionosphere and troposphere, as well as errors due to time and geography. The effects of these errors on both absolute and relative measurement accuracies and the means of reducing them will be analyzed. Some preliminary data for this task will be developed during the ATS-F satellite tests. More detailed information will be available from the later Aerosat and DNDP test programs, as well as from laboratory field tests. The task outputs include the following:

Test plan

Special purpose test hardware

Data collection and analysis results

Data evaluation

Ionospheric and tropospheric models

Effects of errors on surveillance and navigation accuracies

Error reduction techniques

Item 5. <u>Multipath Analysis</u>

The objectives of this task are to characterize the multipath environment; evaluate the effects of multipath on the SAATMS surveillance, communication, and navigation functions; and identify techniques for minimizing these effects. The task will consist of analyses, laboratory studies, and field tests for both satellites and ground subsystems. Here again, preliminary data will be obtained from the ATS-F tests and refined using the Aerosat and DNDP satellites. Laboratory and field tests will be used to support the preliminary satellite tests and develop detailed objectives for the later satellite tests. Task outputs include the following:

Performance of PN waveforms in various terrains at different elevation angles

Multipath model development

Performance of PN waveform vs other candidate waveforms

Laboratory hardware development and testing

Test plan and development specification

Exploratory development equipment

Test report

Technique design specifications

2.4.2.2 Satellite Development

2.4.2.2.1 Satellite Software Development and System Analyses

This portion of the SAATMS RDT&E program involves the satellite subsystem software and the system level design and analyses. Its direction depends heavily upon the result of the requirement studies previously described. Using these results as a base, the engineering analyses and tests needed to resolve the technical and administrative problems and confirm operational and design approaches can be performed. During this period, heavy emphasis will be placed upon projected satellite test programs to confirm specific designs and to provide insight into the various transitional problems of equipment and procedures.

Satellite development tasks are as follows.

Item 1. Navigation and Communication Waveform Design

The objectives of this task are to design the signaling scheme, the waveform, and the channel to be used for the navigation, the ground-to-air (digital communications and voice), the ground-to-ground (digital communications and voice) functions. This task includes an analysis of the modulation techniques and their impact on system performance, design, and cost. The task outputs will include the following:

Optimum modulation techniques, digital and voice

Relationships between modulation techniques and system requirements, e.g., spectrum, cost, data rates, and power

Item 2. Random Access Satellite Surveillance/Communications

The objective of this task is to describe and optimize the random access satellite surveillance and communications link. This will include characterizing the multiple access noise, selecting optimum codes, and optimizing the link parameters. The effects of the link performance on system performance will be established. The analysis will be supplemented by laboratory and field tests. The field tests will include the Aerosat and DNDP satellite experiments. Task outputs include the following:

Specific codes with good autocorrelation and cross-correlation properties

The number of codes available for different system and subsystem performance levels

Multi-access noise characterization

Multi-access noise effects

System performance and detection threshold relationships

Probabalistic GDOP relationship

Laboratory hardware development and testing

Satellite test plan and development specification

Exploratory development equipment

Test report

Item 3. TOA Measurement Techniques

The objective of this task is to perform an analysis directed toward selecting the most appropriate TOA measuring technique. The performance and implementation features of different techniques will be investigated. The accuracies and cost relationships will be determined for each user and signal waveform. The analysis will consider the following:

(1) The state of the art of the hardware required for implementation

(2) Implementation costs

(3) Performance capability

A hardware prototype of the TOA measurement system will be developed and tested. The tests for this task will include the ATS-F and Aerosat satellite experimental programs, supported by appropriate laboratory testing. The task outputs will include the following:

Satellite test plan

Prototype TOA measurement designs

Test report

Item 4. Develop Satellite Tracking Algorithms

The objective of this task is to develop, test, and operationally code the computational programs necessary to predict the location of the SAATMS satellites. This will include analyzing various satellite tracking mechanizations, defining and describing their error source and performance, and selecting that mechanization most compatible with the SAATMS mechanization requirements. Computer programs will be developed for the following:

(1) Precorrection of satellite tracking data

(2) Computation of Kalman filter gains for geographical areas as a function of time

(3) Prediction of future satellite ephemerides

A detailed simulation of the satellite tracking and prediction software will be performed. The programs will be modified as necessary.

The task outputs will include the following:

Satellite tracking and prediction mechanization and program

Program description and testing

Simulation results

Tapes and listings

Item 5. <u>Satellite Navigation Algorithm</u>

The objective of this task will be to develop, simulate, and operationally code the satellite navigation algorithms. Different navigation techniques and mechanizations, including different suboptimal filters, will be analyzed and tested, and the one best meeting the SAATMS requirements will be selected. The sensitivity of the navigation accuracy to equipment (satellite and avionics) and system errors will be determined. The task will result in the following:

Program requirements documents

Algorithm accuracy sensitivities

Tapes and listings

Item 6. <u>Satellite Error Analysis</u>

The objective of this task is to perform a comparable evaluation of different competing techniques and determine subsystem, and ultimately system, performance. A complete and detailed set of error models will be developed. These models will be updated as a result of simulations, satellite, field, and operational tests. The end result will be a detailed error budget for the satellite subsystem and its individual end items and components.

Task outputs will include the following:

Satellite surveillance error model

Satellite navigation error model

Satellite communications error model

Ground surveillance error model

Ground navigation error model

Ground communications error model

Preliminary subsystem performance

2.4.2.2.2 Satellite Hardware Development

These studies are accomplished in parallel with the software and analysis efforts described in the previous section. Due to the magnitude and complexity of the job and the multiplicity of contractors that will be involved, the hardware development problem is of major proportions. It is particularly important that participation in existing and planned satellite hardware system tests be established at an early date. These test results are of primary concern to the early establishment of firm SAATMS hardware requirements. Some of these satellite tests are scheduled to begin in 1974 (ATS-F). Therefore, test planning and development of the brassboard hardware must begin in 1973. Participating in these early tests can lead to significant system performance improvements at less cost to the user and operator. The hardware development tasks are as follows:

Item 1. Satellite Test Equipment Configuration

The objectives of this task are to develop the requirements for and the design specifications of the components and equipments required for the satellite tests. The design specifications for all the satellite electronics subsystems will be prepared as part of this task. This task will involve compatibility design studies for the NASA ATS-F, the Aerosat, the NASA multi-purpose payloads and the AF DNDP (621B) satellite programs. Task output will include the following:

Satellite subsystem test requirements

Design specifications for the following:

Satellite and ground equipment necessary to support the satellite tests

Satellite Antennas

Satellite Transmitter

Satellite Transceiver

Item 2. Satellite Antennas

The objective of this task is to select, design, develop, and test antennas required for the SAATMS satellites. These antennas must serve the C- and L-band links. The task activities include utilization of design techniques which result in minimum antenna weight and size. The integration of the antennas, wherever possible, through the use of multiple feeds or other design techniques will be a prime objective of this task.

Task outputs include the following:

Antenna design requirements

Antenna development

Antenna test plan

Antenna performance

Antenna design specifications

Item 3. Satellite Transmitters

The objective of this task is to design, develop, and test the transmitter required for the SAATMS satellites. The primary objective of this task is to obtain the reliability and lifetime necessary to insure satellite acceptability. The following transmitters will be included:

(1) L-band, high peak power and high average power

(2) L-band, medium peak power and high average power

(3) C-band, low peak power and high average power

Task outputs will include the following:

Transmitter design requirements

Transmitter design

Transmitter laboratory test plan

Transmitter development

Transmitter design specifications

Item 4. Satellite Transponder

The objective of this task is to design, develop, and test the transponders necessary for the SAATMS satellite subsystem. There are two required transponders. The first must receive aircraft L-band transmissions, convert them to C-band, and retransmit them to the ground. The second receives ground transmitted C-band signals, converts them to L-band, and retransmits them to the aircraft.

Task outputs are as follows:

Receiver design requirements

Receiver developments

Receiver-transmitter integration

Test plan

Test report

Design specifications

Item 5. Satellite Power Source

The objectives of this task are to develop the requirements mechanization for and demonstrate the feasibility of the satellite power source. The input power requirements for the SAATMS satellites is expected to be between 7 and 10 kw. The development of a solar cell array capable of meeting these requirements represents an important step in establishing satellite feasibility.

Task outputs will include the following:

Power source requirements

Power source development specification

Exploratory development - power sources

Test plan

Test report

Design specification

Item 6. Long Line Analog Matched Filter

The objective of this task is to design, develop, and test an AMF capable of meeting the SAATMS requirements. Present technology has developed an AMF capable of coherently adding pulses up to 20 μsec long. The need for a longer line (40 μsec) AMF is directly related to reducing user transmitter power requirements and hence overall avionics costs.

The task outputs are as follows:

AMF design requirements

AMF development

AMF test report

AMF design specification

2.4.3 Airports

The airport is composed of (1) the physical plant, including runways, taxiways, and towers, (2) the operational aids such as MLS, runway and taxiway guidance, and local approach and departure orientation, and (3) control software including planning and scheduling, local traffic regulation and coordination, local airspace structure, and emergency procedures. This portion of the RDT&E plan considers only the electronics and software indigenous to the airport. The physical plant is not part of this plan.

Attention has been paid to the FAA 10-year plan to arrive at a logical sequence of events for the development of these SAATMS R&D activities. The schedule for these tasks is presented in Fig. 2.4-3.

To take full advantage of the SAATMS capabilities and cost savings, particularly in user equipments, the R&D activities concerned with the airport subsystem must be fully integrated with the other SAATMS studies. This is to some extent complicated by the fact that several of the recommended developments are currently underway. In these areas, e.g., the Microwave Landing System (MLS), studies must be started to insure a fundamental compatibility of the two systems, i.e., MLS and SAATMS. At the least, this compatibility should include waveform commonality. In addition, the impact of the high navigation and surveillance accuracies and the total navigation and surveillance coverage, coupled with the almost universal ability to fly RNAV routes, on the coverage and range requirements of the MLS should be developed. That is, the capabilities of the SAATMS could significantly reduce the coverage and power requirements for the MLS. In addition, the compatibility of the MLS and SAATMS waveform could reduce overall avionics costs.

To a lesser extent, the ground trilateration surveillance studies are also impacted by presently planned TSC analyses. In this area, however, the studies are in an early enough stage to be influenced by SAATMS designs and capabilities.

Additional activities are concerned with (1) the interaction of the airports with the RCC's and its effect upon automation, (2) the ground control, navigation, and guidance of aircraft, and (3) the surveillance of aircraft at airports not included in the National Airspace System. This last area is of significance since a basic surveillance trilateration system requires airport and aircraft cooperation. A lower cost system can be used in many airports or at particular intersections at busy airports. This second system requires no aircraft modifications and is less complex and costly for the airport.

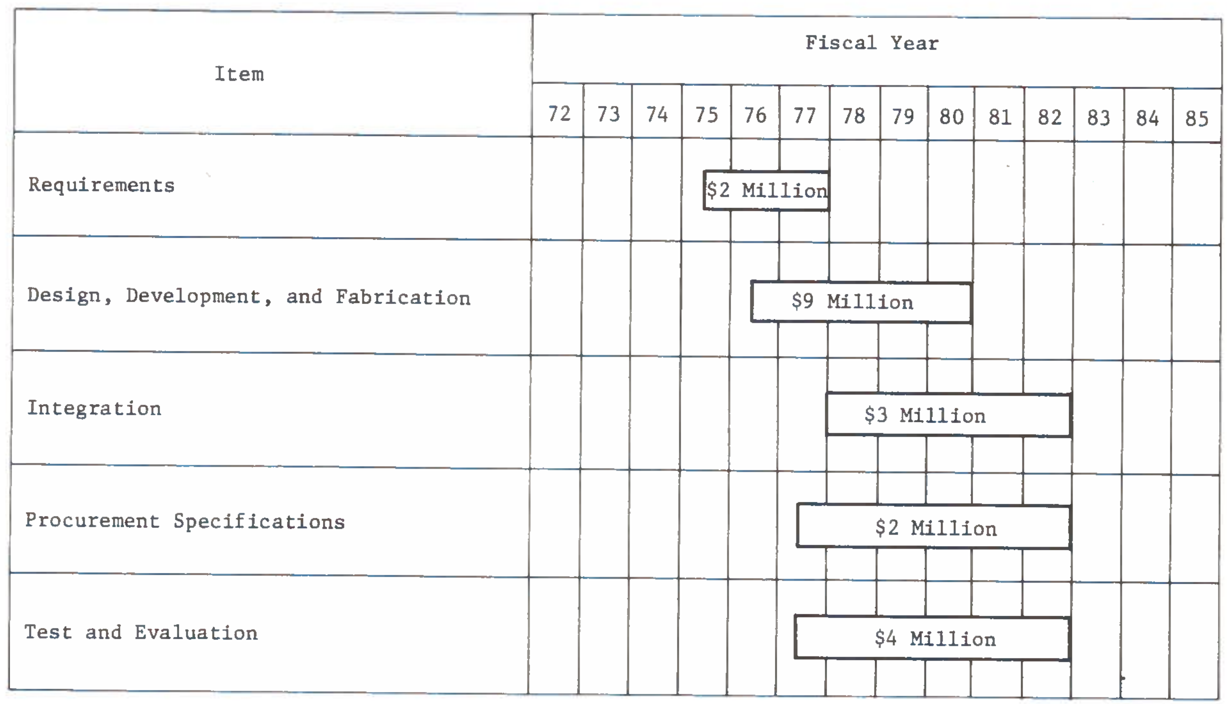

Fig. 2.4-3 Airport RDT & E Schedule and Funding Allocations

2.4.3.1 Airport Requirements

Item 1. Develop ACC/RCC Interaction

The objective of this task is to define the requirements for interaction between the RCC and the ACC or remote airports. Particular attention will be paid to the impact on the RCC of servicing remote airports because of the potential cost savings accruing from remote surveillance and control. The effect of providing user services, including landing, ground surveillance, and separation assurance will be studied. The task outputs include the following:

RCC/ACC interface requirements

Remote airport/RCC interface requirements

SAATMS cost impact

Item 2. Microwave Landing System/SAATMS Compatibility

The compatibility between the planned MLS and the SAATMS waveform and equipments will be developed in this task. The total integration of this function with the SAATMS avionics will result in lower user costs and increased benefits. In addition, the impact of the high navigation and surveillance accuracy on the MLS coverage and range requirements must be addressed. It appears that considerable MLS cost savings will result from the SAATMS capabilities. In addition, this study will consider the use of VVOR in place of the standard ILS. This concept can add an important service to the GA user at almost no additional cost. The task outputs will include the following:

MLS/SAATMS waveform compatibility requirements

MLS requirements

VVOR landing system requirements

Item 3. Ground Surveillance and Navigation Requirements

Requirements for surveillance and navigation of aircraft on runways, taxiways, and ramps will be developed during this task. The effects of poor visibility and the cost impact to low class airports will be included. The requirements study will include an operational analysis to develop a ground control surveillance and navigation philosophy. The outputs of this task will be as follows:

Ground surveillance requirements

Ground navigation requirements

Ground control philosophy

Item 4. Standardization of Airport Approval/Departure Procedures

The flexibility of the VVOR concept lends itself to establishing standardized airport approach and departure routes. The airport airspace standardization will reduce pilot errors and pilot work loads and increase system safety. This is particularly true for the GA pilot who flies infrequently, or often visits airports with which he is unfamiliar. In addition, the study will develop the impact of the SAATMS operational procedures on the skill requirements for the GA pilot. The task outputs will include the following:

Airport standardization requirements

VVOR usage at GA airport

GA pilot skill requirements

Item 5. Flight Service Station Requirements

The value of the presently planned modernization and automation of the FSS may be considerably enhanced through early recognition of the SAATMS requirements. This task is concerned with the development of requirements for the presentation of information to the pilot so that he may perform his flight planning functions including the following:

(1) Plan a VVOR route and altitude profile simply, rapidly, and accurately

(2) Recognize and conform to current specific rules, procedures, airspace restrictions, and contingency measures

(3) Receive, understand, and apply timely and accurate weather information

Task outputs will include the following:

Hardware and software requirements for presentation of pilot briefing information

Hardware and software requirements for pilot data entry

Requirements for interconnects between the FSS and the ACC, RCC, and CCC

Item 6. ACC Control and Display Requirements

The control towers of the present day system will be converted to ACC's in the SAATMS. This conversion will include automating many of the tasks now performed manually in the tower. These tasks include data processing, acquisition and display of both ground and satellite surveillance data, digital communications, and aircraft control. This task is concerned with defining control and display requirements for implementing the ACC concept. Included in this task will be an analysis of the ACC tasks for the purpose of defining the jobs to be performed in the ACC and determining how many control positions are required. Task outputs include the following:

A job description of each ACC position

Information input and output requirements

Display format, content, data rates, and human engineering requirements

Data entry and control requirements

Communications control and display requirements

Requirements for controls and displays for operating, checking out, and maintaining the ACC equipment

2.4.3.2 Airport Design and Development

The equipment and algorithms necessary to implement the requirements developed in the previous studies will be developed here. Both hardware and software tasks are included. The System Manager will be responsible for overall integration and testing.

Item 1. Develop Trilateration Equipments

Trilateration equipment capable of meeting the surveillance and navigation requirements specified earlier will be designed, developed, and tested. This equipment will provide high quality surveillance data on all SAATMS users on the ACC surface. The design techniques will be laboratory and field tested to provide the necessary data on the multipath environment and rejection techniques. Finally, operational equipment will be provided for SAATMS testing. The outputs of this task include the following:

Multiple effects and rejection technique analysis

Trilateration equipment

Design specifications

Item 2. Develop IR Surveillance Equipment

The discrete IR sensors used to provide the high quality surveillance and navigation data at all airports in the NAS will be designed, developed, and tested. During this development, extensive field testing will be employed to determine the visual range improvement factor offered by this technique. Task results will include the following:

The visual range improvement factor

IR sensor equipment

Design specification

Item 3. Develop ACC Displays and Controls

The objectives of this task will be to design, develop, and test the ACC displays and control consoles. The displays and controls will be designed to take maximum advantage of the digital processing features of the ACC. Maximum use will be made of solid-state display, control, and switching components to reduce power, keep costs low, and increase reliability. Task results will include the following:

Control and display equipment design specifications

Control and display software

Item 4. Develop ACC Processor

The objective of this task is to develop a data processor with the necessary speeds, capacities, and formatting capabilities to adequately support the ACC functions. These functions include aircraft control (both ground and airborne), arrival/departure control, and display processing. Task results will include the following:

ACC Processor

Design specifications for an ACC processor including software and hardware

Laboratory mockup and test of preliminary algorithms and data modems

Item 5. Develop Arrival/Departure Spacing Algorithms

Although the airports will not be required to perform the aircraft metering and spacing computations, the ACC will be responsible for interleaving the aircraft for arrivals and departures. The algorithm necessary to perform this function will be studied in this task. Once the basic algorithm has been defined, it will be simulated and modified as necessary. Finally, the program will be operationally coded. Task results include the following:

Arrival/departure algorithm description documents

Listings and tapes

Item 6. Develop Surveillance and Navigation Control Software

The surveillance and navigation control algorithms for the airports are similar in construction and operation to those of the RCC, and will be developed in conjunction with the RCC software. Task results will include the following:

Preliminary algorithm specification for laboratory simulation and test

Preliminary tapes and listings for field test evaluation

Design specifications, tapes, and listings for prototype application

Design specifications, tapes, and listings for operational application.

Item 7. Develop Handoff Software

As aircraft proceed from enroute to terminal flight phases, jurisdictional responsibility changes from the RCC to the ACC. The objective of this task is to design, develop, simulate, and operationally code the ACC software necessary for the automated handoff. Task results will include the following:

Preliminary ACC/RCC specifications for laboratory simulation of handoff

Preliminary specifications for laboratory simulation of handoff interval to the ACC

Preliminary specifications, listings, and tapes of the software for field testing of handoffs

Preliminary specifications, listings, and tapes of the software for prototype testing of handoffs

Design specifications for the handoff software for the operational system

2.4.4 Avionics

Avionics equipments provide the means by which the user interacts with the SAATMS. As such, these equipments represent the major cost to the user for participating in the system. The R&D activities associated with avionics will therefore be geared toward developing equipment which will enable users to obtain the greatest amount of service from the system for the least cost.

This section presents research and development tasks for establishing requirements for navigation, communications, and surveillance avionics, and their associated controls and displays, and for developing the avionics equipment needed to meet these requirements. Emphasis will be placed on assuring that the avionics requirements are compatible with the remainder of the SAATMS. The goal will be to develop avionics equipment that are simple to install, operate, and maintain, and above all, are of minimum cost to the user.

A schedule of avionics R&D activities and cost is presented in Fig. 2.4-4.

2.4.4.1 Lowering User Costs is the Objective of Avionics R&D

The avionics for SAATMS requires no technical breakthrough or significant advancement of the state of the art. Rather, the avionics R&D activities are directed toward making use of present day technology and developing low cost, long-life equipment. For example, in fulfilling the requirements of the surveillance transmitter, several different approaches have been identified. These range from off-the-shelf low cost tubes (ceramic triodes) to solid-state amplifiers that are currently capable of being demonstrated in the laboratory. The tube transmitter requires minimal government funding and development lead time but has an expected life time of only 3000 hr. The solid-state transmitter requires slightly more development time but promises longer life time, approximately 10,000 hr. In addition, the solid-state transmitter lends itself to more efficient production and lower avionics costs. In both cases, the technology is available.

Avionics R&D activities are also concerned with developing the aircraft receiver, navigation processor hardware and software, and aircraft displays. These tasks will make maximum use of data being produced in related DOT and DOD programs. In the area of Air Derived Separation Assurance (ADSA), for example, algorithms required to implement this function are currently undergoing analysis within the FAA, and maximum use of these studies will be made. The ADSA mode is expected to be an integral part of the SAATMS avionics design, and compatibility with present ADSA concepts must be studied.

2.4.4.2 Avionics Requirements

The tasks described in this section are designed to develop requirements for SAATMS avionics equipment. Surveillance, communications, and navigation tasks are described in that order.

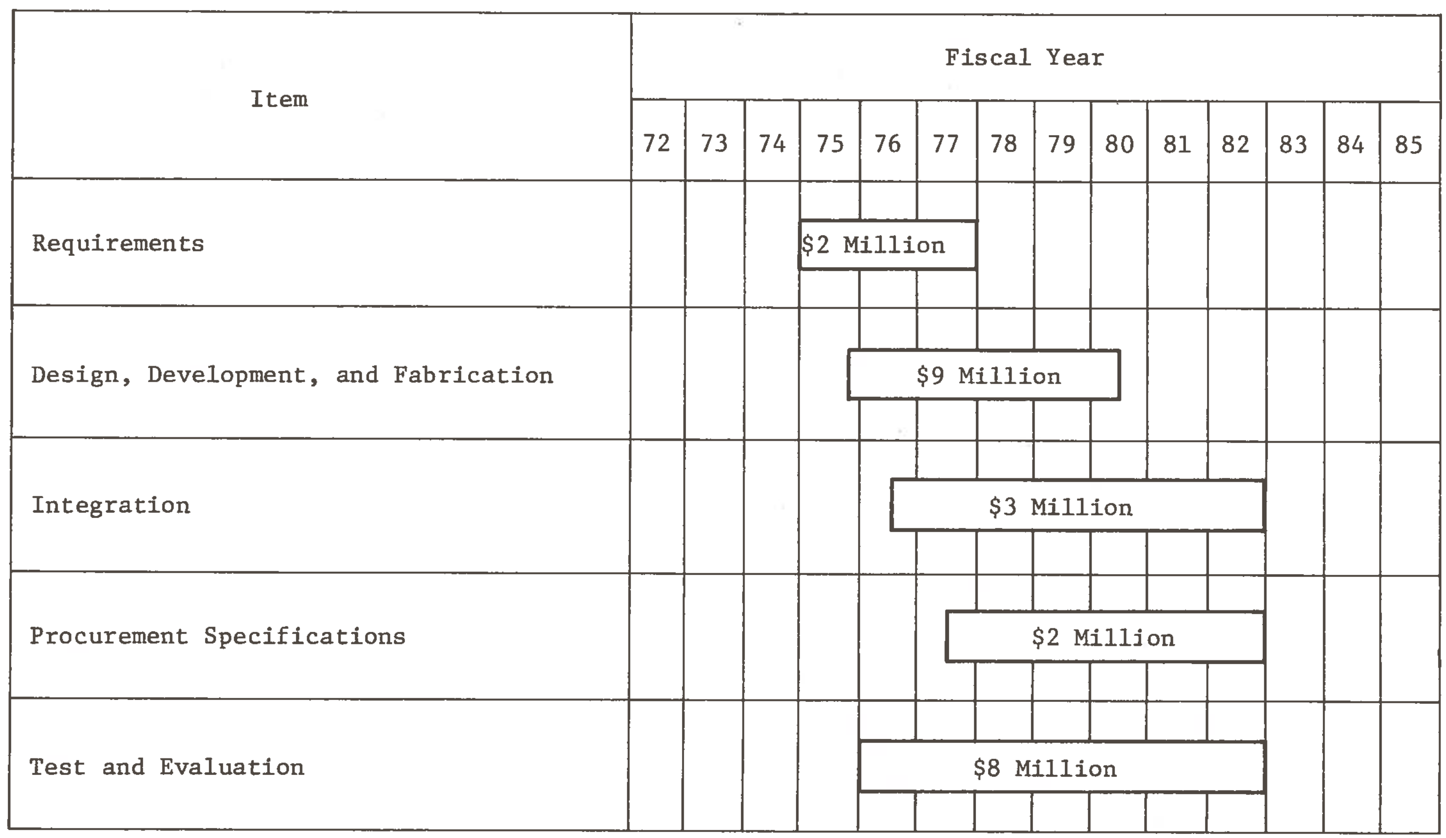

Fig. 2.4-1 Avionics RDT & E Schedule and Funding Allocations

2.4.4.2.1 Surveillance Avionics Requirements

The surveillance function employs satellites to relay aircraft identification from active users to the ground based system. Each aircraft active in the system transmits surveillance pulses encoded with the user's unique identification code. The satellites relay these signals to control centers where the instantaneous position and velocity for every active aircraft in the system can be determined. This technique is employed for aircraft in both enroute and terminal airspace, but the system absolute accuracy is enhanced in high density airspace through the use of calibration stations. This surveillance system allows the control centers to track aircraft, resolve conflicts, guard airspace boundaries, and generate commands required to control the flow of air traffic.

This surveillance scheme will require that aircraft using the system carry SAATMS specific equipment. Tasks that need to be performed to develop surveillance avionics requirements are as follows.

Item 1. Surveillance Controls and Displays

The objective of this task is to develop requirements for surveillance controls and displays. While it is envisioned that the surveillance function will be highly automated in the SAATMS, some avionic controls and displays will be required. These include controls for turning the equipment on and off, selecting the transmission rate, and adjusting gain settings as well as a display for assuring that the surveillance signal is being received by the system. As part of the overall philosophy of integrated avionics, the surveillance controls and displays should be integrated with those required for other functions. This task, therefore, will be concerned with determining the degree to which surveillance controls and displays can be combined with those required for communications and navigation. Part of these requirements will be a time line and mode analysis designed to establish conditions under which surveillance controls and displays are used.

The output of this task will be surveillance control and display requirements.

Item 2. DABS/SAATMS Compatibility Requirements

It is highly probable that the surveillance scheme used in the upgraded third generation system will be a form of the Discrete Address Beacon System (DABS). As the air traffic management system transitions from the upgraded third to the SAATMS, there will be a period where both systems will be functioning simultaneously. The SAATMS equipped user may have to operate for a period of time within the DABS framework. The objectives of this task are to develop avionics requirements for this transition period. The study performed under this task will be an attempt to develop requirements that will obviate the need of the DABS user buying special avionics to be compatible with SAATMS. DABS modifications that will enable the GAATMS user to inexpensively modify his equipment to be usable with the SAATMS will be defined.

The output of this task includes definition of DABS/SAATMS compatibility requirements and techniques.

Item 3. Air-to-Air Collision Avoidance System (CAS)

The objectives of this task are to determine if an ADSA CAS is needed and to develop avionic requirements for this mode of operation. The need for this mode will be determined by the extent to which it provides an independent backup to the ground based separation assurance mode, adds to pilot confidence in the system, and supports the automation philosophy. The avionics includes the means by which identification and position data are transmitted between aircraft, the data processing requirements, and the required controls and displays. The task outputs are as follows:

Air-to-air mode requirements

Requirements for data formatting, transmission, and reception

Requirements for air-to-air controls and displays

2.4.4.2.2 Communications Avionics Requirements

The objective of this task is to define avionics requirements for the communications subsystem. Included in this study are requirements for transmitters, receiver modems, antennas, and controls and displays. The study is primarily concerned with requirements for the physical hardware. This includes transmitter power, receiver memory capacity, canned message storage, antenna configuration, controls required to operate the communications gear and displays for digital and voice messages. Also included will be a study to develop requirements for composing messages and for displaying random content (noncanned) messages. The detailed message analysis will be part of the ATM subsystem requirements study.

The task output is communication avionics requirements.

2.4.4.2.3 Navigation Avionics Requirements

The objective of this task is to define avionic requirements for satellite navigation and for VVOR. The satellite navigation mode makes use of navigation pulses received from the satellite constellation. The avionics must include a means of receiving the pulses, processing their times of arrival, computing present position, and displaying position and steering data to the pilot. The VVOR mode requires avionics for receiving processed course data from the ground, controls for transmitting to the ground the desired destination coordinates, and displays to read out course and course deviation, bearing, and distance to destination.

The task output includes navigation requirements (satellite and VVOR).

2.4.4.3 Avionics Hardware Development

The purpose of this section is to describe the hardware RDT&E activities required to meet the avionics requirements. The plan describes the separate functional areas of surveillance, communication, navigation, and control. This plan is based on the desirability of an integrated avionics system and directs special attention to that area.

2.4.4.3.1 Component Development

The component development tasks are as follows.

Item 1. Frequency Generator

The nucleus of the SAATMS avionics hardware is the clock network. The function of this equipment is to generate the timing signals and local oscillator frequencies. This generator is not part of the present day avionics equipment and must, therefore, be developed.

Several design schemes are available for developing the network. Both analog and digital techniques should be investigated. Particular attention should be paid to the following:

(1) Long-term stability
(2) Short-term stability
(3) Output power at L-band
(4) Output power at local oscillator frequency
(5) Temperature range
(6) L-band frequency
(7) Local oscillator frequencies
(8) Spurious noise level
(9) Timing signals
(10) Life time
(11) Warm-up time

The output of this task will be the frequency generator design.

Item 2. L-Band Amplifiers

An L-band amplifier chain is required for the avionics system. The transmitter is a high power, low duty amplifier. Several methods are presently available for meeting the system requirements. They include the Traveling Wave Tubes (TWT), Cross Field Amplifiers (CFA), planar triodes, and solid-state amplifiers. The most promising in terms of long life, ease of manufacture, and potential low user costs is the solid-state amplifiers. These units, however, are in the developmental stages and will not be available for several years. The planar triode, on the other hand, is available today. In large quantities in the SAATMS time frame these triodes would be very inexpensive, about $100 to $200. However, their useful life is limited to approximately 3,000 hours of operation.

The objectives of this task will be to design, develop, and test the solid-state transmitter system and to demonstrate its feasibility in meeting the surveillance requirements.

The task output will include the L-band solid-state transmitter design.

Item 3. Antenna

The objective of this task is to design, develop, test, and evaluate the L-band antenna to be used in the aircraft-to-satellite link. The characteristics of this antenna will have been determined in the satellite subsystem studies.

The task output will be the aircraft antenna design.

Item 4. Displays

The objective of this task will be to develop, test, and evaluate displays that meet the surveillance, communications, and navigation requirements. The displays will be designed to take maximum advantage of the highly centralized digital processing features of the SAATMS integrated avionics. Most of the display processing for the SAATMS will be accomplished in the central computer rather than in the display itself. This will result in simpler and less costly displays. Further, maximum use will be made of solid-state components such as liquid crystals to reduce power requirements and keep down cost, weight, and volume. This type of display device is in an advanced stage of development and, in the case of alpha/numeric readouts, is already in production. TV quality solid-state displays will undoubtedly be a reality in the SAATMS time frame.

The task output will be the avionics display equipment designs.

2.4.4.3.2 Integrated Surveillance and Communications Equipment

The clock, 2 kw transmitter, and antenna comprise the avionics surveillance equipment. This equipment needs to be integrated into a viable system and given extensive testing. After transmitter testing and evaluation, a digital receiver and modem will be added and a total integrated avionics package developed. The major outputs of this task will be as follows:

Integrated avionics specification

Integrated avionics equipment

2.4.4.3.3 Navigation Equipment

The navigation equipment includes the satellite navigation receiver, the navigation processor, and VVOR equipment. Only the processor will be developed here. Other programs have developed the other items. The navigation processor hardware needs to be integrated with the processing software and the entire package must then be integrated with the avionics receiver and transmitter and its associated controls and displays.

The task output is the integrated navigation processor.

2.4.5 SAATMS Development

The foregoing sections of the RDT&E plan have delineated those activities required to permit the development of each of the major elements that comprise the SAATMS. Activities were planned and scheduled to allow each of the elements to be designed and developed independently. Subsequent to the development, the total SAATMS must be integrated to permit system test and evaluation. The testing and evaluation of the entire system will permit a refinement of the final procurement specifications. These final activities of integration, test, evaluation, and preparation of the SAATMS procurement specifications is the final responsibility of the System Manager and the associated government agency during this RDT&E program. These activities should be completed prior to the initiation of the System Implementation Phase. The knowledge gained during the RDT&E program, however, may permit the implementation of specific end items or even subsystems prior to the completion of the System Development Cycle.

The System Manager's role in the development of a SAATMS has been discussed as part of the introduction to the RDT&E plan. If sufficient control has been manifested during the requirements studies and the development of subsystem prototypes, the activities involved in the SAATMS integration will impact the RDT&E plan to a minimum extent. The schedule for the system RDT&E activities and the funding allocation estimates are presented in Fig. 2.4-5. These funding estimates are required to provide for system monitoring, control, integration, test and evaluation, and development of the system procurement specification.

The ATM Subsystem has been selected to illustrate how the System Manager functions. This subsystem is a complex development, requiring both unique software and hardware design as well as interfacing with the in-being system.

2.4.5.1 ATM Subsystem Integration

The integration of the ATM Subsystem is a complicated, time-dependent task including an evolutionary transition from the in-being system to the SAATMS. The process is further complicated by the need of parallel system operations. The intent of the proposed R&D integration plan for the ATM Subsystem is to provide the means for an orderly development and transition cycle between systems.

A review of the FAA 10-year plan reveals that automatic controller aids, in the form of metering, spacing, sequencing, and aircraft dynamic displays based on radar surveillance, will be implemented and operational in the mid-1970 time period. These capabilities can provide the basis for SAATMS design tests and initial subsystem evaluation. This can be accomplished using the Defense Navigation Development Program (DNDP) satellites scheduled for launch in 1977. Some limited SAATMS equipments and software will be available at that time. These equipments would provide the means of evaluating the functions of surveillance, VVOR navigation, and digital communications typical of the SAATMS system. Thus, a limited version of the SAATMS can be operationally evaluated by the late 1970's.

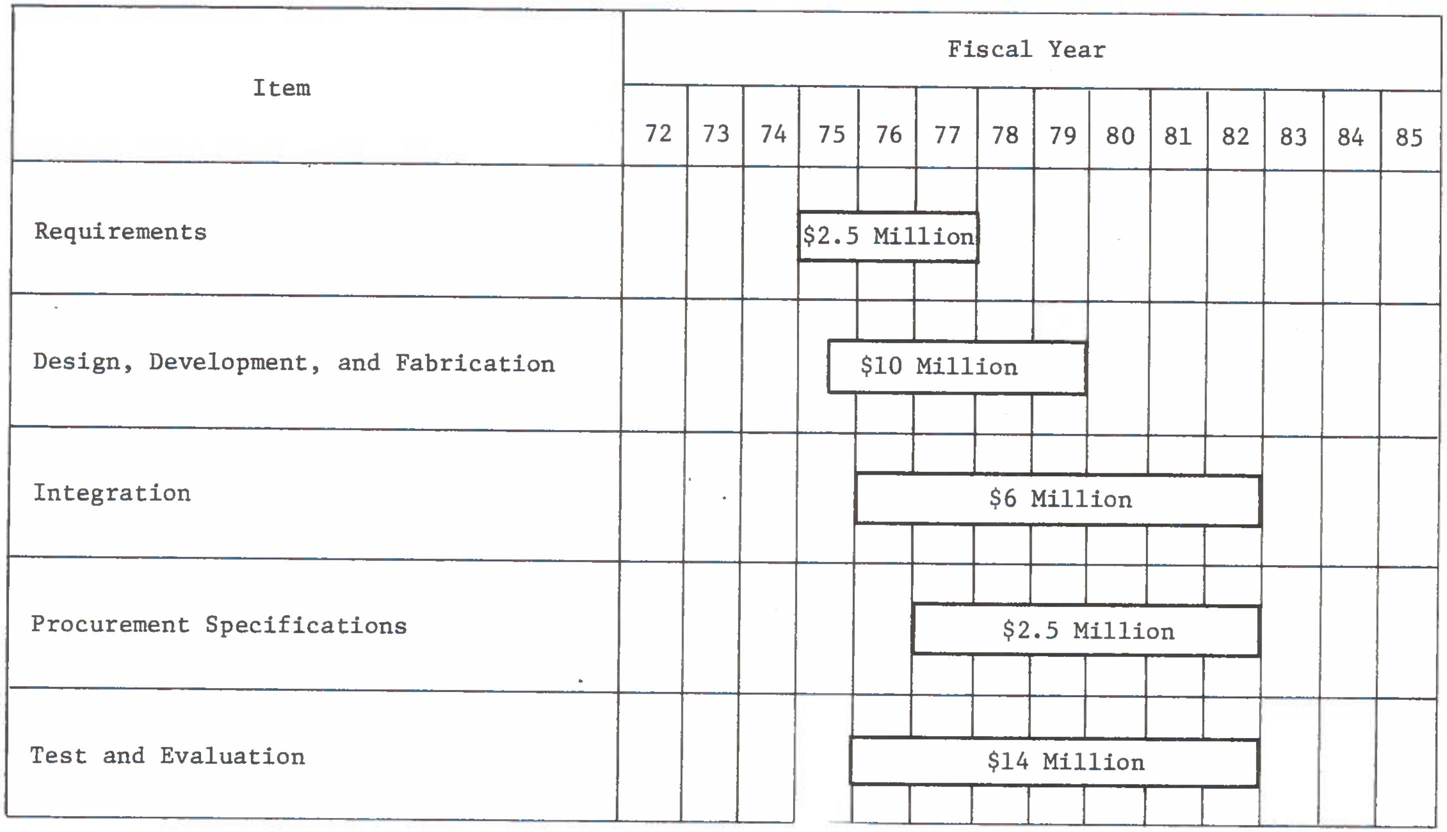

Fig. 2.4-5 SAATMS System Manager RDT & E Schedule and Funding Allocations

This testing can be performed at a collocated facility with the Upgraded Third Generation Air Traffic Management System. Taking this approach to preliminary testing has several advantages. First, by operating the GAATMS and SAATMS in parallel within the same facility, a smooth transition between systems can be made. This approach has already been proven effective as seen from the Atlanta facility. Second, it provides a test bed for debugging the SAATMS system including both the hardware and software. Third, it provides the training ground for the controllers. Fourth, control documentation as well as rules and procedures can be established early in the SAATMS lifetime.

The next phase of the program would involve the step-by-step integration of the actual SAATMS equipments into a fully operational SAATMS, ready for detailed evaluation. This would involve the total integration of the ATM, Satellite, Airport, and Avionics Subsystems.

In summary, the integration of the ATM Subsystem involves four phases from conception to full operation:

(1) Integration of the interim ATM Subsystem elements

(2) Integration of the interim ATM Subsystem with the in-being system

(3) Integration of the SAATMS ATM Subsystem elements

(4) Integration of the ATM Subsystem with the SAATMS

The function of the System Manager is to maintain total cognizance over the individual developments and perform the individual element and subsystem integration. This would involve testing each end item, assuring compliance with design objectives, interfacing the various equipments and testing the overall subsystem. In the case of the ATM Subsystem, the System Manager would have the added responsibility of defining the interface of the test subsystem with the in-being system for initial tests and evaluations. To aid in these activities the System Manager employs various management and control documents. These management and control documents are organized in the form of a specification tree. Thus, the subsystem integration documentation includes the controlling documents for integrating the three system elements, namely the CCC, the RCC, and the ACC. The next level of documentation is then the controlling documents needed for integrating the elements within each of the sub-subsystems, and so on (Fig. 2.4-6).

The structure and format for each of the documents shown in Fig. 2.4-6 is similar for each subsystem. The information contained therein, however, will be consistent with the level for which the document is written. Each level will consist of the following type of documentation:

(1) Parameter control document

(2) Signal interface document

(3) Test plan and procedures document

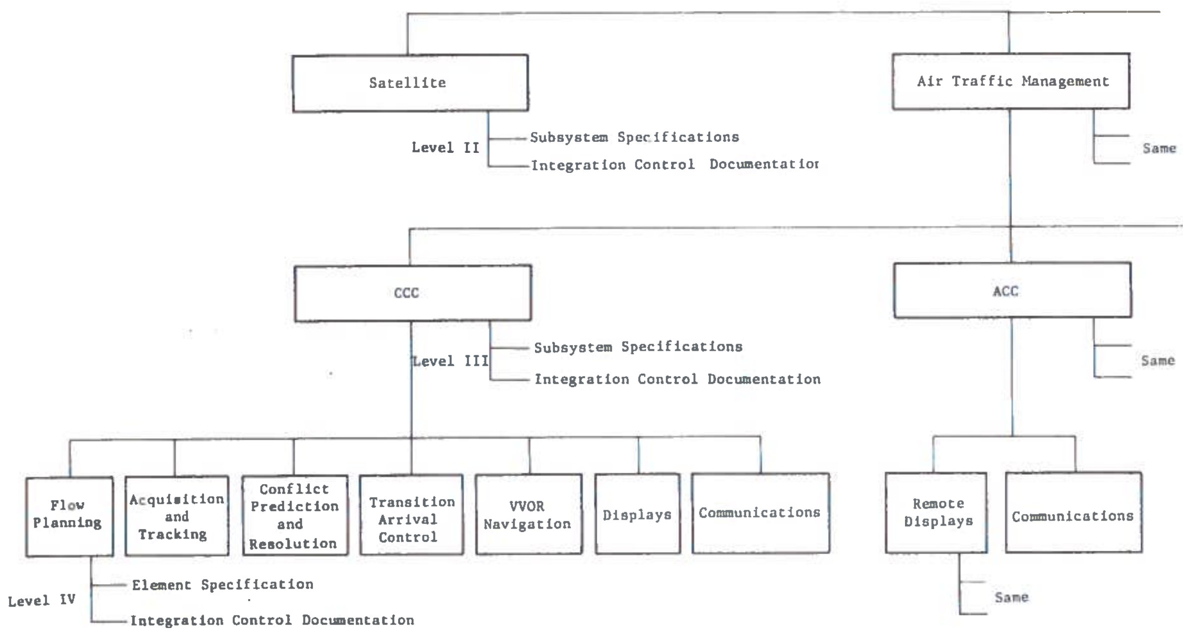

Fig. 2.4-6 Specification and Integration Documentation

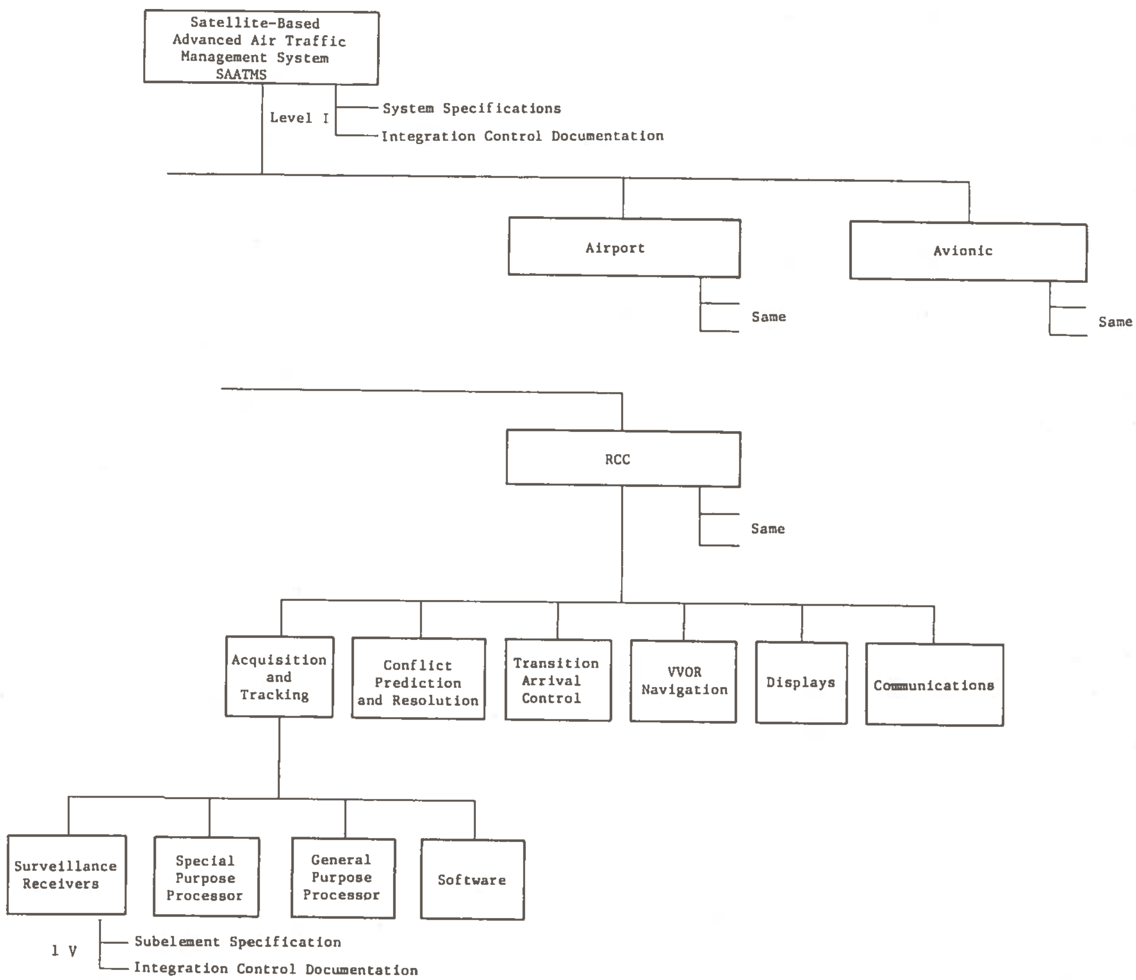

Fig. 2.4-6 (Continued)

2.4.5.1.1 Parameter Control Document

A parameter control document for the ATM subsystems, elements, and subelements should be developed and maintained by the System Manager. This will require monitoring and coordinating the ATM Subsystem's requirements, analyses, and preliminary designs.

The parameter control document will describe the various system parameters, their nominal variations and tolerances, and their effect on performance. This document will aid in control of the item design and development, will serve as a guideline in the test and evaluation phase, and, most important, will highlight those parameters critical to system performance.

2.4.5.1.2 Signal Interface Document

A signal control document for integration control of the ATM subsystems, elements, and subelements should be developed and maintained. This task will require monitoring and coordinating the requirements, analyses, and preliminary design. Subsequent coordination with the test and evaluation phase will also be required to incorporate any changes. The signal interface document is vital to the control of the integration process; it is divided into two parts, functional and quantitative.

2.4.5.1.2.1 Functional Description

All interface signals within the ATM subsystem, including the ground system, will be functionally described. In addition, all signals should be described in terms of being analog (ac), analog (dc), high-Q ground, low-Q ground, discrete, or digital. Furthermore, the source and destination must be included. These data should be defined down to the cable and pin numbers as applicable. Where signals are received and/or transmitted via electromagnetic data links, receiver/transmitter channels must be identified as source and sink. Where signals are encoded, a description of the encoded data must be included.

2.4.5.1.2.2 Quantitative Description

Quantitative descriptions for all interface signals within the ATM Subsystem should be developed. These data will include, as a minimum, the maximum and minimum values of the signal and scale factors as applicable. The description will further include the required loading and/or impedance characteristics as well as rise and fall times. Where discrete and/or digital signals are involved, pulse-widths and/or time event diagrams should be included. In addition, such descriptors as repetition rates, updates, refresh, frequency, most and least significant bits, word size, and data rate should be included. All tolerances associated with each of the signals should also be included.

2.4.5.1.3 Test Plans and Procedures

Test plans and procedures for the ATM subsystems, elements, and subelements should be developed. This task will require the development of a set of plans and corresponding procedures for the development and testing of the software and/or hardware, as well as subsequent integration and testing thereof, as applicable for conformance with the specifications for the ATM Subsystem.

2.4.5.1.3.1 Software

Test plans and procedures for the development and demonstration testing of the ATM Subsystem operational and/or diagnostic software should be developed. The test plan should describe in detail all of the various stages of development and the corresponding levels of testing to be applied at each stage. The plan should further define the procedures for failing and/or passing the various levels of testing. The plan should identify and describe the various inputs and outputs required for each stage of development. Included in the plan should be the identification of all special test equipment, support software, standards, special facilities, and required environmental conditions.

2.4.5.1.3.2 Hardware

Test plans and procedures for the development and demonstration testing of the ATM Subsystem operational and diagnostic hardware should be developed. The test plan should describe in detail the different stages of development and the required level of testing for acceptance. Procedures to be followed in the event of test failure will be developed. The plan should be organized to identify preliminary and critical design points in the development of the hardware. All inputs and outputs required for each stage of the development process should be identified. Furthermore, all special test equipment, support aids, standards, special facilities, and required environmental conditions will be included.

2.4.5.1.3.3 Hardware/Software

Test plans and procedures for integration and acceptance of the software and hardware as required by the various subsystems, elements, and subelements within the ATM Subsystem should be developed. The test plan should describe the different steps in the integration process and the procedures in the event of a failure. The plan should be time-event organized and should reflect both the preliminary and critical development times in this phase of the development. All inputs and outputs should be defined for each step of the integration process. The plan should also identify all special test equipment, software, support aids, hardware aids, standards, special facilities, and environmental control requirements.

2.4.5.2 ATM Subsystem Test and Evaluation

The purpose of the foregoing control and planning documents is to enable an orderly and economic ATM Subsystem integration and test. The SAATMS must eventually be tested in its totality but, because of the complex nature of the various subsystems, such tests will be completed in an incremental fashion. The ATM Subsystem test program, which will comply with the previously outlined test plans, will be accomplished over a period of years in three general categories. These categories are laboratory, field, and service or prototype tests.

Laboratory tests will be performed to test and select design techniques. These tests will usually be performed using laboratory simulation techniques. Following these tests, field tests will begin. The objective of these field tests is to evaluate performance under more realistic conditions than can be simulated in the laboratory. The final series of tests will be performed with prototype SAATMS equipment and subsystems in typical operational situations.

Laboratory tests are usually performed using hardware brassboards. However, most laboratory tests for the ATM Subsystem will be performed on software. There are essentially two phases to the laboratory software testing. The first is that testing necessary to develop the algorithm. This consists principally of simulations to establish feasibility of the analytic techniques within the algorithm. The second phase is concerned with coding and debugging the developed program.

The System Manager will be required to monitor and direct the testing of both hardware and software, establish the test goals, and insure compliance with test procedures. After initial tests, these end items must be integrated into a subsystem and field tested. Based upon these initial tests, the ATM Subsystem will be modified as necessary and the prototypes developed, integrated, and tested. Finally, the ATM Subsystem must be integrated into the overall SAATMS and service tested.

2.4.5.3 ATM Subsystem Specification Development

The complexity of the ATM Subsystem requires that the set of specifications be developed in the form of a hierarchy, i.e., a specification tree. This has the advantage of providing management with the proper control in all areas of the system, down to the subassembly levels. It will also permit the System Manager to delegate responsibility to each of the lower levels while maintaining control over all levels. This approach assures that the specifications and integration control documents are consistent and controlled at the same levels of management as indicated in Fig. 2.3-1.

The development of the system procurement specification is an iterative process. The output of the Concept Definition Study provides preliminary system and subsystem performance specifications. The RDT&E requirements activities will be used in the subsequent RDT&E design and development activities. During the design activities, these specifications will be maintained and upgraded to provide more detail for the prototype development activities. The prototype equipment will be tested and evaluated against the upgraded performance specifications. In the event that problems occur, the equipment and the specifications may be altered as long as the acceptable performance is maintained. At the conclusion of the prototype test, evaluation, and demonstration, the final procurement specifications would be developed. This iterative process is typical and will occur at each level in the specification hierarchy.

The System Manager has responsibility for the development of the Level I group specifications. This group of specifications is concerned with the administration of the total system and the requirements that are imposed on the Level II associate contractors. The Level I group includes the administrative specification and the specifications for each of the subsystems. In addition, the System Manager maintains an overview of all levels of specifications and is the final authority (with concurrence from its related government agency) for changes to specifications at any level.

2.4.5.3.1 Administrative Specifications

The System Manager is responsible for developing the system administrative specifications which control the following:

(1) Maintenance of facilities and automation equipment

(2) Personnel policies and procedures

(3) Training programs and procedures

(4) Emergency rules and procedures

(5) User policies and procedures

(6) Installation procedures

(7) Procedures for modification of all policies

They will include specifications of all other items or contingencies which affect more than one subsystem.

2.4.5.3.2 Subsystem Specifications

The System Manager will develop the performance specifications for each of the end items and will control the RDT&E activities which develop the requirements leading to end item design specifications. These RDT&E activities can be performed by the System Manager, the associate contractors, or by subcontractors at the discretion of the supervisory government agencies. Subsequent to the design specifications, the engineering development of the end items will be initiated. The System Manager will coordinate with the associate contractors and the subcontractors to evaluate their efforts and to effect required changes to the end item and subsystem performance specifications. At the end of the development phase, end items will be developed. These items must be tested for conformance with their performance specifications. The developed prototypes must then be integrated, tested, and evaluated to establish conformance with the subsystem performance specification. During the final integration, test, and evaluation phase, the system, subsystem, and end item procurement specifications will be refined to produce the final version of the procurement specifications.

2.4.5.4 SAATMS Test and Evaluation

The overall testing of a limited version of the SAATMS will take place during 1981-82. During this time period, the software and hardware necessary to establish a limited CCC/RCC capability will be integrated and an existing facility converted to SAATMS use. Concurrently, 6 to 10 SAATMS subelements will be built and launched, and a small number of aircraft will be equipped with SAATMS avionics. The aircraft participating in these tests will, for the most part, be cooperating aircarriers, FAA test aircraft, and some limited military users. In a similar manner, an ACC will be developed.

Both the CCC/RCC and the satellites serve a dual purpose since their use extends beyond the R&D phase into the transition time period. Although some equipment at the CCC/RCC may be modified, the overall function will remain intact. This joint use of R&D and F&E results in a considerable savings to the government while still allowing overall SAATMS evaluation prior to implementation.

The complexity of a SAATMS requires a high degree of control to achieve an orderly, cost-effective system development cycle. The required degree of control can only be achieved through the use of a strong system engineering and management organization and a highly structured and organized RDT&E plan.

2.5 RDT&E Temporal Planning

The foregoing plan has developed the tasks required for establishing SAATMS subsystem feasibility. The tasks have been grouped by subsystem; but to fully depict their relationships to one another as well as to the overall system development, they must be grouped by time. For this section of the plan, the detailed tasks necessary to develop the SAATMS have been grouped according to the year they are initiated. Although the bulk of the RDT&E begins in FY-75, certain selected tasks must begin immediately. These tasks are listed by year on the following pages in order of priority.

FY-74

Satellite Test Plans (ATS-F Tests)

Develop Ground and Airborne Test Equipment

Outfit SAATMS Test Aircraft

SAATMS Concept Definition

Develop SAATMS Subsystem Functional Specification

PN Code Selection

Prepare SAATMS Error Analysis

Prepare Initial SAATMS Control Documents

FY-75

Perform Satellite Experiments

- Multipath Tests
- Multi-access Tests
- TOA Measurement Techniques
- Satellite Link Experiments

Develop Long Line Analog Matched Filter (AMF)

Develop Aircraft Antenna

Develop Aircraft Solid-State Power Amplifier

Ground-to-Ground Communications Trade Study

Random Access Surveillance Waveform Design

Navigation and Communication Waveform Design

Signal Acquisition and Tracking Design Study

Operational Concept Model Requirements and Availability Analysis

Develop Operational Concept Evaluation Models

Select System Manager

Orbit and Constellation Studies

SAATMS Message Analysis

Microwave Landing System/SAATMS Compatibility Analysis

DABS/SAATMS Compatibility Analysis

Aircraft Avionics Requirements Analysis

Avionics Integration Benefits Analysis

Data Measurements Program (Present System Operation)

Develop System Measures and Their Relationship to the SAATMS.

Develop Demand Model

Integrate and Validate Models

Develop Aircraft Scenarios

Operational Concept Evaluation

Determine Impact of Satellites on Automation Assignments

FY-76

Satellite Test Plan (DNDP and Aerosat)

Develop Satellite Airborne and Ground Test Equipment

Multipath Field Experiments

Multi-access Laboratory Experiments

Design and Develop Asynchronous Signal Acquisition, Tracking, and TOA Measurement Equipment

Satellite Power Source Requirements Analysis

Satellite Power Source Design and Laboratory Test

Develop Satellite Transmitters

Design, Develop, and Simulate Strategic Conflict Prediction Algorithm

Design, Develop, and Simulate Tactical Conflict Prediction Algorithm

Design, Develop, and Simulate Aircraft Intrusion Prediction and Avoidance Algorithm

Ground Processing Requirements Analysis

Ground Processor, Architecture, and Organization

Design, Develop, and Simulate Satellite Tracking Algorithm

Design, Develop, and Simulate Aircraft Surveillance Determining Program

Design, Develop, and Test Communications Processing Software

Design, Develop, and Simulate VVOR Algorithm

Design, Develop, and Simulate Satellite Navigation Program

System and Subsystem Requirements Analysis

Prepare Operational Concept Simulation Plan

Prepare Program Development Documents

Control Console Requirements

Display Hardware Requirements

Design IR Surveillance Equipment

Select Associate Contractors

Prepare System Control Documents

Design and Develop Frequency Generator

Satellite Stabilization Requirements Analysis

Satellite Stabilization Equipment Design and Laboratory Test

Satellite Electronics Requirements Analysis

FY-77

Outfit SAATMS Test Aircraft

Integrate SAATMS Ground Test Equipment

Initiate Satellite Experiments

- Multipath
- Aircraft Antenna Pattern Experiments
- Multi-Access Tests
- TOA Measurement
- Link Characterization
- Asynchronous Signal Tests
- Surveillance, Navigation, and Communications Waveform Experiments
- Satellite Tracking Algorithm Validation
- Operational Concept Experiments
- Communications Processing Tests
- Control System Software Validation
- Surveillance and Navigation Software Mechanization Validation (Satellite and VVOR)

Design, Develop, and Simulate Flow Planning and Transitioning Algorithm

Develop Display Software and Hardware

Satellite Antenna Requirements

Ground Station Antenna Requirements

Develop Avionics Receiver and Transmitter

Ground Surveillance and Navigation Requirements Analysis

IR Surveillance Field Measurement Program

Develop Operational Concept Simulator

FY-78

Design and Develop Satellite Antennas

Develop Satellite Transponder

Develop Aircraft Processor Requirements

Aircraft Control and Display Requirements

Develop Aircraft Modem

Design and Develop Ground Station Antennas

ACC/RCC Handoff Requirements

ACC Processor Requirements Analysis

Ground Site Location Study

Launch Vehicle Study

Design and Develop Ground Surveillance and Navigation Hardware and Software

Integrate SAATMS ATM Subsystems - Integrate within GAATMS

Initiate ATM Subsystem Tests

Initiate SAATMS Test Planning

Arrival/Departure Spacing Requirements

ADSA Requirements Analysis

Design, Develop, and Simulate ADSA Algorithm

ACC Display Requirements

Flight Service Station Requirements

FY-79

Operationally Code All Software

- Surveillance
- Control
- Intrusion
- Display
- Planning
- Satellite Tracking
- Communications
- Navigation
- VVOR

Design, Develop, and Simulate ACC/RCC Handoff Algorithm

Design, Develop, and Simulate Arrival/Departure Algorithm

Develop Integrated Avionics

Develop Satellite Antenna Prototypes

Develop Satellite Subsystem Prototypes

- Power Source
- Stabilization
- Electronics

Develop RCC/CCC Ground Processor Prototype

Develop Ground Antenna Prototype

Develop Ground Communications Prototypes

Develop RCC/CCC Controls and Display Prototypes

Develop Aircraft Processor

Develop Aircraft Control and Displays

Perform Ground Surveillance and Navigation Field Tests

Develop Standardized Airport Approach/Departure Procedures

Impact of Automation on Training Study

FY-80

Integrate Satellite Equipment

Integrate RCC/CCC Equipment and Software

Integrate Aircraft Equipment and Software

Plan Satellite Launches

Plan SAATMS Tests and Evaluation

Develop ACC Controls and Display Prototypes

Develop ACC Processor Prototypes

Develop Receiver, Transmitter, and Antenna Prototypes

Update SAATMS Control Documents

Develop SAATMS System, Subsystem, and Administrative Specifications

Design and Develop Training Software

Design and Develop Training Equipment

Develop Ground Surveillance and Navigation Hardware Prototypes

Develop Ground Surveillance and Navigation Software

Operationally Code ADSA Software

FY-81 - 82

Launch Satellites

Outfit Test Aircraft

SAATMS Test and Evaluations (RCC/CCC/ACC)

Integrate ACC Equipments and Software

Operational Tests of Control Concepts

Develop Procurement Specifications

Transition Benefits Analysis

Begin Transition

3. TRANSITION PLAN

3.1 Introduction - An Evolutionary Transition

The SAATMS Transition Plan permits an evolutionary transition over a 13-year period with user benefits as the driving force. Federal budget peaks have been completely avoided. Users will not be required to carry two different avionics equipments for the same function.

Because of the public nature of the civil aviation community (in contrast to military aviation), it is a requirement that changes in the air traffic management system be introduced in an evolutionary manner and without any undesirable economic impact. Thus, the relationship between user benefits and cost impact is perhaps the most important criterion for transitioning.

The transition plan presented herein describes the methods and schedule of transitioning from the in-being system to the SAATMS. (Hereafter, the system in use at the time of the transition is referred to as the "in-being" system.) The selected transition approach was based, on one hand, on a number of significant transition criteria and, on the other hand, on the characteristics and configuration of the SAATMS and the system from which the transition must be made.

The primary transition criteria include the following:

(1) Gradual and evolutionary introduction of operational and functional concepts.

(2) No requirement for users to carry dual avionics equipment for the same function to achieve compatibility with the two systems.

(3) Modular avionics functions to minimize initial user implementation cost.

(4) Increased benefits and added services oriented toward the number of affected enplanements and aircraft operations.

(5) Avoidance of government budget peaks.

(6) Exploitation of the full useful life of ground and avionics equipments.

(7) Single control jurisdiction over all aircraft within a region.

In view of the integrated electronics nature of the surveillance, communication, and navigation functions of the SAATMS concept, it is most cost effective to initially implement the satellite constellation simultaneously with the minimum ground elements required for satellite operation and a ground facility for central system control.

The transition and implementation will be accomplished in two phases. During the first phase, the in-being system and the SAATMS will operate completely in parallel. All control of and communication with user aircraft operating within the same airspace will be performed by the existing ATC facilities, i.e., ARTCC's and TRACON's, although the surveillance data used for control will be obtained by means of different sensors. During the second phase, the remaining ground elements of the system will be implemented, control jurisdiction will be transferred to the Regional Control Centers (RCC) and Airport Control Centers (ACC), and the Upgraded Third Generation System ground facilities will be gradually decommissioned. During this phase, based on user benefits and operational considerations, the time-phased implementation of SAATMS modular avionics equipment will be completed. At the end of the second phase of the transition period, the SAATMS will be fully operational and the in-being system will be fully decommissioned.

The next section presents an overview of the transition approach and schedule. This is followed in Section 3.3 by brief descriptions of the expected 1982 in-being system and the SAATMS to set the stage for the transitioning approach which has been developed. The transition criteria and ground rules which were used for designing the transition approach are presented in Section 3.4. The details of the transition approach are described in Section 3.5, including the transitioning to the SAATMS operational concepts and to the four primary functions of surveillance, communication, navigation, and control. The benefits and additional services provided for each user as a function of transition time and as a result of equipping the aircraft with SAATMS avionics is presented in Section 3.6. (The references used in this Section appear in Section 3.7.)

3.2 Transition Overview - Parallel Operation Without Dual Avionics

Smooth transition to the SAATMS is achieved by early satellite implementation, parallel operation of ground elements without the need for dual avionics to interface with both the in-being system and the SAATMS, and time phasing procedures oriented toward increasing user benefits and services. The transition period consists of two phases, i.e., Phase I from 1982 to 1990 and Phase II from 1990 to 1995. The overall transition schedule is presented in Fig. 3.2-1 and the activities of each phase are detailed in Table 3.2-1.

Phase I of the transition period is immediately preceded by the SAATMS Test and Evaluation (T&E) program, which is scheduled for completion by 1982. During the T&E program, a partial satellite constellation (probably consisting of 6 to 10 satellites) will have been launched and the ground facilities required for tracking the satellites, providing system time promulgation, and receiving and processing surveillance and communication signals will have been implemented. Thus, several Satellite Tracking Centers (STC) and a partial Continental Control

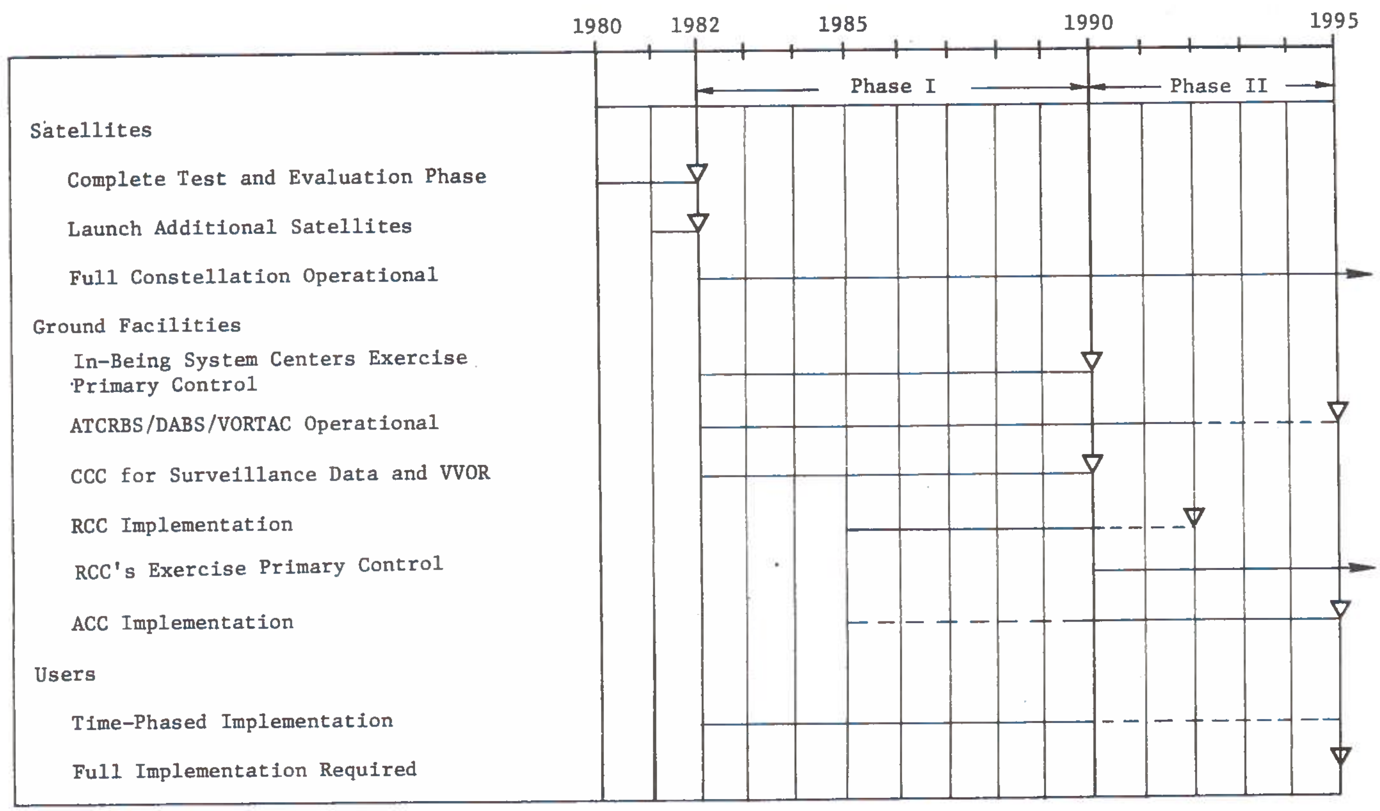

Fig. 3.2-1 Overall SAATMS Transition Schedule

Table 3.2-1. Activities of Transition Phases

Transition Phase I
Full satellite constellation provides CONUS-wide SURV/COM/NAV
CCC obtains and transmits surveillance data to ARTCC's and TRACON's
ARTCC's and TRACON's control all aircraft within their jurisdiction
RCC installation and limited off-line control operation started
CCC and RCC's assume limited on-line control operation
Initial installation, test, and operation of ACC's at primary airports
ATCRBS, DABS, and VORTAC system in full operation
Users have phased implementation requirements of surveillance transmitter and digital communication
Equipped users receive separation assurance and VVOR service
Transition Phase II
RCC's assume surveillance, VVOR, and control functions
ATCRBS and DABS surveillance data on in-being system users transmitted to RCC's
ACC's implemented at all control tower airports
CCC assumes NFCC and RCC backup function
Surveillance calibration stations fully implemented
Users complete phased implementation of digital voice communication and navigation
ARTCC's and TRACON's decommissioned in stages and controllers reassigned
VORTAC, ATCRBS, and DABS sites are decommissioned
SAATMS fully operational by the year 1995

Center (CCC) facility at Fort Worth, TX, will have been installed and will be operating during the T&E program. During the two years just preceding the start of Phase I of the transition period, the remaining satellites for full CONUS and oceanic coverage will be launched and the CCC will be placed in full operation. The satellites will carry all of the electronics equipment required for the surveillance, communication, and navigation functions of the SAATMS. The CCC will be implemented for its normal functions as well as some of those functions which will later be performed by the RCC's, e.g., VVOR processing. Thus, all of the basic SAATMS functions will be available during Phase I throughout CONUS to those users equipped with the compatible avionics. However, during most of Phase I, users will be under the primary control jurisdiction of the in-being control centers, i.e., the ARTCC's and TRACON's. These centers will continue to receive the surveillance position data on all Third Generation-equipped users within their jurisdiction from ATCRBS or DABS sites. In addition, they will receive the surveillance position data on SAATMS-equipped users from the CCC via satellite communication links or in some cases, via land lines. The processing required for conflict detection and resolution will be implemented at the ARTCC's and TRACON's. Hence, the latter will perform these functions on all aircraft within their jurisdiction.

A potential problem arises when conflict prediction and resolution is based upon data derived from two completely independent sensors. The problem is concerned with possible bias differences between the two sensors (SAATMS satellites and DABS). In cases where only one surveillance sensor is used, bias errors can be reduced to the extent that they result from correlated error sources. To this extent, relative accuracy is better than absolute accuracy. The differences between relative and absolute SAATMS surveillance accuracy is discussed in Volume III. In the case of DABS, the differences between absolute and relative accuracy are small. This is because most range and altitude error sources are uncorrelated, since they are based largely on transponder and altimeter errors. Azimuth errors are more highly correlated although uncertainties within the beam width (to left or right of the actual centerline) are uncorrelated. To avoid any bias errors during the transition period, the conflict detection and resolution algorithms would be based upon the absolute accuracy of the two sensors. In the case of DABS-equipped users, little effect will be noted. In the case of SAATMS, however, full advantage will not be taken of its inherent relative accuracy during the transition period.

For Third Generation users, any conflict resolution safety commands (or boundary intrusion commands) will be transmitted to the aircraft either via voice (ATCRBS-equipped users) or via DABS data link (DABS-equipped users). Safety commands for SAATMS-equipped users will be transmitted from the ARTCC or TRACON to the aircraft via a link to the CCC and thence to the user via SAATMS satellite digital data link. This approach assures the establishment of a single control jurisdiction over all aircraft operating within a region. During Phase I, selected ACC's will be implemented at a few high density terminal area TRACON's, initially operated off-line for evaluation purposes and later operated on-line in conjunction with the cognizant TRACON. Ultimately, these ACC's will be tied in directly to the cognizant RCC.

Requirements for equipping aircraft with SAATMS avionics will be on a phased basis during Phase I. Cooperative and controlled users will receive CONUS-wide, down-to-the-ground surveillance by equipping the aircraft with a SAATMS surveillance transmitter. By also adding the modular digital communication function to the avionics equipment (thus including the ground-to-air data link), the user will inherently avail himself of the VVOR function which provides a low cost, flexible RNAV capability for both enroute and approach at all altitudes, anywhere within CONUS. Users carrying a simple VHF Voice/VOR (NAVCOM) transceiver will thus receive the benefits of separation assurance and VVOR by adding the surveillance/ communication SAATMS avionics. A temporary rebate on aviation taxes may be granted to users during the early part of Phase I to provide an economic incentive for implementing these SAATMS avionics functions. Later in Phase I, e.g., by 1985, all new aircraft sold will be required, by regulatory procedures, to carry at least the surveillance transmitter and all used aircraft will be required to carry this equipment by 1987. Similarly, controlled users will be required to add the SAATMS navigation receiver/processor function to the L-band surveillance/ communications transceivers. Use of the navigation processor will provide CONUS-wide down-to-the-ground navigation coverage and higher and more uniform navigation accuracy. The latter will lead to improved direct routes for both enroute and terminal areas. Aircarrier and military users are expected to begin implementation of the SAATMS navigation function during Phase I; however, regulatory requirements on this equipment should be deferred until Phase II, since the VORTAC network will still continue in full operation during Phase I.

During the last few years of Phase I, the two RCC's and additional ACC's will be installed and checked out. This will include the software development and checkout of the RCC control functions, such as enroute-to-terminal transition, sequencing, spacing, and RCC-to-ACC handoff. The software and hardware checkout of the RCC's and ACC's will be completed by the end of Phase I, i.e., by 1990. By that time, the bulk of the fleet will have transitioned to SAATMS. Therefore, at the end of Phase I, the primary surveillance and control functions will be transferred from the ARTCC's and TRACON's to the western and eastern RCC's; and the CCC will assume its normal SAATMS functions.

The previously described transition procedure during Phase I will serve to avoid excessive federal budgetary peaks. During this period, the primary Operations and Maintenance (O&M) costs are those associated with the Third Generation System facilities, except for the operation of the CCC, and limited, staged transfer of control jurisdiction of a few selected ARTCC's to the CCC and RCC's. The primary Facilities and Equipments (F&E) costs during Phase I will be those associated with the software and hardware of the partial RCC's and ACC's.

At the beginning of Phase II, primary control jurisdiction over all aircraft will be transferred at an accelerated rate to the RCC's. Third Generation System facilities will be gradually decommissioned during the 5-year period from 1990 to 1995. By the start of Phase II, only a small percentage of users in the system will not be SAATMS-avionics equipped. Regulatory procedures will require that all new aircraft be equipped with SAATMS surveillance/communications functions by 1992, and used aircraft by 1995.

During the early part of Phase II, surveillance position data on non-SAATMS-avionics equipped users will be obtained at ATCRBS or DABS sites and transmitted via the cognizant TRACON's and ARTCC's to the cognizant RCC, the latter link probably via satellite. The RCC will thus perform the conflict detection and resolution processing on all aircraft regardless of the source of surveillance position data. Conflict resolution commands to SAATMS-equipped users will be over the normal SAATMS digital data link. Conflict resolution commands to the non-SAATMS equipped users will be via the cognizant ARTCC or TRACON over the DABS data link or VHF voice. However, by 1995 all users will have transitioned to the SAATMS surveillance/communications function and Third Generation ATC facilities; i.e., ATCRBS, DABS, TRACON's, and ARTCC's will be decommissioned. At approximately the same time, decommissioning of the VORTAC sites will begin. By that time, the bulk of the controlled users will be equipped with SAATMS navigation avionics as a consequence of benefit incentives and federal regulations. Lower class general aviation may still use VOR on a limited basis during this period. However, by the end of Phase II, the entire VORTAC net will be decommissioned. Low class general aviation users will receive navigation service either by means of VVOR or with low cost versions of the SAATMS satellite navigation function. Thus by 1995, SAATMS will be in full operation, and the Third and Upgraded Third Generation facilities will be fully decommissioned.

During Phase II, the primary O&M costs will be those associated with SAATMS and the primary F&E costs will be those associated with ACC implementation. Third Generation System O&M and F&E costs will be insignificant during Phase II of the transition period.

The transition plan presented herein is based on the assumption of the existence of a combined ATCRBS/DABS surveillance system by 1982, with limited implementation of DABS. It is evident from the timing of the recommended SAATMS implementation schedule that it may not be cost effective to carry out the complete ground facility implementation of DABS, or, indeed, any DABS implementation, particularly if the SAATMS RDT&E program demonstrates the cost/benefits and performance characteristics of the SAATMS.

3.3 System Descriptions

This subsection describes the expected in-being ATC System (GAATMS) (see Ref. 1 and 2) and the recommended SAATMS.

3.3.1 1982 In-Being ATC System, GAATMS

Phase I of the GAATMS is currently planned for the 1975-1978 period and Phase II is planned for the 1978-1985 period. Therefore, the beginning of the proposed SAATMS transition in 1982 falls within Phase II of the GAATMS.

The airspace structure of the in-being system consists of three regions: positively controlled (for IFR users), mixed, and uncontrolled (for VFR users). The nominal allocations of these regions for enroute airspace consist of a Positively Controlled Airspace (PCA) floor at 14,500 ft MSL; mixed airspace floor at 6,000 ft AGL; and uncontrolled airspace below 6,000 ft. Positively controlled airspace exceptions occur in certain high density traffic regions and over the Rocky Mountains. Enroute traffic control will be exercised by the presently existing 20 Air Route Traffic Control Centers (ARTCC).

Positively controlled airspace in terminal regions is serviced by a Terminal Radar Approach Control (TRACON) facility which serves all airports within a designated terminal airspace area. This airspace (PCA) is restricted to IFR and cleared VFR flights. Mixed types of terminal areas (servicing both IFR and VFR traffic) include Terminal Radar Service Areas (TRSA) serviced by a TRACON or TRACAB and airport traffic areas serviced by VFR (non-radar) control towers. Uncontrolled terminal airspace, serving VFR traffic only, is characterized by non-tower airports. Extensive upgraded automation capabilities will be added to the ARTCC and TRACON facilities to provide such functions as flow control, separation assurance, and metering and spacing on an automated basis. Table 3.3-1 lists the services provided for IFR and VFR traffic, together with the functional and control concepts for Phase II of the GAATMS (see Ref. 1).

The primary link with aircraft for surveillance and communication in high and medium density terminals will be provided by ATCRBS and DABS. Intermittent Positive Control (IPC) will be accomplished in mixed airspace by the use of DABS. The current development of DABS has not defined the waveform. However, it is intended that DABS-equipped aircraft and ATCRBS-equipped aircraft will be able to operate in conjunction with the same ground facilities.

The existing VHF/UHF air-ground voice radio network will complement the DABS data links system for nondata link messages, for communication in airspaces not covered by DABS, and for DABS backup.

The ground-ground communication system is composed of a variety of networks (e.g., voice intercom, telephone, teletype, computer and remote lines, radar site land lines, and microwave links).

Table 3.3-1. GAATMS Characteristics, Phase II

Function	Characteristic
Data Processing and Control	
Flow Control	Centralized automated
Clearance Processing	Automated via data link
Separation and Sequencing	Automated safety commands via data link: Intermittent Positive Control to VFR, ATC to IFR
Metering and Spacing	Automated; data link control
Ground-Ground Communication	
Intrafacility	Fully automated or via controller display or voice
Interfacility	Digital plus voice
Air-Ground Communication	
Primary	DABS data link and VHF/UHF voice
Backup-Ground	Backup emergency
Backup-Airborne	UHF/VHF voice
Navigation and Landing	
Enroute and Terminal	VOR/DME/TACAN plus increased RNAV
Landing	Increased MLS plus VHF ILS (Category II)
Surveillance	
Primary	4096 Code ATCRBS plus 99 DABS introduced
Backup	Radar
Oceanic Navigation and ATC	
Surveillance	Automated via data link/satellite surveillance
Communication	HF voice, dedicated VHF, plus L-band and data link via satellite
Control	Increased computer aids to controller
Navigation	Hybrid inertial (Loran/Omega)
Airports	
Runway Operations	Precision MLS approaches to 2500 ft spaced runways
Ground Guidance and Control	Comprehensive airport ground traffic control
Flight Services	Pilot self-service automation (flight plan filing and briefing)

Navigation aids consist of VOR installations for enroute and terminal areas. In addition, low frequency Non-Directional Beacons (NDB) will service certain terminal areas. The VOR sites will be collocated with TACAN and DME sites.

As indicated in Table 3.3-1, the major control functions to be automated in 1982 are metering and spacing, conflict prediction and resolution, flow control, and clearance processing. CONUS enroute traffic control will be exercised by 20 ARTCC's using upgraded NAS Stage A automation. Traffic control at large and medium terminals will be implemented with upgraded ARTS III automation in TRACON facilities. Automated tower cabs (TRACABS), as satellites of the ARTS facilities, will control low density airport traffic using ARTS II. Also, non-radar tower cabs will exchange data with the ARTCC's. National traffic flow (as influenced by weather and system disturbances) will be managed by the Central Flow Control Facility in Washington, D.C.

3.3.2 SAATMS

The SAATMS concept is based on the definition of three types of aircraft operations, i.e., controlled, cooperative, and uncontrolled. Of these, only the first two are active participants in the system and are provided services. The third category of operational aircraft is restricted to uncontrolled airspace. The controlled aircraft must file a flight plan, must operate in accordance with the assigned route, and are required to carry certain avionics equipment. The cooperative aircraft need not file a flight plan nor operate in accordance with an assigned route, but must carry a minimum of avionics complement.

The airspace structure is categorized as controlled, mixed, cooperative, and uncontrolled. Enroute altitude assignments corresponding to the airspace structure are as follows: (1) Controlled: Above 12,000 ft, MSL (2) Mixed: 6,000 to 12,000 ft MSL (3) Cooperative: Ground to 6,000 ft MSL (4) Uncontrolled: Ground to 3,000 ft AGL. Only controlled aircraft (in controlled and mixed airspace) are required to comply with a route structure (3D, RVAV). The airspace in high density terminals and nearby is divided into certain bounded regions and corridors which are restricted to the controlled users (see Section 1.2.3 of Volume IV).

Table 3.3-2 lists the flight services provided for controlled and cooperative aircraft, together with the functional and control concepts for SAATMS. A discussion of the corresponding user avionics is presented in Section 1.2.2.3 of Volume IV.

Table 3.3-2. SAATMS Characteristics

Service	Characteristic
Data Processing and Control	
Flow Planning	Automated by CCC
Clearance Processing	Automated via FSS/CCC
Path Conformance Control	Primarily Air Managed
Separation Assurance	Automated via RCC
Sequencing, Metering, Spacing	Automated via RCC
Ground-Ground Communication	
Intrafacility	Fully automated or via display or voice
Interfacility	Automated via satellite
Air-Ground Communication	
Primary	Digital L and C-band via satellite
Backup	L-band voice via satellite
Navigation and Landing	
Enroute and Terminal	L-band satellite navigation processing or VVOR
Landing	MLS as required
Surveillance	
Primary	L-band (aircraft to satellite); C-band (satellite to ground)
Backup	Multiple Satellites/ Transmit Navigation Data
Oceanic Navigation and ATC	
Surveillance	L-band (aircraft to satellite); C-band (satellite to ground)
Communication	L-band (aircraft to satellite); C-band (satellite to ground)
Control	Air and ground managed
Navigation	L-band Satellite Navigation Processing

Table 3.3-2. (Continued)

Service	Characteristic
Airports	
Runway Operations	Precision MLS (2500 ft spacing)
Ground Guidance and Control	Automated trilateration and IR sensors
Flight Services	Pilot self-service automation (flight plan filing, briefing, weather)

The SAATMS operation uses a constellation of 15 satellites at synchronous altitude. Of these, six satellites are equatorial (geostationery) with two satellites each longitudinally associated with CONUS, the Atlantic, and the Pacific. To provide 24 hr coverage to each region, a total of 15 satellites is required with an end result of 8 to 10 satellites being instantaneously available. The integrated electronics in each satellite performs the functions of two-way communication relay between the aircraft and the ground control facilities, relay of aircraft transmitted surveillance signals, and the transmission of L-band navigation to all aircraft.

The surveillance function employs satellites to relay surveillance data from all users in the system. Each aircraft transmits surveillance pulses encoded with the user's unique identification code. The satellites that are in view of the user relay these signals to control centers where the instantaneous aircraft position and velocity are generated for every aircraft in the system. This technique is employed for aircraft in both enroute and terminal airspace, but the system absolute accuracy is enhanced in high density terminal airspace through the use of calibration stations. Approximately 50 such surveillance calibration stations transmit surveillance signals on L-band to the satellites which are retransmitted to the RCC's. Since these surveillance transmissions are from precisely known fixed points, they are used directly to determine spatially correlated propagation path anomalies for greater aircraft position accuracy in the terminal areas.

The communication subsystem is designed to provide the basic data interchange between all of the ground, satellite, and airborne elements in the system. Basically, all airborne-to-satellite or ground links operate in the L-band region, while all ground to satellite links operate in the C-band region.

There are two primary navigation modes provided for in the SAATMS. For suitably equipped aircraft, a navigation scheme based on satellite transmitted signals is provided. This scheme is completely independent from the surveillance scheme. For aircraft which do not possess the navigation avionics, a simpler, less expensive navigation scheme, called Virtual VOR (VVOR), is employed. This scheme is based on retransmitted surveillance data processed in a VOR format.

Primary control for CONUS and oceanic enroute and terminal-to-final approach/departure will be exercised by the two RCC's. At all control tower airports, the control of traffic during final approach and takeoff as well as on the airport surface will be exercised by 729 ACC's. A CCC provides national flow planning and backup surveillance and control for the RCC's. Also, the CCC performs satellite constellation ephemeris computation and time promulgation. Data for the ephemeris computation function is obtained by means of seven STC's which receive normal satellite L-band navigation signals for tracking and ephemeris computation. These seven STC's are collocated with the CCC, RCC's, and four ACC's.

3.4 Transition Criteria

The primary criterion for a viable transition plan is the minimization of economic impact on both the users and the federal budget. In addition, no degradation in services or safety may occur during transition, and the transition must be scheduled so that the user will realize increased benefits as his aircraft becomes equipped with the new avionics. The criteria for transition are described in the following paragraphs.

3.4.1 Gradual Introduction of Equipment and Concepts

Gradualism is required in imposing new avionics requirements on the GA user. Since avionics cost frequently represents an appreciable percentage of the total aircraft cost, major attention must be given to this aspect of transition. The GA user desires to amortize the investment in his present avionics over a useful lifetime. If the imposed initial acquisition costs are too severe, the GA user may not be able to participate in the SAATMS. In general, the aircarrier user is considered to be more able to afford the cost for new avionics, but he expects to derive more immediate economic benefits as a result of the equipment implementation.

3.4.2 No Requirements for Dual Avionics

The transition process should not require users to carry dual type avionics to be compatible with two ATC systems for the same function. The requirement of no dual avionics does not prohibit the retention of some of the old avionics.

3.4.3 Modular Approach for Avionics

A modular approach to equipping aircraft with SAATMS avionics should be provided as an option. The modular approach permits a low cost entry into the system while realizing certain initial benefits from SAATMS.

3.4.4 Added Benefits with no Degradation in Existing Services

Irrespective of the increased benefits to be derived from SAATMS after the transition is completed, the separate benefits of the in-being system and the SAATMS should not be degraded during the time of transition. For example, reduced safety or capacity must not result during transition. Moreover, shortcomings of the in-being system, such as bottlenecks and limited safety and capacity, should be corrected.

3.4.5 No Excessive Federal Budget Peaks

The avoidance of federal budget peaks due to ground facilities, satellites, and manpower is a most important criterion. However, total accumulated costs must also be considered in the process of minimizing the budget peaks. A deviation from this criterion may be indicated regarding the launching of satellites. It is estimated that practically all of the satellites are required for 24 hr service to any major region within CONUS. Hence, it would be inadvisable to schedule the satellite launchings over a period of years.

3.4.6 Exploit Full Useful Life of Ground and Avionics Equipment

This criterion supports the basic objective of minimizing the economic impact to both the users and the federal government. All aspects of the transition must be so scheduled that the life of previously purchased equipment, whether for the aircraft or the ground, can be fully utilized. The nation cannot afford any unnecessary or wasteful discarding of facilities.

3.4.7 Single Control Jurisdiction of All Aircraft Within a Region

In order to assure safety, all aircraft operating within the same region must, at any given time, be under a single control jurisdiction during the transition period, although the surveillance data used for control may be obtained from different sensors. Jurisdictional authority may of course be transferred for different flight phases.

3.4.8 Other Transition Criteria Considerations

Additional considerations include the following:

(1) Adequate time for system software development should be provided.

(2) The satellite and ground facilities should be in place and operational before the user can be expected to conform.

(3) Efficient use of existing controller personnel.

(4) The transition pace, progress, and procedures should be responsive to public attitude.

3.5 Transition Approach

3.5.1 Operational Concept

The similarities in the airspace structure and the management concept of the in-being system and the SAATMS will give rise to an ease of transition in the operational concepts of the two systems.

The in-being system (1982) makes use of three enroute airspace regions, i.e., positively controlled (above 14,500 ft MSL), mixed (6,000 ft AGL to 14,500 ft MSL), and uncontrolled (below 6,000 ft AGL). In contrast the SAATMS has four enroute airspace regions, i.e., positively controlled (above 12,000 ft MSL), mixed (6,000 to 12,000 ft MSL); cooperative (0 to 6,000 ft MSL), and uncontrolled (selected, posted airspace regions from 0 to 3,000 ft AGL).

The rules and procedures used in the positively controlled airspace regions of both systems are essentially the same so that no transition problems whatever exist in this region, except possibly for changes in the altitude floors. The operation in the mixed airspace regions of the two systems is also similar in that they are designed to accommodate both controlled and cooperative aircraft. However, major differences exist in the definition of the uncontrolled airspace of the in-being system and the cooperative and uncontrolled regions of the SAATMS. Operation in the cooperative airspace of the SAATMS involves a definite avionics requirement for the user (such as a surveillance transmitter, two-way digital and voice communication, plus VVOR), while operation in the uncontrolled airspace of the in-being ATM system, which covers essentially the same altitude region, does not require such avionics. As a result of this difference, users who have transitioned to SAATMS by equipping themselves with the avionics required for the cooperative airspace region will be permitted to fly in the airspace which was previously within the uncontrolled airspace of the in-being system. These users will then receive the benefits of separation assurance and VVOR service. As more users become SAATMS-equipped, the uncontrolled airspace will gradually be reduced until the final SAATMS airspace structure (see Volume IV, Section 1.3.2) is achieved

The terminal airspace structures of the two systems are quite similar, except that the SAATMS uses somewhat less airspace for the approach and departure routes for the Terminal Control Airspace (TCA) of primary airports, as a result of the higher navigation/surveillance accuracies. Rules and procedures used in the terminal airspace regions are essentially the same, however, so that no transitioning problems arise in this area. As controlled users become SAATMS-equipped, the smaller separation standards in the TCA regions will be adopted for the corridors allocated to these users. Non-TCA control tower airports of the in-being system do not have surveillance data. They will be ACC-equipped in the SAATMS. Thus during Phase II of the transition period, more and more of these airports will begin to have these added capabilities of accurate surveillance derived position monitoring and airport surface control.

Therefore, during transition, the airspace and route structure will be configured so that all users may retain the routes of past practice. In addition, SAATMS users will be able to fly in certain preferred corridors within a route structure where the airspace permits. As transition proceeds, the SAATMS-equipped users will then have an increasing number of corridors made available to them.

The control concepts used in the in-being ATM system and the SAATMS are extremely similar. The SAATMS control concept is described in detail in Volume IV, Section 1.2.5.6, of this report and is summarized in Tables 1.2-4, 1.2-5, and and 1.2-6 of that section.

In the SAATMS, in most airspace regions, path conformance is an air managed function. This is not the case in the present ATC system. Since flight plan conformance is fundamentally a pilot responsibility in SAATMS, whether or not ground management is exercised in the in-being system will not affect the ease of transition to SAATMS from an operational viewpoint.

All of the other management and control functions, such as flow planning, clearance generation, metering and spacing, and separation assurance will be performed in the same manner in the two systems, thus avoiding any transition problems.

During transition, the jurisdiction of any of the ground-managed control functions will depend on the specific time period in question. During Phase I, these control functions will be exercised primarily by the existing ARTCC's and TRACON's, although the surveillance data will be derived by means of different sensors, thereby assuring a single control jurisdiction for all aircraft within an airspace region. The control jurisdiction over selected regions will be transferred to the CCC and partial RCC's in a staged manner during the latter period of Phase I, following some off-line operation at these facilities. During Phase II, the single control function will be primarily performed by the two RCC's of the SAATMS. In all cases, intervention commands are transferred from the single jurisdictional control facility to the proper ground-based communication terminal which is equipped to communicate with the user aircraft in question. The control processing aspects of the transition period are discussed in more detail in Section 3.5.3.

3.5.2 Surveillance/Communication/Navigation Transition

3.5.2.1 Phase I Transition

The satellite-oriented and integrated nature of the SAATMS functions permits the simultaneous and CONUS-wide implementation of the full surveillance, communication, and navigation services at the start of the transition period.

3.5.2.1.1 Surveillance Transition

During the period preceding Phase I of the transition period, 6 to 10 fully equipped satellites (probably including four equatorial satellites) will already be in orbit for use in the SAATMS Test and Evaluation Program. A CCC facility at Fort Worth, TX, with limited capabilities for such functions as satellite control, ephemeris computation, and surveillance/communication will also be in operation, as will the STC's required for satellite tracking. Immediately prior to the start of Phase I, the additional fully equipped satellites required for complete 24-hr CONUS coverage will be launched. At the same time, the CCC facility will be upgraded to nearly full operation by adding such functions as VVOR processing, national flow control, and interfacility satellite communication. Thus, at the start of Phase I (1982), CONUS wide, down-to-the-ground surveillance coverage will be available to all SAATMS-equipped aircraft.

The CCC will continuously compute the surveillance position and velocity data on aircraft (from the differential time-of-arrival signals) and will transmit these data to the ARTCC's and TRACON's within whose jurisdiction the aircraft are located. Handoff from one ARTCC to another ARTCC or to a TRACON is handled through the CCC; therefore, the CCC has continuous knowledge of these jurisdictions. Surveillance data on non-SAATMS equipped aircraft are obtained by means of the existing ATCRBS or DABS sites, which are normally interconnected with the associated ARTCC's and

TRACON's. Thus, the latter facilities will have available the surveillance data required for the conflict detection and resolution computations, metering and spacing, and other control functions exercised over all of the aircraft within their regional jurisdiction for both SAATMS-equipped and non-SAATMS equipped aircraft.

During Phase I, the oceanic surveillance function will be performed largely in the same manner as it is in the in-being system, except that surveillance position and velocity data on SAATMS-equipped aircraft will be available at the CCC. These data will be transmitted to the existing cognizant, oceanic ATC centers for control processing in conjunction with the surveillance data on non-SAATMS equipped users. (At this writing, it has not been determined whether the in-being 1982 system will employ satellites for over-ocean position reporting/dependent surveillance or for independent surveillance purposes. In either case, during Phase I, the oceanic ATC centers will make use of both SAATMS and non-SAATMS surveillance data for control advisories to over-ocean aircraft.)

3.5.2.1.2 Air-Ground Communication Transition

At the start of Phase I, the full SAATMS communication function will be available to those aircraft which are suitably equipped, except for local airport communication at those control tower airports which are not yet ACC-equipped. During all but terminal phases, air-ground communication of SAATMS-equipped users will be via satellite to the CCC facility and thence to the cognizant ARTCC or TRACON. Ground-air communication to these users will be via the reverse link. Communication of the non-SAATMS equipped users will be via VHF voice or the DABS data link. During the initial period of Phase I, some low class GA users will have the SAATMS surveillance transmitter but not the SAATMS communication function, since their aircraft may have recently been NAVCOM-equipped (VHF voice plus VOR). In this case, air-ground communication of these users will continue with the ARTCC's and TRACON's via VHF voice. Communication with oceanic aircraft will be performed essentially in an equivalent manner, i.e., the same ground terminal is used by all aircraft but the actual RF link employed depends on the avionics equipment available on the aircraft.

3.5.2.1.3 Navigation Transition

The full SAATMS navigation service, in its two forms, will be available CONUS-wide and with down-to-the-ground coverage at the start of Phase I of the transition. Since the satellites initially launched will transmit the L-band navigation signals, all users equipped with the SAATMS navigation receiver and processor will be able to receive full SAATMS satellite navigation service. The VVOR area navigation service will also be available throughout CONUS and down-to-the-ground to all users equipped with the SAATMS surveillance transmitter, the digital communication function, and the VVOR display. During most of Phase I, the VVOR processing for all of CONUS will be performed at the CCC, and the VVOR data will be transmitted from the CCC to the aircraft via satellite. During this phase, non-SAATMS equipped users will continue to use the VORTAC network for VOR/DME service for radial or nonradial (area navigation) routes. Essentially, no transition problems exist for the navigation of oceanic aircraft since they will continue to use inertial or hybrid radio-inertial navigation, which will be supplemented by SAATMS satellite navigation as the aircraft become so equipped.

3.5.2.2 Phase II Transition

At the beginning of Phase II of the transition period (1990), the bulk of the fleet is expected to be equipped with SAATMS avionics. During the four years preceding the start of Phase II, installation, checkout, and personnel training of the two RCC's will have been accomplished. This includes development and checkout of the software required for automation and operational test and evaluation of each of the RCC's. Thus, by the year 1990, the primary surveillance processing for CONUS will be transferred from the CCC to the two RCC's, as will the VVOR processing. At the same time, the control functions will be transferred in rapid stages from the ARTCC's and TRACON's to the RCC's, including conflict and intrusion detection and resolution. Hence, all ground-air communication origination within the two regions must also be transferred from the ARTCC's and TRACON's to the two RCC's. Decommissioning of the ATCRBS and DABS sites will begin at that time. During a large part of Phase II, a small number of aircraft, including some foreign aircraft entering or leaving CONUS, may still be equipped only with ATCRBS or DABS transponders. Surveillance data on these aircraft will then be obtained by the ATCRBS or DABS sites and will then be transmitted to the cognizant RCC for control purposes. By the middle of Phase II, regulatory procedures will require most users in the system to be equipped with SAATMS surveillance/communication equipment. Hence decommissioning of ATCRBS, DABS, ARTCC, and TRACON facilities will be accelerated at that time and will be complete by the end of Phase II (1995).

Similarly, by the start of Phase II, very few users will have need for the VOR/DME service from the VORTAC network, since they will be equipped with the SAATMS satellite navigation receiver/processor or the VVOR display. Therefore, the VORTAC network will be decommissioned by the end of Phase II (1995).

Figure 3.5-1 presents an overall schedule for the transition of the surveillance, communication, and navigation functions.

3.5.3 Control and Ground-Ground Communication Transition

In view of the similar automation plans for both the in-being 1982 ATM system and the SAATMS, the control function can be transitioned smoothly, provided a single control jurisdiction for any region is maintained at all times.

3.5.3.1 Phase I Transition

During Phase I (1982-1990), the ATC facilities of the in-being system, i.e., the ARTCC's, TRACON's, and TRACAB's will be largely maintained in normal operation. Some satellite ground-to-ground communication capabilities will have to be added at these facilities early in this phase to permit communication with the CCC and later with the RCC's. No major change in geographic or airspace jurisdiction of

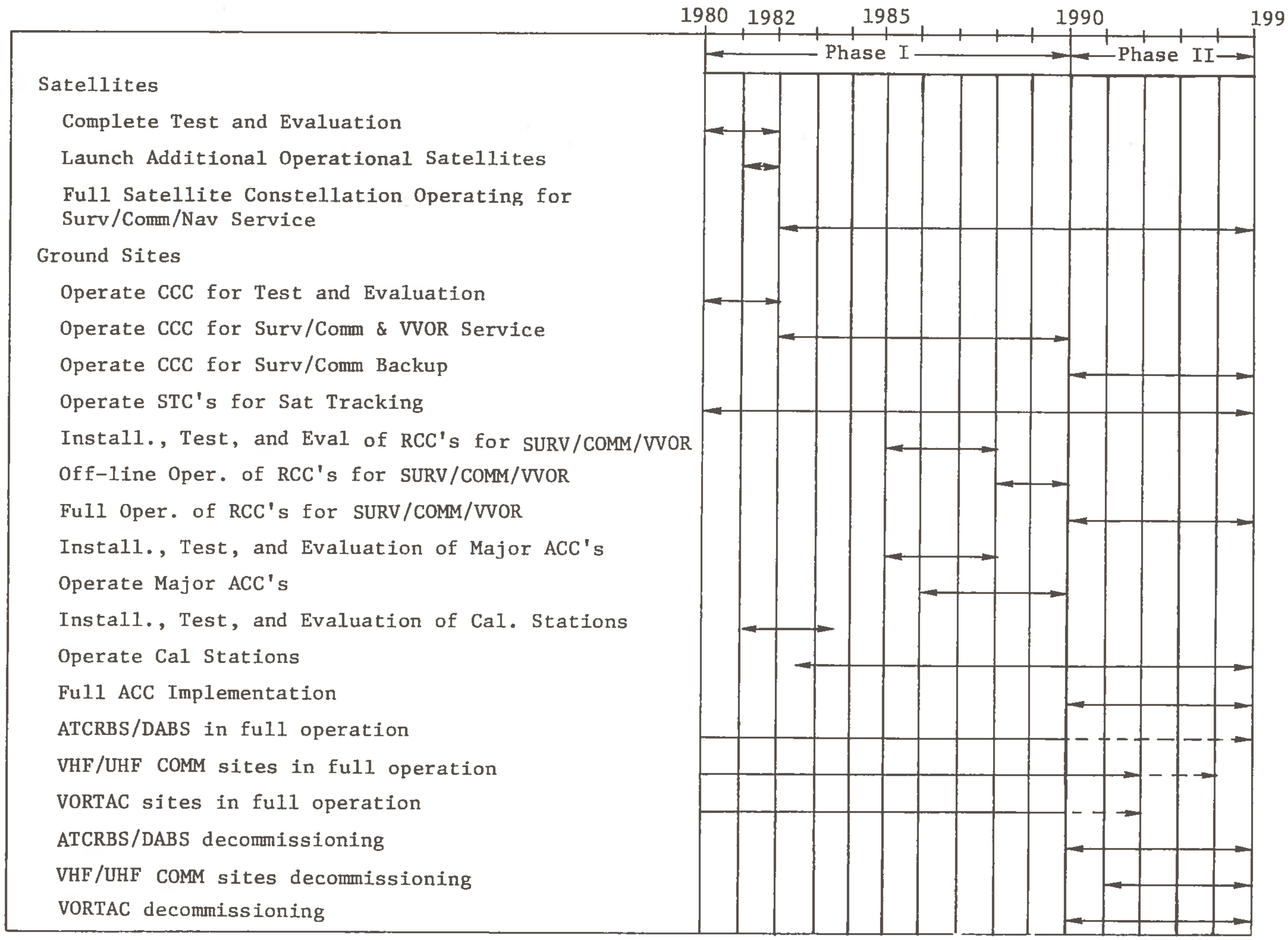

Fig. 3.5-1 Surveillance/Communication/Navigation Facilities Transition Schedule

most of these existing ARTCC's will be made during this phase. Flow planning and flight planning functions will be performed as in the past, i.e., by the Central Flow Control Facility, the FSS facilities, and the ARTCC's. All aircraft operating within an airspace region will be under the control of a single jurisdictional authority, although the surveillance data used for control will be derived from different sensors. Surveillance data on non-SAATMS-equipped aircraft for use at the ARTCC's and TRACON's will be derived from the ATCRBS or DABS sites. Surveillance data on SAATMS-equipped users will be derived from the CCC surveillance processor via suitable satellite or land line ground-ground communication links between the CCC and the ARTCC's. Conflict detection and resolution computations on all aircraft within its jurisdiction will be performed by the cognizant ARTCC or TRACON. Based on the present plans for the Upgraded Third Generation ATC system, the automation required for these functions, as well as sequencing, metering, and spacing, will already exist at these facilities. However, some software, processing, and communication hardware additions may be required to accommodate the introduction of SAATMS surveillance and communication, as well as the SAATMS airspace corridor allocations. Control intervention commands will be initiated by the ARTCC's and TRACON's and transmitted to the users either via VHF voice, DABS data link, or SAATMS communication link (via the CCC as ground terminal), depending on the avionics equipment carried by the user aircraft.

Also during Phase I, the CCC and, later, the two RCC's will be partially implemented to permit them to exercise all of the control functions over a limited region, such as one or more ARTCC regions. This will first be done on an off-line basis. Only after extensive off-line operation will the control of such a region be transferred to the CCC or RCC on an on-line basis. This will be accomplished on a staged, region-by-region basis and will therefore result in an efficient use of existing controller personnel and no net increase in O&M costs. While it is possible to transfer limited regional control on this basis during the early part of Phase I, operation of ATCRBS and DABS sites must be fully maintained during this phase, since a large fraction of the users will not yet be SAATMS-equipped.

During Phase I, control of aircraft in the airport region will be by the local controller, as in the past. However, implementation of ACC's at selected primary airports will begin during this phase. In many cases, these ACC's will be collated at existing TRACON's, thus making use of existing controllers, processors, and displays. Initially, these ACC's will be operated off-line, with their processors and displays receiving surveillance position data from the ATCRBS and DABS sites, as well as the CCC or RCC facilities. During the latter half of Phase I, after extensive off-line operation, these ACC installations at major airports will be converted to on-line operational status.

3.5.3.2 Phase II Transition

During Phase II, the primary control functions of the remaining regions will be transferred at an accelerated pace to the RCC's. CONUS wide flow and flight planning functions will be transferred to the CCC, which will operate in conjunction with the national FSS network. The CCC will also assume CONUS-wide system backup for the two RCC's.

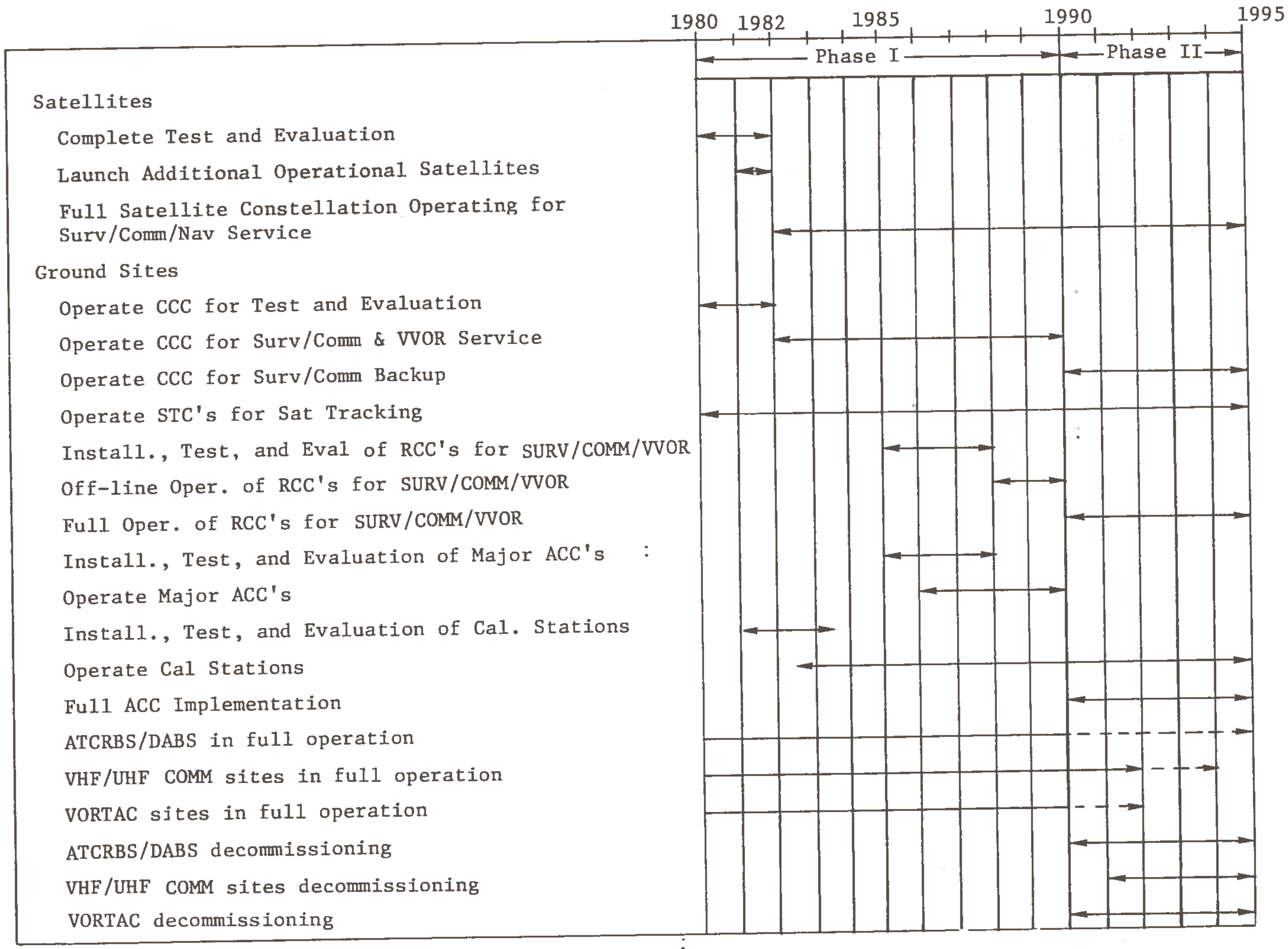

Fig. 3.5-1 Surveillance/Communication/Navigation Facilities Transition Schedule

most of these existing ARTCC's will be made during this phase. Flow planning and flight planning functions will be performed as in the past, i.e., by the Central Flow Control Facility, the FSS facilities, and the ARTCC's. All aircraft operating within an airspace region will be under the control of a single jurisdictional authority, although the surveillance data used for control will be derived from different sensors. Surveillance data on non-SAATMS-equipped aircraft for use at the ARTCC's and TRACON's will be derived from the ATCRBS or DABS sites. Surveillance data on SAATMS-equipped users will be derived from the CCC surveillance processor via suitable satellite or land line ground-ground communication links between the CCC and the ARTCC's. Conflict detection and resolution computations on all aircraft within its jurisdiction will be performed by the cognizant ARTCC or TRACON. Based on the present plans for the Upgraded Third Generation ATC system, the automation required for these functions, as well as sequencing, metering, and spacing, will already exist at these facilities. However, some software, processing, and communication hardware additions may be required to accommodate the introduction of SAATMS surveillance and communication, as well as the SAATMS airspace corridor allocations. Control intervention commands will be initiated by the ARTCC's and TRACON's and transmitted to the users either via VHF voice, DABS data link, or SAATMS communication link (via the CCC as ground terminal), depending on the avionics equipment carried by the user aircraft.

Also during Phase I, the CCC and, later, the two RCC's will be partially implemented to permit them to exercise all of the control functions over a limited region, such as one or more ARTCC regions. This will first be done on an off-line basis. Only after extensive off-line operation will the control of such a region be transferred to the CCC or RCC on an on-line basis. This will be accomplished on a staged, region-by-region basis and will therefore result in an efficient use of existing controller personnel and no net increase in O&M costs. While it is possible to transfer limited regional control on this basis during the early part of Phase I, operation of ATCRBS and DABS sites must be fully maintained during this phase, since a large fraction of the users will not yet be SAATMS-equipped.

During Phase I, control of aircraft in the airport region will be by the local controller, as in the past. However, implementation of ACC's at selected primary airports will begin during this phase. In many cases, these ACC's will be collated at existing TRACON's, thus making use of existing controllers, processors, and displays. Initially, these ACC's will be operated off-line, with their processors and displays receiving surveillance position data from the ATCRBS and DABS sites, as well as the CCC or RCC facilities. During the latter half of Phase I, after extensive off-line operation, these ACC installations at major airports will be converted to on-line operational status.

3.5.3.2 Phase II Transition

During Phase II, the primary control functions of the remaining regions will be transferred at an accelerated pace to the RCC's. CONUS wide flow and flight planning functions will be transferred to the CCC, which will operate in conjunction with the national FSS network. The CCC will also assume CONUS-wide system backup for the two RCC's.

The staged decommissioning of the remaining ARTCC's and TRACON's will be completed during the five-year period of Phase II (1990-1995). However, in regions where non-SAATMS equipped users may still operate, such as ports of entry of foreign users, the in-being surveillance facilities will be retained during Phase II. ATCRBS or DABS surveillance position data on these users will be transmitted to the cognizant RCC's and thence to the ACC's via appropriate satellite or land line communication links. The single control concept during transition will thus be maintained during Phase II.

During Phase II, the remaining ACC's will be implemented throughout CONUS. These ACC's will then assume control over the aircraft within the airport regions, i.e., during landing, takeoff, and on the surface. The ACC operation involves essentially an automated monitoring and control function which was previously not available at the airport.

Early in Phase II, the SAATMS satellite ground-ground communication network between the CCC, the RCC's, and the ACC's will be completed. As the ARTCC's, TRACON's, ATCRBS, and DABS sites are decommissioned, it will also be possible to decommission the ground-ground microwave links and landlines previously used between these facilities.

Figure 3.5-2 presents a schedule for the transition of the control and ground-ground communication functions.

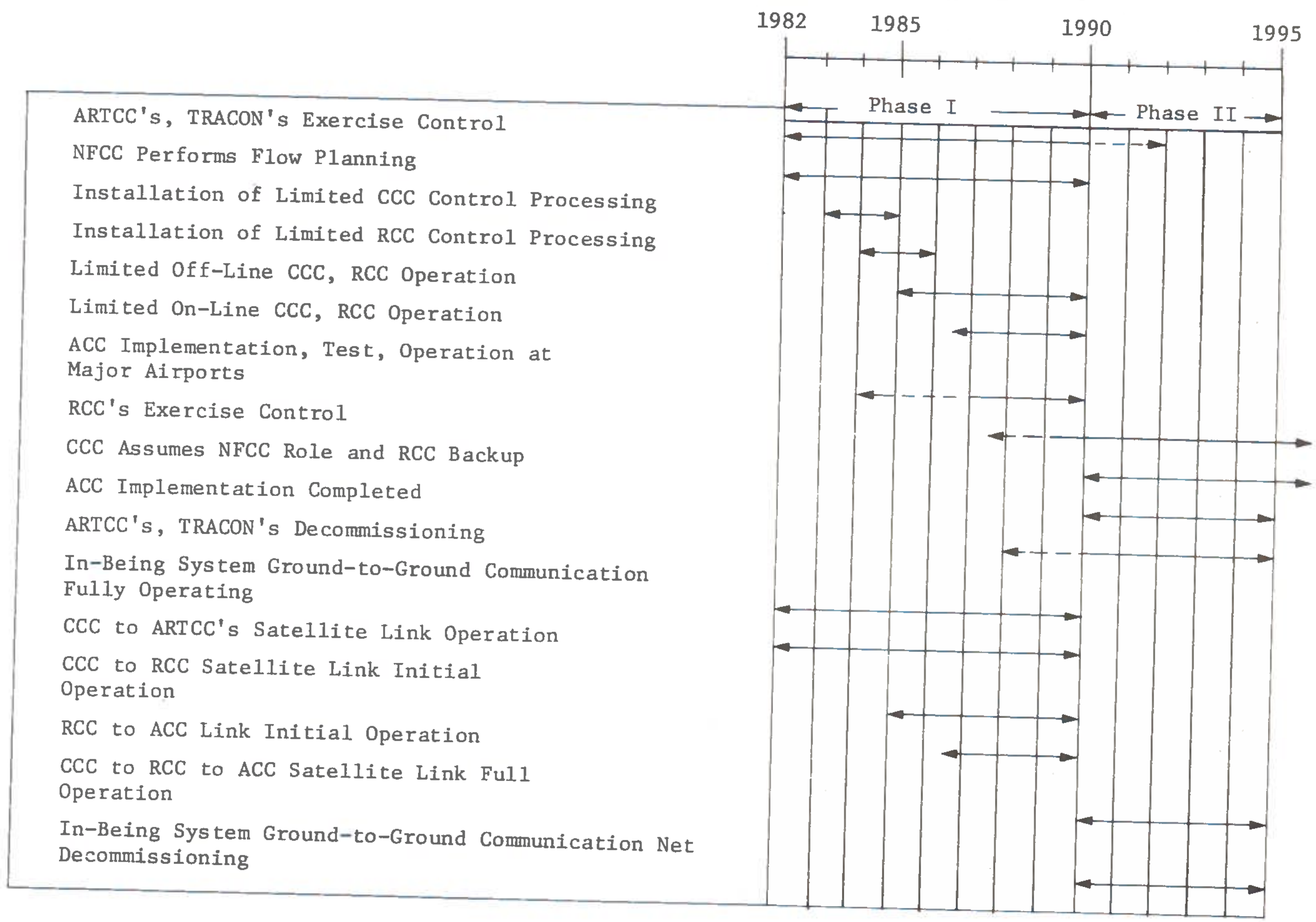

Fig. 3.5-2 Control Processing and Ground-to-Ground Communication Transition Schedule

3.6 Avionics Transition Based on User Benefits

The users operating in the in-being system will carry a variety of separate Third Generation avionics equipment, which, during transition, will be supplemented by SAATMS modular avionics.

FAA statistics on the avionics equipment carried by General Aviation (GA) users in 1972 and those projected for the 1982 time period indicate the direction required for the avionics transition to SAATMS. The data presented in Table 3.6-1 (Ref. 4) show that in 1972 practically all GA users (96 percent) carried NAV/COMM (VHF voice plus VOR) and over half of these users carried dual NAV/COMM. equipment. Based on the percentage of users equipped and the approximate cost of the equipment, the average avionics cost for GA users operating in the fleet in 1972 was $6,365. However, data obtained from the Aircraft Owners and Pilots Association indicate that the average cost of the avionics equipment in new GA aircraft sold in 1972 was $9,109. A projection for GA avionics equipment which will probably be required by the year 1982 is shown in Table 3.6-2 (Ref. 5). The avionics equipment required for operation in the transition period can be determined by comparing the data in Tables 3.6-1 and 3.6-2 with the SAATMS avionics described in Volume III. The avionics for the 1982 in-being system and SAATMS are shown in Table 3.6-3 for low and high class users.

The SAATMS avionics concept is based on the use of an integrated L-band transceiver in the aircraft. However, the various functions provided by this transceiver will be available in modular form so that during the transition period, the user can add these functions on an incremental basis to minimize his initial acquisition cost. Which of these modular functions the user will add first will depend on the avionics with which he is already equipped and on the added benefits and services which he desires. These options are summarized in Table 3.6-4 and are discussed in the following paragraphs.

A typical low class GA user will be equipped only with NAV/COM which typically includes VHF voice communication, VOR navigation, a Localizer/Indicator, and possibly a Marker Beacon receiver. Hence, for this user, the most beneficial and lowest cost option for transitioning to SAATMS is to add only the surveillance transmitter. By doing so, the user is provided with CONUS-wide down-to-the-ground surveillance service. Conflict resolution commands will be transmitted to him via the VHF voice link of his NAV/COM equipment. He will continue to use VOR navigation by means of the VORTAC network. Later, the same user (as well as a user carrying a VHF radio only) may have a requirement for a low cost area navigation service. A user carrying NAV/COM and an ATCRBS transponder also may have a requirement for low cost area navigation. By adding the SAATMS digital communication/VVOR display module, the user avails himself of the VVOR service, which is a CONUS-wide, down-to-the-ground area navigation service and is usable for enroute flying as well as Category I approaches. Both the VVOR and the digital communication modules represent a reduction in pilot work load since the frequent switching of frequency channels is eliminated. Backup communication for this user will continue to be via VHF voice. The third option for the GA user is to add the voice communication module

Table 3.6-1. 1972 General Aviation User Avionics

Avionics Equipment	Number of Users*	Percent of GA Fleet	Approximate Cost ($)**
Navigation/Communication (NAVCOM) (VHF Voice + VOR)	130,000	96	2000
Dual Navigation/Communication (NAVCOM)	70,000	52	4000
Localizer/Marker Beacon	56,000	41	700
Automatic Direction Finder (ADF)	80,000	59	1300
Distance Measuring Equipment (DME)	36,000	27	2700
Transponder (without Altitude Encoder)	50,000	37	700
Average GA avionics cost in 1972 of all aircraft in fleet:		$6365	
Average GA avionics cost in 1972 of all new aircraft sold: (Source: Aircraft Owners and Pilots Association)		$9109	

*Source: Federal Aviation Administration (Ref. 4)

**Source: King Radio Company and Aircraft Radio Corporation Catalogs

Table 3.6-2. 1982 Projected Cost for General Aviation Avionics Requirements

Avionics Equipment	Estimate Cost ($)
1. ATCRBS Transponder (4096 codes, Mode C)	1000
2. Discrete Address Beacon System (DABS) Transponder	1200
3. Universal Data Link	5000
4. 25 kHz VHF Communication	2000
5. 50 kHz VOR	1000
6. 50 kHz ILS	1000
7. Collision Avoidance System	2000
8. Area Navigation	3000

*Source: Federal Aviation Administration (Ref. 5)

Table 3.6-3. Avionics Complement During Transition

1982 In-Being System Avionics		
Equipment	Service	Approximate Cost ($)*
Low Class GA User		
NAV/COMM	Navigation/Communication/Localizer	2000
ADF	Approach Guidance	1300
Marker Beacon	Approach Guidance	300
		3600
High Class GA User		
Dual NAV/COMM	Navigation/Communication/Localizer	4000
ADF	Approach Guidance	1300
DME	Navigation	2700
Glide Slope	Landing Guidance	700
Transponder	Surveillance	1000
RNAV	Navigation	3000
Marker Beacon	Landing Guidance	300
		13,000
Average GA Cost: ≈ $6000		
Sources: King Radio Company and Aircraft Radio Corporation Catalogs and Federal Aviation Administration (Ref. 5)		

SAATMS Avionics		
Equipment	Service	Approximate Cost ($)*
Low Class GA User		
Transceiver	Surveillance	2500
	Digital Communication	
	Voice Communication	
Basic Displays	VVOR RNAV/Approach Guidance	525
		3025
High Class GA User		
Dual Transceiver	Surv/Dig Comm/Voice Comm plus Backup	5000
Basic Displays	VVOR RNAV/Approach Guidance	525
Nav Rec/Proc	3D Navigation	800
Advanced Displays	RNAV/ATC Communication	2800
		9125
Average GA Cost: ≈ $4500		

*Acquisition cost only; does not include installation and maintenance.

Table 3.6-4. Avionics Transition Options and Benefits

GAATMS Avionics Equipment	Services	SAATMS Avionics Equipment	New Services and Benefits
Navigation/Communication/Localizer	Lateral Navigation Communication Approach Guidance	Surveillance Transmitter	CONUS-Wide Separation Assurance and Ground Separation Assurance
DME	Longitudinal Navigation	Digital Communication/VVOR Display	Low Cost RNAV, Approach Guidance, Landing Guidance
Transponder	Separation Assurance	Voice Communication	Communication
Glide Slope	Landing Guidance	Navigation Receiver/Processor	Satellite Derived Horizontal and Vertical Navigation; Surface Navigation
		Air-Air Surveillance Processor/Display	Air Derived Separation Assurance (Backup)

to the SAATMS L-band transceiver, thereby relegating the VHF voice channel to a backup function or replacing it completely. The final user option, notably one in a higher class category wishing to fly in controlled SAATMS airspace, is the satellite navigation receiver/processor module. The satellite navigation function will provide the user with 3D CONUS-wide, down-to-the-ground navigation service with considerably greater and more uniform accuracy than that of the VOR/DME system. In addition, the navigation receiver/processor module will provide 4D RNAV capability for flying more direct or multilane parallel routes, in both enroute and terminal areas.

Aircarrier and military users will be fully equipped with Upgraded Third Generation surveillance, communication, and navigation equipment. The integrated SAATMS transceiver will provide the aircarrier with CONUS-wide separation assurance. The satellite navigation receiver/processor option will permit the aircarrier to fly the more direct preferred SAATMS routes in the enroute and terminal areas. The final option listed in Table 3.6-4 is probably of particular benefit to the aircarrier. This is the air-to-air surveillance processor/display module, which provides an air managed backup conflict prediction and resolution (collision avoidance) capability and serves to establish pilot confidence in the ground managed conflict intervention function of the RCC's.

As soon as those satellite/ground facilities of the SAATMS which are required to provide the basic services of the system are available (1982), some of the GA and aircarrier users will begin to equip their aircraft with the modular SAATMS avionics. However, for the SAATMS to be able to provide the system improvements in safety and capacity on a CONUS-wide, timely, and cost-effective basis, it will be necessary to establish regulatory procedures requiring users to have specified avionics equipment on their aircraft before a given date. This method is already in use by the FAA in the present system. These implementation date requirements will be scheduled differently, depending on whether the aircraft is new or used and in which airspace category the user wishes to operate. The design of the SAATMS is based on the concept of having virtually all users at least "cooperative" (to the extent of being equipped with certain minimum avionics), thereby providing the added safety of CONUS-wide, down-to-ground separation assurance to all users in the system. Therefore, typical low class GA users will derive the most unique benefits from the system, and it is desirable to have early implementation requirements for these users. The recommended SAATMS avionics implementation requirements schedule is summarized in Fig. 3.6-1. All but the last two items on this schedule apply to both cooperative and controlled users. For example, it is envisioned that by 1985 (i.e., three years after initial operation of the system), all new aircraft will be required to have surveillance transmitters, thus enabling the SAATMS to provide ground managed separation assurance. The users of these aircraft could continue to use the Third Generation NAV/COM equipment for air-ground-air communication and navigation. Similarly, all used aircraft would be required to carry the surveillance transmitter by 1987.

As indicated in Fig. 3.6-1, the SAATMS digital communication function plus VVOR display should be required on all new aircraft wishing to operate in designated higher density regions by 1988 and for all used aircraft by the end of Phase I (1990).

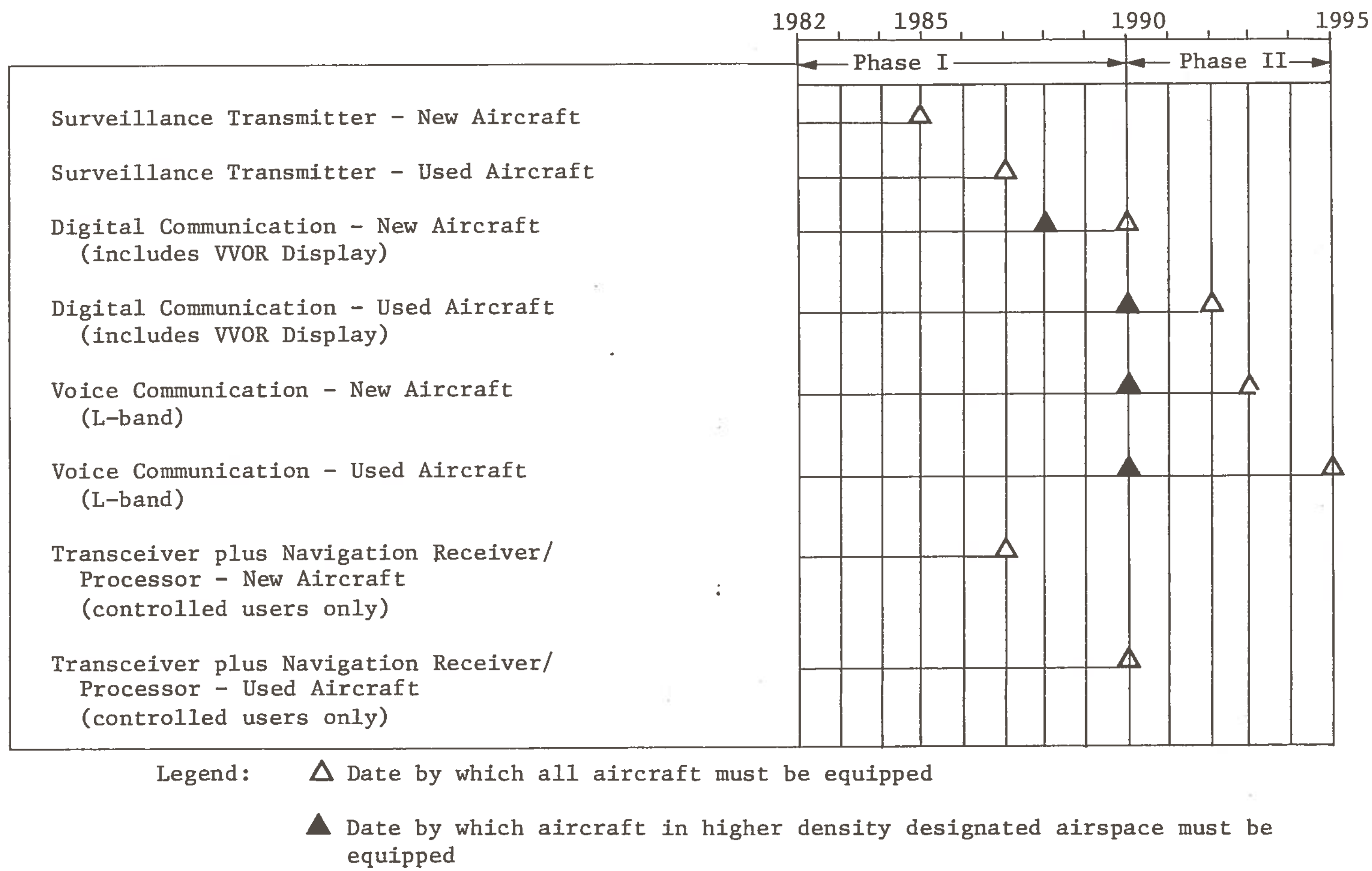

Fig. 3.6-1 SAATMS User Avionics Requirements Schedule

For lower density airspace regions, the legal requirement for this function could be delayed until 1992. It is expected, however, that the majority of GA users will add the digital communication/VVOR function as early as possible, in view of the inherent benefit of the low cost universal RNAV capability.

The legal requirement for the L-band voice communication function, which is more costly because of the higher average power required, might be delayed until Phase II. In view of the significant amount of air-ground voice communication required in the system, users wishing to operate in certain higher density designated airspace will be required to carry the L-band voice equipment by the end of Phase I (see Fig. 3.6-1). Similarly, within five years after the initial operation of the system (1987), all new aircraft of controlled users would be required to carry the SAATMS L-band transceiver, including the more accurate satellite navigation function. All used controlled aircraft would have this requirement imposed by the end of Phase I (1990).

Near the middle of Phase II, it will be possible to begin the decommissioning of the ATCRBS, DABS, and VORTAC sites since the bulk of U.S. aircraft will be equipped with SAATMS surveillance and navigation avionics by that time, and the ATCRBS/DABS will be used primarily for backup and for the unequipped foreign aircraft. Similarly, the VORTAC sites will be used primarily for foreign users and GA users who are still VOR/DME equipped. Decommissioning of the ATCRBS/DABS and VORTAC sites will be completed during Phase II, along with the VHF Remote Communication Air-Ground sites and the ARTCC and TRACON facilities.

To provide an added incentive to the low class GA user for equipping his aircraft with the surveillance transmitter or integrated transceiver during Phase I, an aviation tax rebate policy might be instituted by the federal government. Data obtained from the Department of Transportation (Ref. 6) indicate that, in the future, the GA fleet should be paying a "fair share" of approximately 28 percent of the National Aviation System budget allocation, although the GA fleet is currently paying only 16 percent of the "fair share" value. Based on the projected 1982 GA fleet of 203,000 aircraft (Ref. 2) and the projected 1982 Upgraded Third Generation System O&M costs, the annual "fair share" GA allocation of the O&M expenditure will be approximately \$1800 per user. As a result of the much smaller O&M cost of the SAATMS (Section 1 of this volume), as well as the increasing size of the fleet, the annual GA user aviation tax allocation to the O&M of the system will decrease to approximately \$500 by 1995. This consideration represents one of the primary benefit incentives to the user for transitioning to the SAATMS, namely, the ultimate reduction of the aviation taxes levied on him to support the O&M costs of the National Aviation System. A portion or all of this amount might be deducted from the total annual aviation tax for users initially purchasing the SAATMS avionics equipment.

As a result of the integrated electronics design of the SAATMS airborne L-band transceiver, the acquisition cost of the SAATMS user avionics will ultimately be considerably less than that for equivalent avionics functions of the present or Upgraded Third Generation systems. This consideration represents the other major user cost/benefit incentive for transitioning to the SAATMS.

In summary, transitioning to the SAATMS provides to the General Aviation user the benefits of increased safety and freedom of flight as a result of the CONUS-wide, down-to-the-ground separation assurance and the universal VVOR RNAV service. The aircarrier transition cost/benefits, on the other hand, include shorter, more direct route profiles, increased capacity due to reduced separation standards, and greater safety with lower pilot work load because of the navigation system coverage characteristics, the digital communication, and the automated conflict intervention. These cost/benefits to both General Aviation and aircarrier users will serve to accelerate the process of transition to the SAATMS.

3.7 References

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