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A DESCRIPTION OF THE PHASE I AUTOMATED TERMINAL SERVICES CONCEPT

November 1976

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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
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16. Abstract

Research has been initiated to study the concept of Automated Terminal Services (ATS). Work is being done to: 1) define a Phase I baseline system for airports with operations rates near the threshold of eligibility for a manned control tower and 2) in Phase II, to explore advanced hardware and control concepts (such as Discrete Address Beacon System data link). Potential roles for the Phase I system are:

1. Substitute for new control towers
2. Additional safety at presently uncontrolled airports
3. Shift reliever at manned control towers.

This document describes the Phase I Automated Terminal Services concept in sufficient detail to let analysis, simulation, and flight test efforts proceed. The hardware and software configuration of the system is described along with specific services which generate automatic voice messages to the aircraft operating at an ATS airport. Examples of pilot interaction with the system are presented.

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1. INTRODUCTION

As part of the Future ATC System Concepts program, the Federal Aviation Administration Office of Systems Engineering Management has initiated a project to study the concept of Automated Terminal Services (ATS). The primary emphasis in this work is on possible techniques for providing services to pilots via automated systems at airports.

No pilot directly receives computer derived services or commands in any civil air traffic control (ATC) system today. The primary use of automation has been to handle flight data and generate more effective displays for the human controller. Further refinements in these areas will continue to contribute to the integrity and effectiveness of the ATC system. However, it is clear that considerable gains in productivity might be achievable if automation can be applied to presently manual control activities.

Automation of actual aircraft control and service functions can be viewed as having two broad paths:

1. Manned systems with advanced automation - These concepts deal with systems that supplement the human controller by providing automated management of routine functions and advanced data presentation techniques. The man remains in the decision making loop and is an integral part of the system, but now handles more traffic.

2. Unmanned systems - The concept of providing automated services without a man in the decision making process involves a sharper break with existing ATC systems. Considerable care will be required in designing systems that can effectively operate in an operational environment. However, rapid advances in computer technology now make possible the practical use of total processing power and software techniques once reserved to major research installations.

The Automated Terminal Services project will address both manned and unmanned systems for terminal (airport) environments.

The ATS project consists of two research areas:

1. Phase I: Baseline System - This effort is concerned with defining an unmanned system for use at airports with operations rates that are near the threshold of eligibility for a manned control tower. The system is based on radar surveillance and computer generated voice messages transmitted directly to pilots. Construction of a functional test bed will permit an evaluation of ATS ideas in an environment that is a natural extension of the pilot procedures and advisory services used today at uncontrolled airports. A considerable immediate economic payoff could exist if such systems are found to be feasible.

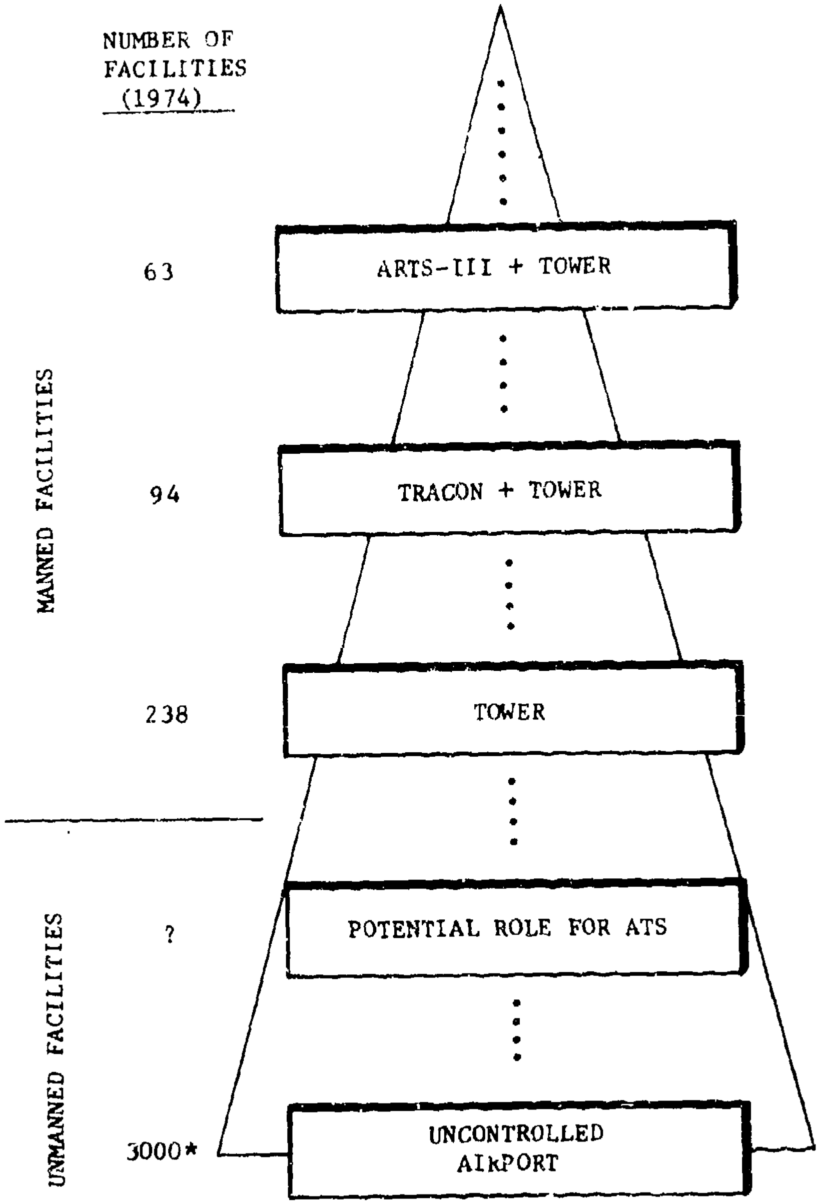
2. Phase II: Advanced Concepts - This portion of the project will explore more advanced techniques for unmanned automated control (e.g., computer issued commands such as vectoring of aircraft) and use of new technology such as the Discrete Address Beacon System (DABS) data link. Test bed facilities and results of the baseline system effort will directly assist in this work. The features developed might be applied across the entire spectrum of terminal facilities.

   Also in this phase of the work, concepts for advanced aids for the air traffic controller will be explored. These ultimately might permit an increase in controller productivity by providing a system that handles routine traffic functions at the terminal.

This document describes only the Phase I baseline ATS system. The following paragraphs will briefly review the potential role for this system.

The spectrum of terminal ATC facilities is shown in Figure 1-1. At present, there is no intermediate step between operating an airport in an uncontrolled mode and installation of a manned control tower. Potential applications of the baseline ATS system are:

1. Substitute for New Control Towers - A primary role would be as a substitute for control towers at those airports just reaching the operation rate threshold for tower installation. As shown in Figure 1-2, there is a considerable economic advantage in using an ATS system when compared with the costs of even a low staff Visual Flight Rules (VFR) control tower.



*IN NATIONAL AIRPORT SYSTEM PLAN

FIGURE 1-1
SPECTRUM OF TERMINAL ATC FACILITIES IN THE NATIONAL AIRSPACE SYSTEM

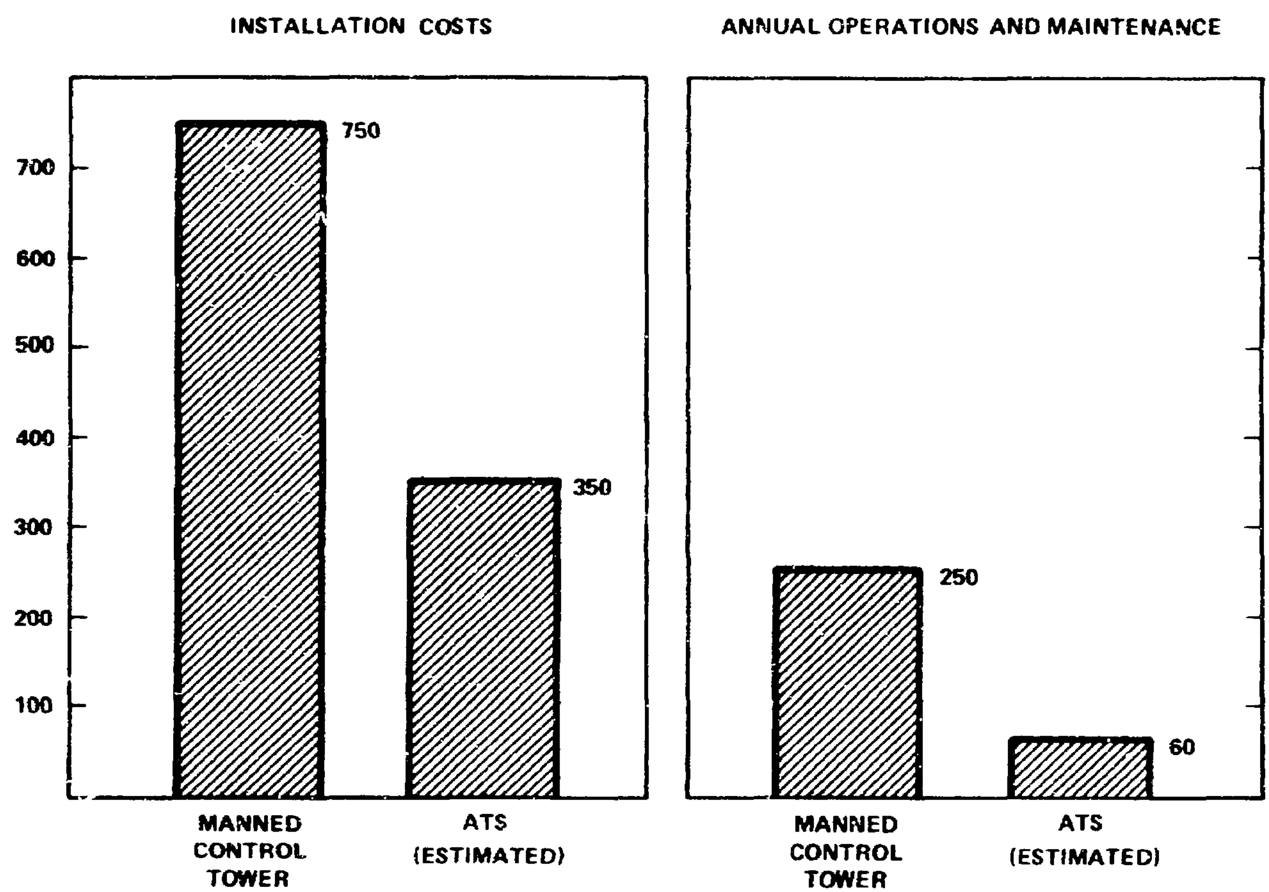


FIGURE 1-2
ATS COST ELEMENTS (THOUSANDS, PER SITE)

It is assumed that as the operations rate at an airport continues to grow, there will be some new level of complexity at which the unmanned system becomes ineffective. A control tower would then be installed. Suppose that the automated system is utilized at each airport until traffic growth causes its voice channel to saturate. The delay in installation of each of the expected new towers between 1976 and 2000 under this scenario could result in a discounted net savings of $53 million dollars [1]. Estimates indicate that even modest delay in the installation of the tower (2-5 years) yields significant potential savings in operations and maintenance costs.

2. Additional Safety at Presently Uncontrolled Airports - Over the period 1964-1972, 54% of all midair collisions occurred at uncontrolled airports resulting in 17% of the total fatalities. Five of the airports where collisions occurred were served by certificated route carriers. A potential role for ATS is to extend service to airports where a manned control tower is not justified but additional safety is desired. None of the presently defined system elements of the FAA separation assurance program (e.g., conflict alert, IPC, BCAS, or even the discontinued ACAS) is effective in the traffic pattern environment.

3. Shift Reliever at Manned Control Towers - Many airports, while requiring a manned control tower during peak hours, may experience periods of lower activity and traffic complexity when the tower still remains open (for example, night or weekend operations). It may be desirable and feasible to install an ATS system for use during these periods and thus reduce the total staff required to operate the facility.

This description will discuss the baseline ATS system in detail. There are two somewhat separable areas that must be addressed to assure that the concept is feasible:

1. Interaction between pilots and an automated system - It was possible to develop a set of simple procedures for interacting with ATS. These procedures require no new avionics, and, in

fact, are natural extensions of present operations. Sections 3 and 4 will emphasize this man-machine coordination. The ATS coordination procedures defined here are felt to be a reasonably effective basis for evolution of the ATS concept. Modifications will be made as necessary during flight tests.

2. ATS services - Once communication between the pilots and ATS has been established, a broad range of services can be proposed. The specific services presently defined have been designed to be natural extensions of existing advisory and traffic management procedures. They are expected to demonstrate that it is feasible to provide services directly to pilots in a completely automated system. These initial services have been selected to provide useful assistance to operations and to cover the most prevalent incidents that impact safety. (They do not include providing pilots with altitude, speed or vectoring instructions for optimizing runway utilization or assuring spacing. For such services, the requirements on avionics equipage, equipment reliability, and pilot participation must be explored further in the advanced concept phase).

However, it must be recognized that the features described are only a first iteration, and are expected to receive improvement and modification during flight testing and continuing system engineering. The services will be revised to "tune the system" to the pilot: the feasibility demonstration effort will include evaluation in normal traffic pattern environments as described in Appendix B.

There is a considerable potential for evolutionary growth in the baseline system as advanced concepts are developed (e.g., advanced control and DABS data link functions). Software and hardware retrofits could be done at particular sites as system developments become available and the needs of the airport change.

The baseline ATS concept defined here has been subjected to preliminary analysis and to a computer simulation that includes a general aviation cockpit simulator. The technical results and pilot reaction have been favorable. A feasibility test bed is being assembled and will soon enter the testing stage (see

Appendix B). The test bed is a functional model of ATS, but does not reflect production equipment. It will be exercised in both a controlled environment at the National Aviation Facilities Experimentation Center (NAFEC) and in a "live" environment at a typical public non-tower airport. System testing and feasibility demonstration will be performed in 1977.

The actual technology of the ATS system is off-the-shelf, with the possible exception of a refined beacon sensor. If the ATS test bed demonstrates the expected pilot acceptance and a level of performance suitable for the intended applications, a prototype basic ATS could be procured with only a short contractor development effort.

This document is organized as follows: Section 2 identifies the elements of the ATS system. Section 3 discusses the basic services concept and flight operations using the system. It briefly identifies the individual services given to the pilot. Section 4 reviews procedures for instrument flight rule (IFR) aircraft that are under control of a manned ATC facility. Section 5 is a detailed description of the services and message phraseology. A typical pilot-oriented example is presented in Section 6. The appendices describe key aspects of the computer software required to implement the system and the test bed activity presently underway.

2. THE AUTOMATED TERMINAL SERVICES SYSTEM

The Automated Terminal Services concept is supported by a relatively inexpensive computer based system located at the airport. It is operated as an essentially unmanned installation, with only minimal inputs from a Fixed Base Operator (FBO) or airport manager at the site.

The ATS system has three major elements:

1. A short range (~15 nmi) beacon radar located at the airport to provide tracking and identity on transponder equipped aircraft.

2. A minicomputer to process this data and make decisions about the traffic situation, and

3. A voice response system (VRS) to generate VHF voice messages based on the results of the computer processing and to record aircraft call signs, supplied by the pilot, for use in the messages.

At selected sites, a digital ground line interface to the responsible ATC facility, along with remoting of the ATC VHF voice frequencies, would be provided. These interfaces support special handling of controlled traffic operating at the airport.

The services and operational procedures supported by the system will be described in detail in subsequent sections. This section reviews the system requirements of the ATS concept: the hardware elements, avionics, frequency and transponder code allocations, and philosophy for the management of failures. The relation of ATS to other Upgraded Third Generation ATC System developments is then briefly reviewed.

2.1 Basic ATS Hardware Configuration

Figure 2-1 is a block diagram of the elements of the ATS system hardware. The ATC facility interfaces will be discussed in Section 2.2. The elements common to all ATS sites are as follows.

2.1.1 Minicomputer

The central processor for the ATS system will be similar in capability to a general purpose minicomputer with a 1 μsec cycle time and medium memory size (e.g., 64K of 16 bit words). It is interfaced to all the other elements at the site. The computer's

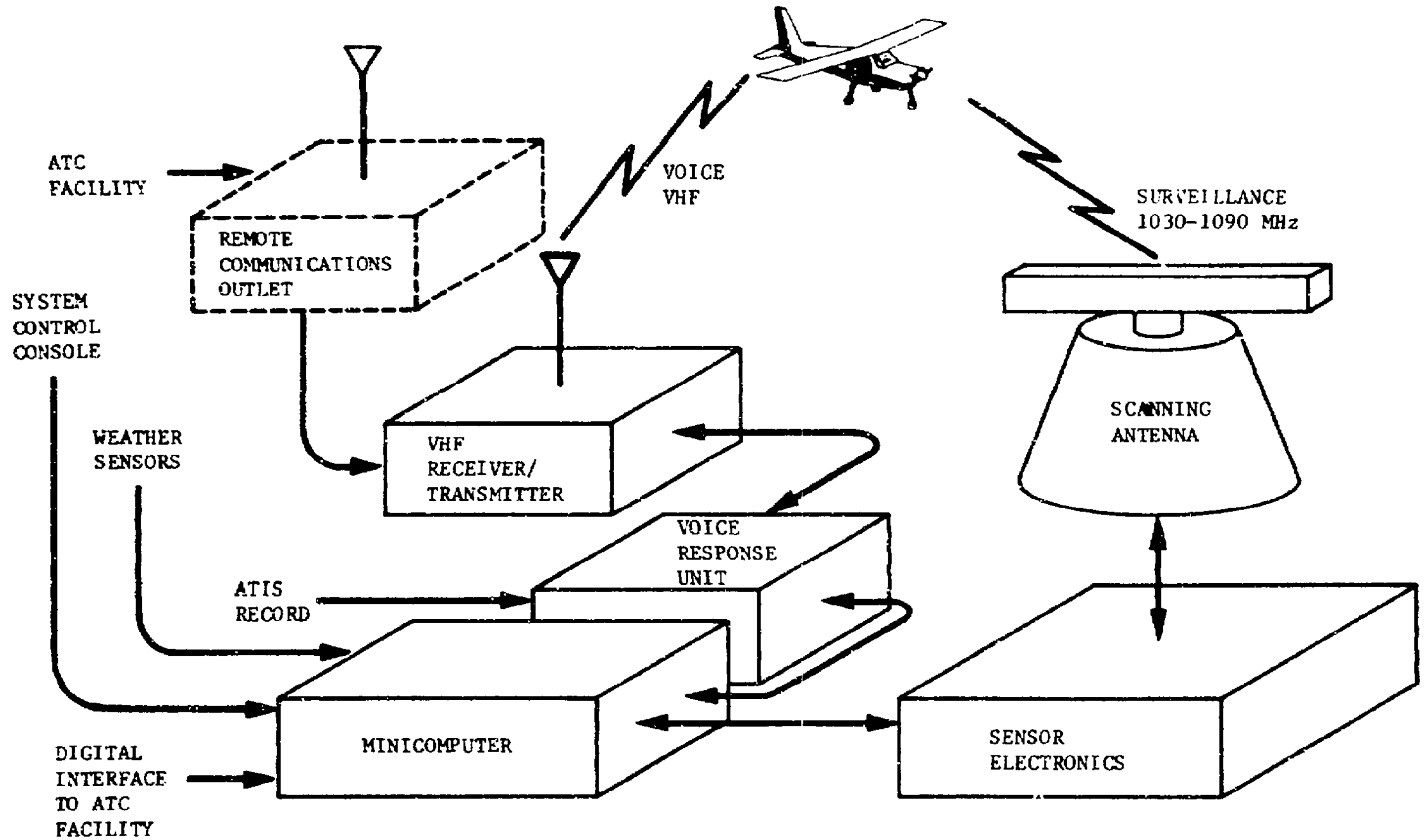


FIGURE 2-1
ELEMENTS FOR AUTOMATED TERMINAL SERVICE

primary functions are to perform radar data processing, execute the ATS algorithms that examine traffic to generate advisory and management messages, and drive the Voice Response System.

2.1.2 Beacon Sensor

ATS tracks all transponder-equipped aircraft using a scanning beacon sensor which is located at the airport. The sensor consists of a drive pedestal which rotates the antenna, a directive beacon antenna, and front end hardware which is functionally similar to the ARTS III BDAS (Beacon Data Acquisition System). This front end digitizes and transfers the radar reply data to the ATS minicomputer. Note that only transponder equipped aircraft can be tracked; no primary or skin-track radar is planned.

Key technical features of the ATS sensor include:

1. The rotating beacon antenna of the sensor is designed to operate effectively in the traffic pattern. Vertical antenna lobing is shaped to reduce multipath from ground reflectors and to provide null-free coverage of high elevation angles (the traffic pattern at some sites will provide targets at 30-45° in elevation). Monopulse azimuth measurement capability provides both high accuracy data and the ability to utilize only those hits that are overlap-free in declaring partially garbled targets.

2. Scan time (period of revolution) is nominally four seconds.

3. Effective range is ∿15 nmi.

4. Both Mode 3 (Identity) and Mode C (Altitude) interrogations are used in a suitable interlace pattern, with a pulse repetition frequency (PRF) of about 400 interrogations per second.

5. Suitable provisions are made for defruiting and deinterleaving in the traffic pattern environment.

6. The ATS concept does not depend on tracking (i.e., estimation of position and velocity) for targets on the ground. However, the sensor will be

designed to acquire transponder replies of aircraft on the airport ramp. This supports the ground "login" process of Section 3.2. (The login process procedurally limits the number of active transponders on the airport surface by requesting pilots to place the transponder in standby until ready for takeoff). If the coverage of the rotating antenna at particular sites is inadequate, a very low power non-directional interrogator at the airport ramp could be used to perform this acquisition function (with no azimuth or range data recovered).

In conjunction with the computer, the beacon sensor provides ATS with a track (identity and estimated position and velocity) on each transponder equipped aircraft in the ATS coverage area.

While a primary search radar might be attractive as part of ATS, several factors have influenced the decision to use secondary radar for fundamental surveillance in the baseline concept: First, developing a reliable primary radar (with high quality tracking of small aircraft that are operating in traffic pattern geometries) would increase cost and complexity of the system. Second, the required ATS identity and intent data exchange (discussed in Section 3) is naturally supported by transponders. Finally, the increasing transponder utilization discussed in Section 2.3, along with techniques for accommodating occasional unequipped aircraft, imply an effective system can be based on beacon alone.

The use of a simple primary radar to permit detection of unequipped intruders in the traffic area might be a useful option for ATS.

2.1.3 Voice Response System (VRS)

The VRS constructs ATS messages from voice segments which have been stored electronically and then transmits the message over a discrete VHF frequency. The type, timing, and content of each message are under computer control and vary with the traffic and service situation at the airport. Present estimates indicate that 200 to 300 total seconds of vocabulary phrase segments are required to support the ATS services.

Since ATS operates unmanned, a procedure is required to provide the computer with call signs to be used in directing messages to individual aircraft (the "login" procedure). As discussed in detail in Section 3.2, one approach is to have the pilot transmit his own call sign over the VHF frequency for recording by ATS.

The VRS system must provide for recording such a voice segment under computer control and retrieving it for use in subsequent messages. The VRS will be able to monitor the presence of another carrier on the channel.

The VRS subsystem includes standard VHF transceivers and appropriate antennas. At some sites there will be a requirement for simultaneous, independent operation on two distinct VHF channels (see Section 2.4).

2.1.4 Weather Sensors

The ATS computer can utilize inputs from local weather sensors to gather data to be used in the generated voice messages. The actual complement of sensors could vary with each installation depending on specific needs.

The most likely candidates include:

1. Barometer - local barometric pressure is required to permit the ATS computer to pressure correct the Mode C transponder altitude code replies to actual altitude (transponders reply with altitude referenced to a standard 29.92" Hg). One way to input the local pressure would be to have the airport operator enter it through the System Control Console, but this is subject to human error and omission. It is preferred that a direct measurement be available for unattended operation.

2. Anemometer and Wind Vane - provide wind speed and direction for inclusion in an ATIS messages. The computer can average and smooth the measurements to provide stable estimates.

3. Ceiling and Visibility - instrument might be provided to measure ceiling and runway visual range (RVR). This would be valuable for IFR approach operations to airports some distance from the nearest facility providing a full National Weather Service sequence report (SA report).

4. Aviation - Automated Weather Observation System (AV-AWOS) - the Flight Service Station modernization program includes the concept of an automated system that would acquire a full spectrum of weather observations and generate a complete SA report to be replaced on the National Weather Service data circuit [2].

It would be possible and advantageous at a site where ATS and AV-AWOS were colocated to interface the two systems and utilize this data for ATS messages.

2.1.5 System Control Console

Presently, at uncontrolled airports, certain tasks are performed by the designated Fixed Base Operator (FBO), airport manager, air carrier "ramp-mike" operator, or on-site FSS. Typical responsibilities include designation of the active runway, declaring the airport closed, announcing special conditions on UNICOM, etc. These tasks are still present at an ATS airport. However, the concept does not require a full time attendant to be available.

The ATS system will provide a simple console convenient to the designated airport operator. Capabilities would include:

1. Monitoring of the ATS VHF frequencies.

2. Ability to input and record voice information for inclusion in the ATIS messages, or if necessary, to transmit directly on the frequencies.

3. Selection of operating conditions such as active runway, touch and go status, ATS shut down for maintenance, close airport, etc. This might be accomplished through simple keyboard entries.

2.1.6 Field Installation

The ATS system is intended to be located at the airport. Figure 2-2 is an artist's conception of a transportable ATS field shelter. This would be used at airports without adequate existing buildings to house the system. Only modest site preparation is required and the total installation is compatible with the typical real estate constraints of the ATS class of airports.

2.2 Additional Equipment for ATC Facility Interface

ATS with the basic hardware elements discussed above can accommodate both Visual Flight Rule (VFR) and Instrument Flight Rule (IFR) traffic. However, at sites with significant IFR traffic, further equipment to interface with the responsible ATC facility can improve capacity and convenience of IFR operations. Operations with this equipment will be discussed in Section 4.

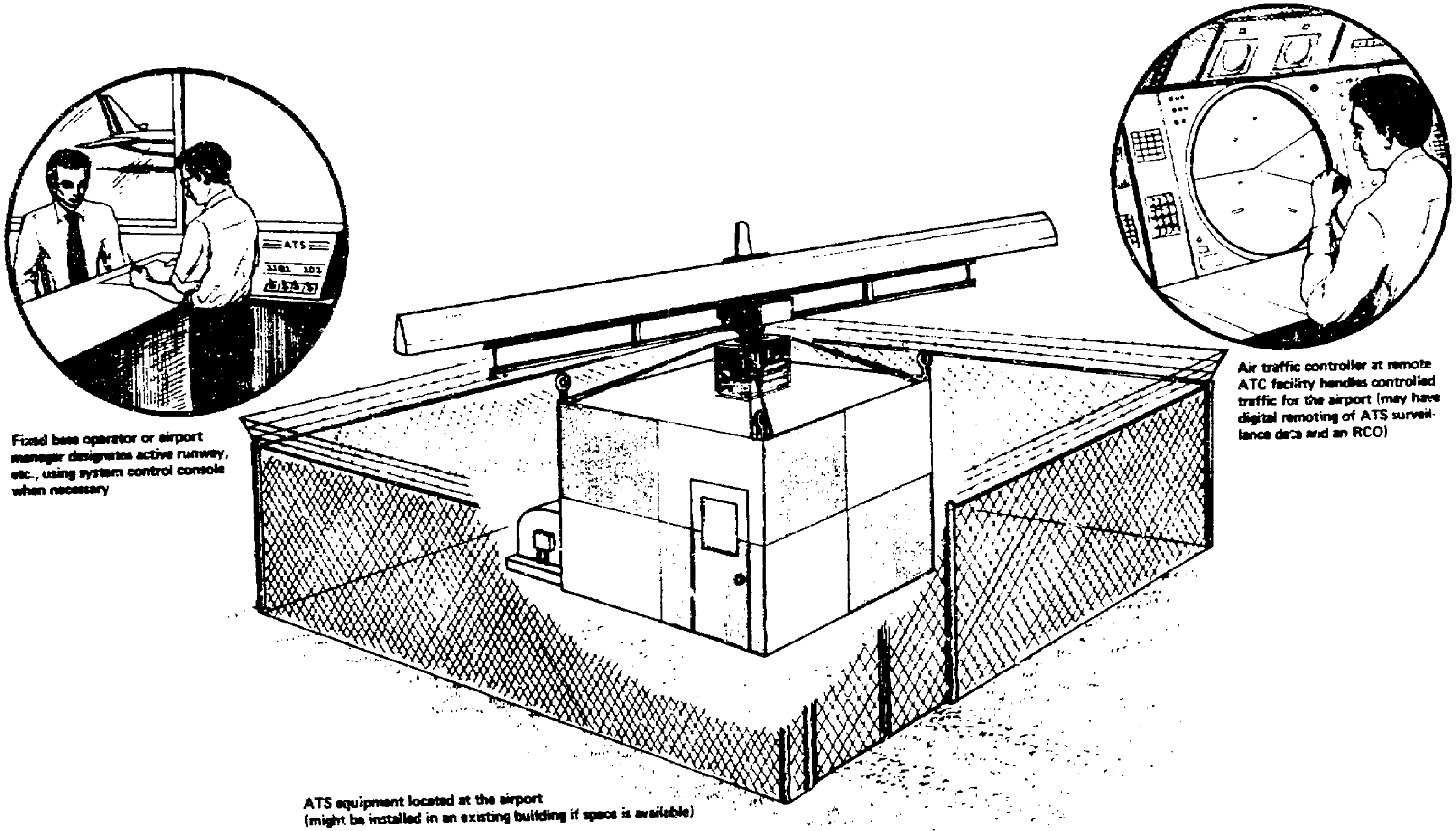


FIGURE 2-2
ARTIST'S CONCEPTION OF
AN AUTOMATED TERMINAL SERVICES SITE

2.2.1 Remote Communications Outlet (RCO)*

At uncontrolled airports, the radio coverage of the responsible ATC facility (e.g., approach control at an adjacent hub or a low altitude en route sector) may not extend to the surface. A Remote Communications Outlet is a transceiver at the airport which is remoted to the facility via ground telephone lines. The ATC controller can continue to communicate with the aircraft throughout approach, departure, and taxi operations. For ATS services, the features that the RCO would support are:

1. Remoting of the standard ATC approach/departure frequencies for reliable coverage.

2. Remoting of the ATS frequencies to allow the controller to monitor the voice messages generated by ATS and, when desired, to preempt the channel himself.

This capability could be integrated with the VRS transceiver subsystem.

2.2.2 Digital ATS to ATC Facility Data Link

Provisions will be made at selected sites to provide a digital ground-line data link between the ATS system and the responsible ATC facility. This would be a narrow band link (e.g., 2400 bps) perhaps supported by leased telephone lines. Basic capability of the link would be:

1. Remoting of surveillance data to the facility to permit the controller to use ATS surveillance down to near the airport surface. Many uncontrolled airports presently are well beneath the coverage floor of the responsible facility.

2. Digital interaction between the ATS and facility computers to permit automatic handoff and flight plan data exchange.

---

* We will adopt the terminology "RCO" to refer to the ATS voice channel remoting described here. In current ATC practice, there are several similar remoting systems used: Remote Communications Outlet (RCO) associated with Flight Service Stations, Remote Transmitter/Receiver (RTR) associated with terminals, and Remote Communications Air/Ground (RCAG) units associated with ARTCCs.

Detailed functions of the link will be described in Section 4.

2.3 Avionics

The ATS concept involves no new avionics equipment and, in fact, a majority of the general aviation fleet is already equipped. Two items of avionics are used.

First, aircraft operating at an ATS airport are expected to carry an Air Traffic Control Radar Beacon System (ATCRBS) 4096-code transponder* and preferably an encoder for Mode C altitude data. However, in view of the limited number of aircraft equipped with altitude encoders, the system is designed for non-altitude reporting aircraft. Since transponder equipage, although high, is not complete, occasional non-transponder aircraft can be handled as well. This is discussed in Section 3.4. Second, the aircraft must be equipped with two-way VHF aeronautical radio. This equipment is carried by essentially 100% of the fleet.

It will be necessary for a large percentage (e.g., 80-90%) of the airborne population at an ATS airport to be equipped with transponders for the system to operate as described in this document.** Several broad trends indicate that this equipage is not an unreasonable assumption for even the near future. First, present equipage and rate of growth in equipage is favorable. In 1974, essentially 100% of public (air carrier) and federal aircraft (including military) were transponder equipped. General aviation was estimated at 70%. The more active aircraft in the fleet are usually better equipped, so the effective airborne ratio may in fact be higher.

Second, the Federal Aviation Administration has many interrelated programs which encourage or require transponder equipage. The current terminal and en route automation facilities utilize transponders nationwide. Transponders are today mandatory in certain regions of controlled airspace (the Positive Control Area and in Terminal Control Areas). As the result of a detailed review of separation assurance in the national

* Or a Discrete Address Beacon System (DABS) transponder when that system is available for use.

** Engineering estimates. The impact of unequipped aircraft will be further explored in the feasibility test bed.

airspace system, the Administrator announced in February 1976 a broad program to increase protection against midair collision [3]. This included several elements directly related to transponder use: implementation of conflict alert automation in ATC facilities, use of Beacon Collision Avoidance System (BCAS), evolution to the DABS-based Intermittent Positive Control System [4] in high density airspace, etc. To support this program, the FAA intends "to initiate rulemaking proposals to extend the requirements for mandatory carriage of beacon transponders and reporting altimeters by aircraft operating in (selected) controlled airspace" [3]. ATS takes advantage of the transponders required by these existing programs rather than imposing a new requirement.

Third, the cost of transponders has decreased significantly since their original introduction. A pilot, already strongly encouraged to become equipped by these other programs and requirements, may find the services made available by ATS sufficiently useful to warrant a purchase.

The ATS system will provide service to the general aviation pilot who might receive no other directly visible benefit from purchasing a transponder that is mandatory for entering controlled airspace used by public air transportation.

2.4 Frequency Allocation and Transponder Codes

An ATS airport is assigned one or two discrete VHF frequencies on an interference free basis. They are functionally assigned as:

1. ATS Login Frequency - This frequency is used to perform the VFR login process discussed in Section 3 and to provide messages to the pilot similar to the Automatic Terminal Information Service (ATIS) at larger airports today. Upon completion of the login process, pilots transition from the login frequency to the ATS tactical frequency.

2. ATS Tactical Frequency - This frequency provides the bulk of the ATS services and is monitored by the pilot after completion of the login process.

At lower operation rate airports, both functions could be combined on the same channel (see Section 5).

The problems of allocating frequencies to ATS are eased with respect to other facilities since only low-altitude interference free service is required. The geographic separation required of co-channel stations would be similar to the "smallest" inter-station spacing now used: that for precision radar approach facilities [5]. The assignment of ATS frequencies would presumably continue the present attempt to use "whole number" 100 KHz and 50 KHz frequencies as much as possible for low-altitude general aviation applications, while assigning 25 KHz frequencies to the high altitude route structure. (It might be noted that where ATS is replacing a tower otherwise scheduled for installation or is being used in a shift reliever application, the frequencies used would be those that had been already allocated for tower service).

The concept also requires that a set of transponder codes be allocated for ATS use. This allocation must be used exclusively for the ATS system within the ∿15 nmi coverage area, but many non-overlapping ATS sites could reuse the same code set (aircraft on the same codes within line of sight but beyond 15 nmi would not be a problem to ATS). Table 3-1 in the next section is a hypothetical example of such an allocation with functional assignment of the codes (to be discussed in more detail in Sections 3 and 4). The code set could be allocated within a single 64-code subset, but this is not critical. Allocation might be different in each Air Route Traffic Control center to be compatible with the National Beacon Code Allocation Plan [6] but a standard national assignment of at least the special intent codes is preferred for pilot convenience (see Section 3.1.2).

2.5 Failure Mode Operations

The baseline Automated Terminal Services system is initially addressed to airports without critical National Airspace System requirements for maintaining capacity and traffic flow. These airports have modest operations rates and low levels of IFR traffic. Furthermore, baseline ATS is an advisory service to pilots rather than a control function. Thus, it is not critical that ATS meet aggressive equipment availability and reliability goals in order to serve its purpose.

The philosophy for management of failure modes in ATS is:

1. Good engineering practice will be applied to achieve adequate reliability of the total system. The most demanding requirements for reliability are expected to result from maintenance cost considerations rather than operations.

2. The ATS system will have sufficient self monitoring capability to fail safe. This will consist of clearly terminating services. ATS will then generate a periodic message on the ATS frequency (or frequencies) to announce the failed status of the system.

3. Operations at an ATS airport during failure conditions revert to normal uncontrolled airport procedures. The ATS discrete VHF frequency will be used instead of UNICOM for the normal pilot self-announcing of pattern position.

At certain airports (e.g., those which are reliever airports for high density terminals) a requirement may exist for a high availability system. Special hardware versions using more redundancy and fault tolerant techniques could be provided. The advanced concept ATS systems mentioned in Section 1 (which would provide more critical control services) will require high reliability implementation.

2.6 Relation to Other ATC System Developments

The ATS system provides a new option in terminal ATC service. It requires no new avionics. Only minor modifications to the hardware and software of the responsible ATC facility are needed to support the RCO and digital interfaces. For the standalone configuration, the system is totally self contained.

While not requiring the availability of other major new elements of the Upgraded Third Generation ATC E&D program [7], ATS is compatible with and can take advantage of those developments. Particular items include:

1. <u>Discrete Address Beacon System</u> (DABS) - This system provides high integrity surveillance, identity, and data link capability. By using a DABS mode sensor, the ATS system can take advantage of these capabilities (an ATCRBS-only ATS site would continue to service DABS aircraft since their transponders will respond to ATCRBS interrogations).

Aircraft equipped for DABS data link operation can be specially serviced by the ATS site (e.g., clearance delivery to IFR departure aircraft, etc). This also opens up the possibility of more aggressive control automation in future ATS developments.

2. <u>Intermittent Positive Control</u> (IPC) - The IPC cockpit display for collision avoidance and proximity warning information can be driven by a DABS-equipped ATS site using a variant of the special ATS traffic pattern threat detection logic. This would provide high integrity communication to the pilot for the most critical ATS threat detection message [4].

Various approaches exist for coordinating the transfer of service between ATS and a "surrounding" IPC area serviced by a standard DABS sensor.

3. <u>Beacon Collision Avoidance System</u> (BCAS) - The BCAS system also relies on ATC transponder equipage. BCAS is planned to have ground commanded threat detection desensitization and inhibit logic for use in terminal environments. The DABS-equipped ATS site could also command these functions [8].

3. OPERATIONS AT AN ATS AIRPORT

The automation system described in Section 2 is designed to provide services directly to the pilots operating at an ATS airport. Basic ATS is planned as an advisory and management service based on aircraft adherence to standard procedures without actual "control" of aircraft. It is a natural extension of procedural uncontrolled airport operations where pilots, in the absence of a controller, follow a prescribed pattern and announce their own pattern position over UNICOM or other available VHF frequencies [9].

This system can include a digital ground line and a Remote Communications Outlet (RCO) connected to the responsible ATC facility. This permits special techniques for operations with controlled traffic (the standalone ATS also provides for IFR traffic). IFR operations will be described in Section 4.

For the baseline ATS concept described in this document, an evolutionary approach was taken: services were designed to enhance safety without becoming operationally difficult to implement in an unmanned system. The advanced concept work will explore more aggressive control concepts starting from a base of unmanned service experience, achieved in the baseline ATS test program.

Basic ATS is an advisory service in that, for example, it advises aircraft about airport conditions and runway in use (ATIS-like messages), possible conflicts, traffic at pattern entry, landing sequence, position of IFR aircraft not using the standard pattern, and the position of uncooperative aircraft (i.e., those that have not made their intentions known to the ATS computer). It is a management service in that, for example, it warns aircraft which are straying from the pattern, requests aircraft to extend their downwind leg to make room for departures, and temporarily suspends touch-and-go's and other forms of landing practice if the traffic pattern becomes too congested.

This section will provide the background for basic ATS operations, describe the "login" process for establishing pilot-ATS contact, briefly review the services, and identify special procedures for partially equipped aircraft.

3.1 Basic ATS Operations

The ATS concept has been designed to provide a familiar operating environment for the pilot. Basic to this ATS environment are VHF service frequencies to be monitored by all pilots in the standard traffic pattern and a set of transponder codes which have special functional meanings.

The pilot's view of ATS is simple:

1. The pilot tunes to the appropriate ATS login channel - a standard VHF frequency.

2. He performs the "login" process described in Section 3.2 which is very similar to establishing normal contact with ATC.

3. Once "logged-in", the pilot need only monitor the tactical channel in a manner similar to use of the ATC tower frequency at a controlled airport. The ATS system will provide information specific to the pilot (via messages which include his call sign) or general information on traffic operations important to all pilots. The pilot does not acknowledge transmissions and normally does not transmit on the channel frequency during operations. All messages are in near standard ATC phraseology and should be readily understandable by the pilot.

Aircraft continue to operate in the normal manner, and the pilot remains responsible for separation as at a conventional uncontrolled airport today. However, the pilot now has the assistance of the ATS service messages.

Services will be summarized in Section 3.3 and are suggested by Figure 3-1. There are two key points about the pilot's use of the automated service messages. First, the messages are generated by computer logic that takes into account the traffic situation, rules of the traffic pattern, and the normal intent of the aircraft. However, the pilot need not be aware of the details of the logic used by the computer to issue a message; only that the message is appropriate to his current status and useful in conducting safe operations. Second, the rate of message delivery is not large. In fact, if only standard traffic pattern operations are occurring, only a few sequencing aid messages will be routinely generated.

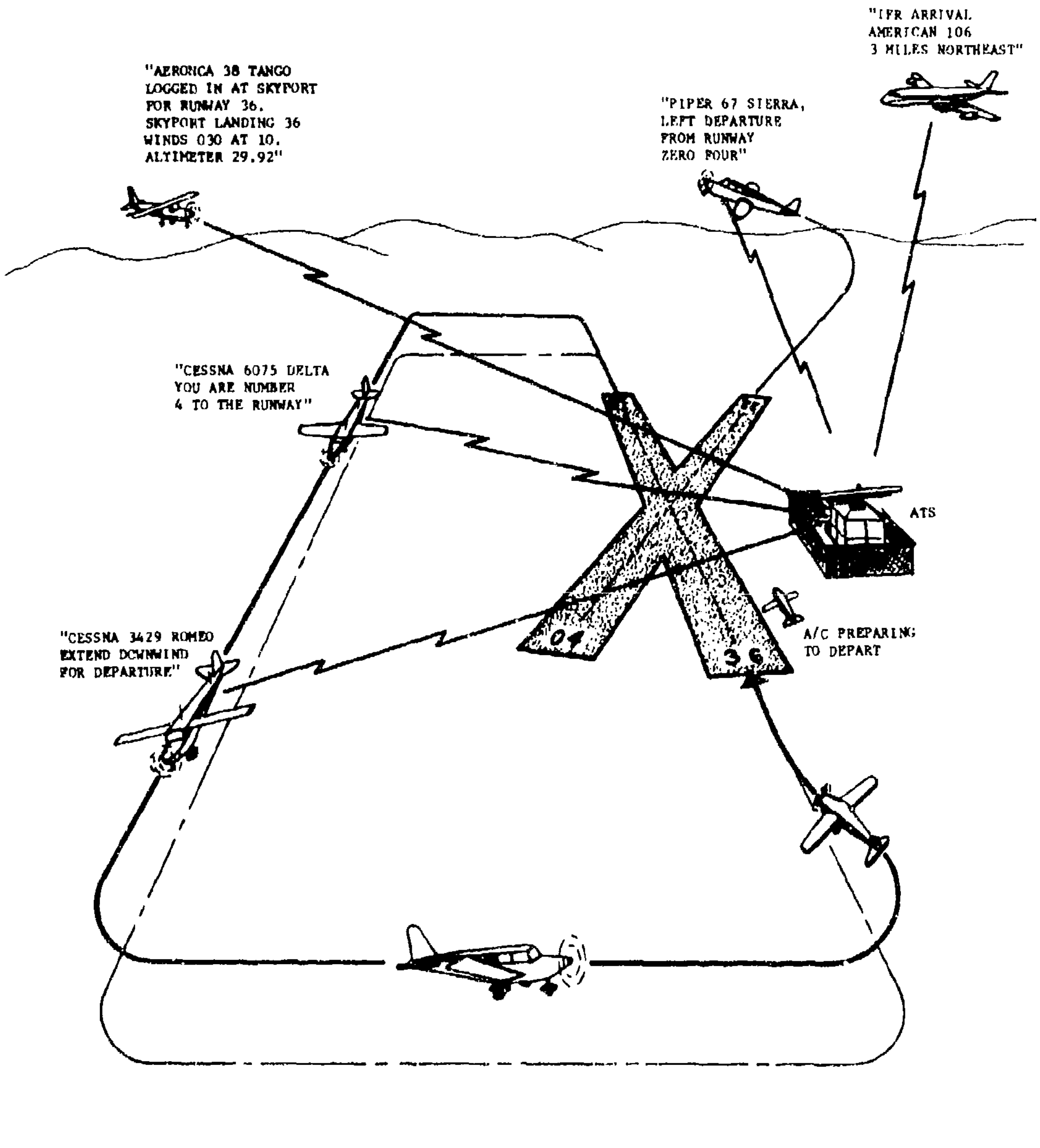


FIGURE 3-1
AUTOMATED TERMINAL SERVICES

The ATS advisory functions complement normal traffic pattern procedures in two primary ways:

1. By issuing messages (such as calling downwind traffic to entering aircraft) that assist in maintaining traffic awareness.

2. By providing special messages about exceptions (such as threat warnings).

The ATS management functions provide more strategic messages to encourage orderly traffic pattern operations.

3.1.1 The Standard Traffic Pattern

The ATS system uses the traffic areas shown in Figure 3-2. The primary regions are:

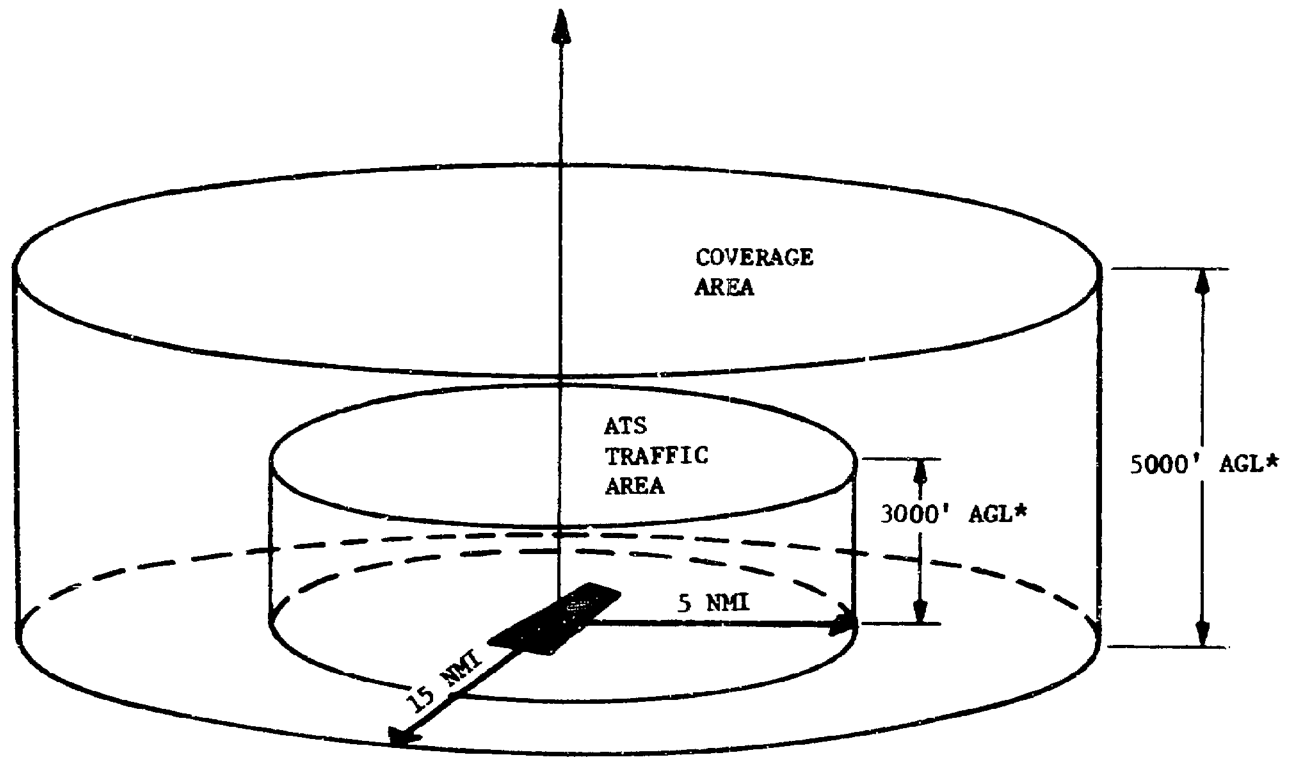
1. Coverage Area - ATS tracks all equipped aircraft in the coverage area and can provide service to any equipped aircraft that requests it. The login process of Section 3.2 is used by the pilot to request service.

2. ATS Traffic Area - This area is reserved to the ATS airport and all equipped aircraft are required to complete login prior to entry. Full services are provided, and all VFR aircraft are expected to follow the nominal traffic pattern when operating to the primary runway (an IFR approach which terminates in a circle-to-land phase is accommodated, even if the circling maneuver produces a nonstandard pattern).

The nature of the services that can be provided in each area will be discussed further in Section 3.4.

Uncontrolled airports operate with a single primary active runway, and this is continued in ATS. Provision is made for aircraft to execute practice operations to a crossing runway, with special service messages to handle this situation.

All VFR aircraft operating at an ATS airport are expected to conform to a standard traffic pattern as recommended by the FAA in Advisory Circular #90-66 [10] and as further discussed below:



*AGL - ABOVE GROUND LEVEL

FIGURE 3-2
ATS SERVICE REGIONS

1. Aircraft entering the traffic pattern at an ATS airport should avoid the ATS traffic area until they have descended to traffic pattern altitude and are established on the entry leg.

2. Arriving aircraft should be at traffic pattern altitude before entering the standard traffic pattern, using a 45 degree angle to the downwind leg, abeam the midpoint of the runway. This will initially be the only form of entry permitted, although the ATS computer logic can be made to accommodate other approaches (e.g., straight-in). A nonstandard VFR entry will result in an alert message (see Section 5.6.1).

3. Aircraft should observe a 1000 foot AGL traffic pattern altitude.

4. The traffic pattern altitude should be maintained until abeam the approach end of the landing runway, on downwind leg.

5. The downwind leg should be extended far enough to assure a final approach leg of at least 1/4 mile.

6. Landing and takeoff should be accomplished on the designated ATS active runway (which will usually be most nearly aligned into the wind). However, if another runway is used, pilots using such other runways should avoid the flow of traffic to the ATS active runway and declare their intentions as discussed in Section 3.2.5.

7. Aircraft on takeoff or go-around should continue straight ahead until beyond the departure end of the runway: aircraft remaining in the traffic pattern should not commence a turn to the crosswind leg until within 300 feet of traffic pattern altitude, ensuring that the downwind leg will be entered at traffic pattern altitude. Aircraft departing the traffic pattern should continue straight out or exit with a 45° left turn (right turn for right traffic pattern) after reaching traffic pattern altitude.

8. Aircraft should not be operated in the traffic pattern at speeds of more than 156 knots (180 mph) if reciprocating engine powered, or 200 knots (230 mph) if turbine powered.

Figures 3-3 and 3-4 illustrate a standard left and right traffic pattern. The designated ATS active runway and traffic direction will be announced via the ATIS message.

The traffic pattern provides the same assistance to pilot self-management at an ATS airport as it does at an uncontrolled field. A key point is that while good conformance to the pattern is desired for safety, the pilot does not need to use special care or procedures to accommodate the ATS system.

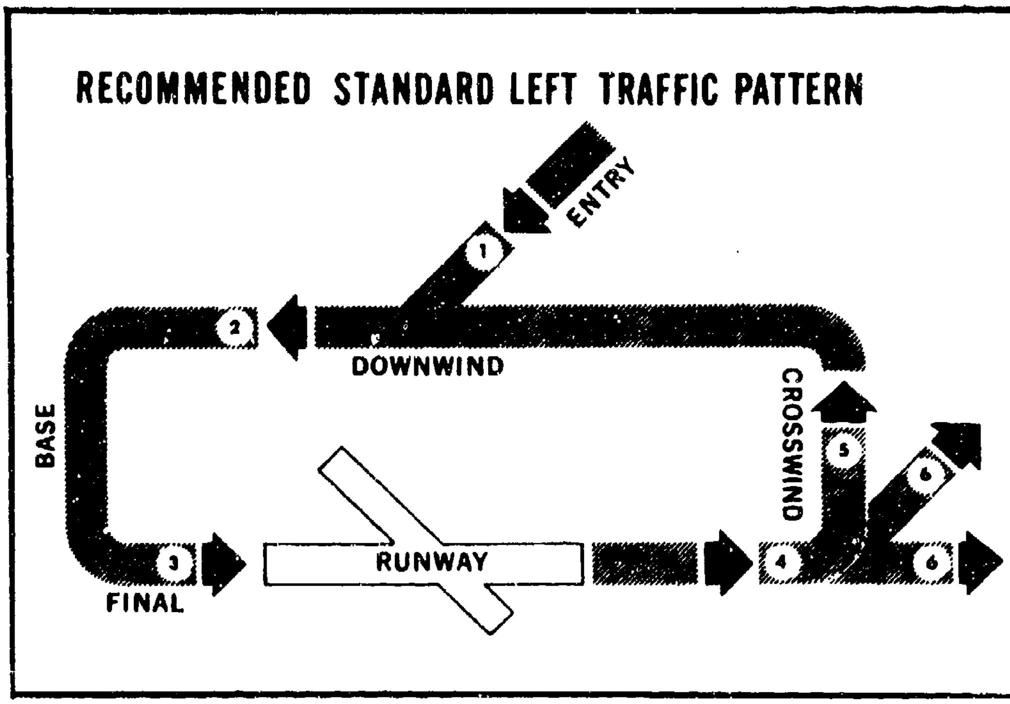
Ground operations at an ATS airport are performed under normal uncontrolled airport rules. The pilot retains responsibility for "clearing the airspace" (i.e., scanning the approach areas for possible landing traffic) prior to taking the active runway for takeoff.

3.1.2 Transponder Code Set

The ATS system at any given site has allocated to it a set of transponder codes. These codes are used independently of any other ATC beacon code assignments being made in the surrounding airspace. As discussed in 2.4, the allocation might be a contiguous block of codes but a non-contiguous allocation would be acceptable. Table 3-1 is a hypothetical assignment of codes to their functional ATS uses. It will be used for all examples in this document.

The primary code groups and their functions are:

1. Login or Intent Codes - These codes are used by the pilot to initiate the login process (see Section 3.2). The primary login code, VFR General Login Code, indicates to ATS that the aircraft wishes to operate on the normal active runway. One of the Alternate Runway Codes is used to indicate that the pilot will use an alternate runway (there would be one code per runway end; here we are allowing for three runways and thus six codes). When used after an aircraft is already logged, the alternate runway codes indicate a change in intent (see Section 3.2.5).



1 Enter pattern in level flight, abeam the midpoint of the runway, at pattern altitude.

2 Maintain pattern altitude until abeam approach end of the landing runway, on downwind leg.

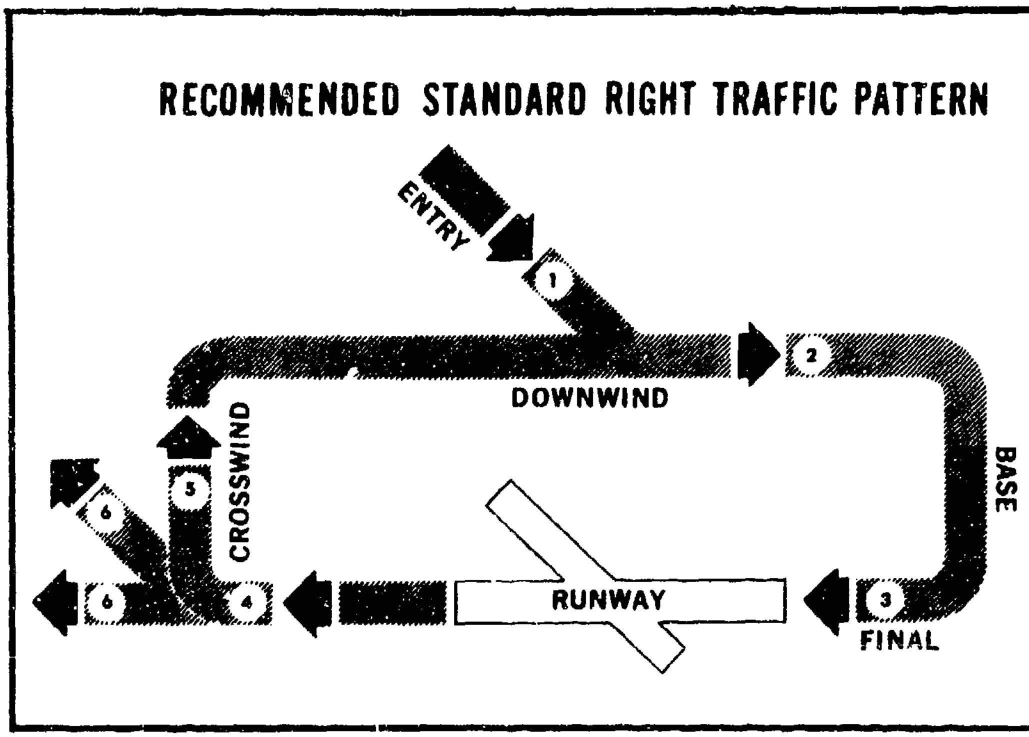
3 Complete turn to final at least 1/4 mile from runway.

4 Continue straight ahead until beyond departure end of runway.

5 If remaining in the traffic pattern, commence turn to crosswind leg beyond the departure end of the runway, within 300 feet of pattern altitude.

6 If departing the traffic pattern, continue straight out, or exit with a 45° left turn beyond the departure end of the runway, after reaching pattern altitude.

FIGURE 3-3
RECOMMENDED STANDARD LEFT TRAFFIC PATTERN



1 Enter pattern in level flight, abeam the midpoint of the runway, at pattern altitude.

2 Maintain pattern altitude until abeam approach end of the landing runway, on downwind leg.

3 Complete turn to final at least 1/4 mile from runway.

4 Continue straight ahead until beyond departure end of runway.

5 If remaining in the traffic pattern, commence turn to crosswind leg beyond the departure end of the runway, within 300 feet of pattern altitude.

6 If departing the traffic pattern, continue straight out, or exit with a 45° right turn beyond the departure end of the runway, upon reaching pattern altitude.

FIGURE 3-4
RECOMMENDED STANDARD RIGHT TRAFFIC PATTERN

TABLE 3-1

DISCRETE TRANSPONDER CODE SET FOR ATS

CODE*	USE
1501	Restart Login Code
1502	VFR General Login Code
1503 1504 1505 1506 1507 1510	Alternate Runway Codes
1511 . . . 1524	IFR Departure Codes IFR Arrival Codes
1525 . . . 1562	Unique Codes for Logged-In Aircraft
1563 . . 1566	IFR Practice Approach
1576	Message Repeat
1577	Position Request
7600	Radio Failure
7700	Emergency

* This table includes specific codes only as a hypothetical example allocation for ATS service. An actual allocation compatible with the National Beacon Code Allocation Plan [6] would be developed for field use. The general use of the codes would remain the same with any allocation (even one using non-contiguous assignments).

For temporary test bed use at National Aviation Facilities Experimental Center, Atlantic City, New Jersey, the 1500 block (1500-1577) has actually been assigned by FAA Air Traffic Service. This applies only for the duration of experimental test flights (1976-1977).

2. Discrete Codes for Logged-In Aircraft - A logged-in VFR aircraft is directed to squawk a discrete code that will be unique to that aircraft for the duration of its flight in the ATS coverage area. The code is assigned by the ATS computer from this pool of discrete codes. When an aircraft leaves the ATS system, its code is available for reuse.

3. IFR Codes - The arrival group of codes is assigned by the ATC approach controller to aircraft making an IFR approach to the ATS airport. The codes are grouped so that a small number of codes are associated with each published instrument approach. ATC will assign the codes to approaching IFR aircraft such that they are unique (see Section 4.3.2). There is a special process for handling departing IFR aircraft (see Section 4.3.1). These codes are not utilized when a digital interface between the ATC facility and ATS exists (see Section 4.2).

4. IFR Practice Approach - These codes are used for aircraft making practice approaches in contact with ATS (see Section 4.6).

5. Message Repeat - When a logged-in aircraft transitions to this code, ATS will repeat the most recent message involving this aircraft or intended for the traffic pattern at large, as appropriate (see Section 5.7.2). The aircraft would transition back to its unique code.

6. Position Request - Temporarily squawking this code will cause a position fix message to be spoken (see Section 5.7.1).

The pool of unique codes for logged-in aircraft must be large enough for the maximum number of aircraft simultaneously in the system (perhaps 30 aircraft during busy hour traffic).

Two points about the frequencies and codes:

1. The pilot needs to acquire from his charts or the Airman's Information Manual (AIM) at most one frequency and a few special access codes (e.g., Login Code) for the airport. All other code or frequency changes are directed by ATS or ATC. He is no more aware of the structure of the functional allocation in Table 3-1 than an IFR pilot is aware of the frequency assignments for en route sectors - they are seen as simply one at a time frequency changes as the flight progresses.

2. The standard emergency (7700) and radio failure (7600) codes are always recognized by ATS for special treatment (see Section 5.4.1).

3.2 Login

The purpose of the "login" procedure is to establish communication between the pilot and the ATS system. The login procedure:

1. Confirms that the pilot intends to cooperate with ATS while operating at the airport and that he is monitoring the proper VHF frequency.

2. Provides the computer with a voice identification (ID) or call sign to use in generated messages.

3. Assigns the aircraft a unique discrete transponder code to aid the ATS system in tracking and maintaining identity via the surveillance system.

Pilots are requested to log into the system before taxiing onto the runway if departing from an ATS airport or before entering the ATS traffic area (5 mile radius) if inbound to the airport. However, the pilot is able to initiate a login procedure at any time.

The ATS concept does not include a special human controller to enter the aircraft identification into the computer by keyboard or other means (such as was done during the Knoxville Voice Advisory System experiments [11]). Instead, the pilot himself provides the identification using the techniques described in the next several paragraphs. In the special case of IFR traffic at a site with a digital ground line to the ATC facility, the identification is provided by computer to computer communication (see Section 4.2).

3.2.1 Overview of Login Options

Two types of login procedures have been suggested. They are noted here and described further in the next sections. The first option requires the pilot to transmit his aircraft identification (ID) over the airport's login frequency so that the ATS computer can record the information for later use (the login channel may in fact be combined with the tactical channel at some airports). The basic sequence starts with the pilot tuned to the airport's login frequency and squawking* the published airport login code appropriate to the runway to be used (see Section 3.2.5). The computer "sees" the aircraft target with the special code and requests the aircraft ID from the pilot. The pilot responds by transmitting on the login frequency a brief, 3-5 second description of the aircraft. The description could include color, aircraft type, and tail number (e.g., "Red and White Cherokee 35 Tango"). This ID is recorded by ATS and used in subsequent communications. The computer then assigns the pilot a discrete transponder code from a list of available codes associated with ATS. The process is then complete and the pilot, at computer requests, changes frequency and monitors the tactical message channel.

The second option is somewhat shorter and is based on using the assigned transponder code as the aircraft ID. As in the recorded ID option, the pilot tunes to the login frequency and squawks the published aircraft login code. The computer then assigns the discrete transponder code to the aircraft. All subsequent communications use that code to identify the aircraft.

The first option (computer records pilot ID) is preferable from a human factors viewpoint since the form of ID that will be

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* In aviation phraseology, to "squawk a transponder code" means to set that code into the transponder so that it will be automatically sent to the ground site on subsequent radar interrogations. An ATC controller commands pilot operation of the transponder using phrases such as: "SQUAWK ONE FIVE ZERO THREE", "SQUAWK STANDBY", "SQUAWK IDENT", etc.

used in the service messages (aircraft type and "tail number") is the same as the form of call sign used in ordinary ATC operations. Also, the descriptive information ("Red and White Cherokee") may help pilots identify traffic pointed out by the computer. However, two factors may influence use of the recorded ID:

1. In high traffic periods where voice channel utilization could become an issue, the selection of the second option (identification by transponder code) may be desirable, since it is significantly shorter than option 1 in the amount of time required to complete the login procedure. It also produces a shorter aircraft ID. The latter is important since the aircraft ID is repeated in most of the ATS messages and directly adds to channel loading.

2. Recording pilot IDs from an operational VHF channel (given the quality of aircraft transmitters, electronic noise, gain control, etc.) may not be feasible. However a retry capability in the login process does exist for occasional faulty recordings.

The final choice will depend on flight test results. Throughout the remainder of this document it will be assumed that the recorded ID option is used. The basic operation of each login option is described in the next two sections, each followed by a summary chart of the pilot-computer responses. Certain logic for retry and recovery from errors is described in Section 3.2.6.

Examples of messages in the remainder of this document use "Manassas Airport" as the airport name. This is historically due to system studies [12] based on this general aviation airport, Harry P. Davis Field, located in Manassas, Virginia (identifier W10). Underlined portions of the messages indicate items which are variable under computer control and would change according to environmental factors and different traffic configurations. Items in parentheses are phrases which are transmitted only if logically required. Phrases in angle brackets, "<Red and White Cherokee>", are recorded during login.

3.2.2 Option 1: Computer Records Pilot ID

The login procedure for airborne aircraft in which the ATS computer records the pilot's ID as spoken over the VHF frequency, consists of the following actions taken by the pilot and the computer (see Figure 3-5):

PILOT: Tunes to the airport's login frequency and squawks the airport login code. (The airport codes and frequencies will be included on all standard aeronautical charts of the area, see Section 3.1.2).

ATS: Selects the first aircraft on its list of aircraft squawking the airport code and transmits the following message over the login frequency.

AIRCRAFT REQUESTING LOGIN
7 MILES N.W. OF MANASSAS,
SAY YOUR ID...

The position information is included to resolve the problem of simultaneous login requests.

PILOT: Transmits a description of the aircraft which includes a portion of the tail number over the login frequency.

e.g. <RED AND WHITE CHEROKEE 35 TANGO>

ATS: Records up to 5 seconds of the description. The ID is then transmitted back to the pilot in a message that assigns a discrete transponder code. All further transmissions that reference this aircraft will include this ID.

AIRCRAFT, <RED AND WHITE CHEROKEE 35 TANGO>:
SQUAWK 1527

Where 1527 is selected by the computer from a pool of codes allocated to the airport.

AIRBORNE LOGIN

PILOT: Squawks airport discrete code and tunes to login frequency.

ATS: AIRCRAFT REQUESTING LOGIN
7 MILES N.W. OF MANASSAS
SAY YOUR ID ...

PILOT: Broadcasts aircraft description over login frequency

<RED AND WHITE CHEROKEE, 35 TANGO>

ATS: Records aircraft description and assigns discrete code.

AIRCRAFT, <RED AND WHITE CHEROKEE 35 TANGO>:
SQUAWK 1527

PILOT: Squawks assigned discrete code

ATS: <RED AND WHITE CHEROKEE 35 TANGO>:
LOGGED IN AT MANASSAS FOR RUNWAY 34

GROUND LOGIN

PILOT: Squawks airport discrete code and tunes to login frequency.

ATS: AIRCRAFT REQUESTING LOGIN
ON RAMP AT MANASSAS
SAY YOUR ID ...

PILOT: Broadcasts aircraft description over login frequency.

<RED AND WHITE CHEROKEE 35 TANGO>

ATS: Records aircraft description and assigns discrete code.

AIRCRAFT <RED AND WHITE CHEROKEE 35 TANGO>:
SQUAWK 1527

PILOT: Squawks assigned discrete code

ATS: <RED AND WHITE CHEROKEE 35 TANGO>:
LOGGED IN AT MANASSAS FOR RUNWAY 34.
SQUAWK STANDBY UNTIL READY FOR TAKEOFF

PILOT: Squawks standby

FIGURE 3-5

SUMMARY OF OPTION 1 LOGIN PROCEDURE
(COMPUTER RECORDS PILOT ID)

PILOT: Pilot then squawks the assigned code.

ATS: When ATS observes the aircraft squawking the assigned transponder code, the following message is issued:

<RED AND WHITE CHEROKEE 35 TANGO>:
LOGGED IN AT MANASSAS FOR RUNWAY 34

The procedure for logging in on the ground is basically the same. When ready to taxi, the pilot squawks the login code. The process follows the steps above except that:

1. The initial ATS message will reflect the fact that the aircraft is on the ground.

AIRCRAFT REQUESTING LOGIN
ON RAMP AT MANASSAS
SAY YOUR ID ...

2. Pilots will be directed to squawk standby from the time that the login is complete until they are ready to roll on the runway:

<RED AND WHITE CHEROKEE 35 TANGO>:
LOGGED IN AT MANASSAS FOR RUNWAY 34.
SQUAWK STANDBY UNTIL READY FOR TAKEOFF

This assists in early acquisition of tracks on departing aircraft by reducing garble in the surveillance system and providing a positive indication of takeoff roll.

3.2.3 Option 2: Identification by Transponder Code

The login procedure can be shortened by referring to aircraft by their assigned discrete codes (see Figure 3-6). While this is not as recognizable as "tail number" call signs that are permanent for a given aircraft, the code is displayed on the thumb wheels of the pilot's transponder for easy reference. This option would use the following type of exchange between the pilot and ATS:

AIRBORNE LOGIN

PILOT: Squawks airport discrete code and tunes to login frequency

ATS: AIRCRAFT REQUESTING LOGIN
_7_ MILES _N.W._ OF MANASSAS
SQUAWK _1527_

PILOT: Squawks assigned discrete code

ATS: AIRCRAFT 1527:
LOGGED IN AT MANASSAS FOR RUNWAY _34_

GROUND LOGIN

PILOT: Squawks airport discrete code and tunes to login frequency.

ATS: AIRCRAFT REQUESTING LOGIN
ON RAMP AT MANASSAS
SQUAWK _1527_

PILOT: Squawks assigned discrete code

ATS: AIRCRAFT 1527:
LOGGED IN AT MANASSAS FOR RUNWAY _34_.
SQUAWK STANDBY UNTIL READY FOR TAKEOFF

PILOT: Squawks standby

FIGURE 3-6

SUMMARY OF OPTION 2 LOGIN PROCEDURE
(IDENTIFICATION BY TRANSPONDER CODE)

PILOT: Tunes to the ATS login frequency and squawks the published airport login code.

ATS: Selects the first aircraft on its list of aircraft squawking the airport code and issues the following message when the channel is free:

AIRCRAFT REQUESTING LOGIN
7 MILES N.W. OF MANASSAS
SQUAWK 1527

Where 1527 is selected by the computer from a pool of codes allocated to the airport.

PILOT: Squawks the assigned discrete code.

ATS: When aircraft squawks the assigned code, the following message is issued.

AIRCRAFT 1527:
LOGGED IN AT MANASSAS FOR RUNWAY 34

All subsequent transmission will refer to the aircraft as "AIRCRAFT 1527.

The procedure for logging in on the ground is basically the same with the following exceptions:

1. The initial ATS message will reflect the fact that the aircraft is on the ground.

AIRCRAFT REQUESTING LOGIN
ON RAMP AT MANASSAS
SQUAWK 1527

2. As in Option 1, pilots will be required to squawk standby from the time that the login is complete until they are ready to roll on the runway.

AIRCRAFT 1527:
LOGGED IN AT MANASSAS FOR RUNWAY 34
SQUAWK STANDBY UNTIL READY FOR TAKEOFF

3.2.4 Leaving the ATS System

Leaving the system is very simple. Aircraft leaving the radar coverage area (15 nautical miles from the radar site), changing to an en route code (e.g., VFR code 1200), or turning off their transponders are automatically dropped from the system. Once dropped from the system, the pilot must reinitiate the login procedure if he wishes to re-enter the ATS airport.

An exception is made, however, for ground aircraft; when joining or rejoining the departure queue, pilots are required to squawk standby until ready for takeoff. An inactive track will be maintained until that aircraft "reappears" and the aircraft will remain logged in.

Aircraft can show their intent to rejoin the departure queue after an approach by squawking IDENT before going to standby mode. ATS will respond with an acknowledgement of the following form:

<ID>: SQUAWK STANDBY UNTIL READY FOR TAKEOFF

and place the track in inactive status as above.

3.2.5 Establishing Intent

The process of login, which confirms that the aircraft is cooperating with ATS, also permits limited aircraft intent to be communicated to the ATS computer. This is done via the choice of the login code as shown in Table 3-1. The three primary intent categories are:

1. Use of the VFR General Login Code indicates the aircraft will operate on the designated ATS active runway in a standard fashion.

2. Use of one of the Alternate Runway Codes indicates that a VFR crossing runway operation will be conducted and gives the particular runway involved. A code will exist for each available runway direction. The aircraft is then subject to various crossing runway messages (see Section 5.6.3).

3. Use of the IFR Arrival Codes or a standard IFR clearance discrete code (see Section 4.2.1), as directed by ATC indicates the type IFR operation that will be conducted. The arrival code indicates which IFR approach will be used. Codes are also available to indicate a practice IFR approach.

To reduce the complexity of pilot inputs; the transponder codes are used to set the general class of operations rather than indicate stages of tactical maneuvers. For example, the difference between a touch-and-go operation and landing to a full stop is determined by ATS using surveillance data rather than pilot input.

The login procedures that were described in the previous sections apply to the use of the VFR General Login Code and the VFR Alternate Runway Codes (IFR login is slightly different and is described in Section 4.2.1).

The pilot may redesignate the type of operation involved at any time by transitioning to another of the login codes. If the aircraft is already logged in, ATS will respond on the tactical channel with the following message which acknowledges the pilot's new intent:

<ID>: LOGGED IN AT MANASSAS FOR RUNWAY 16,
SQUAWK 1527

The pilot is not required to repeat the entire login procedure or change VFR frequencies. After having the new intent confirmed, the pilot returns to his originally assigned unique code.

3.2.6 Login Error Recovery

Although the login process will run smoothly in the vast majority of cases, there are a few potential problem cases which are addressed by special logic:

1. Noise on the VHF frequency or a pilot with mike fright could garble the spoken ID.

2. Pilots could fail to respond to computer requests for a spoken ID or requests to squawk an assigned code.

3. Two pilots might attempt to log in at the same time. (e.g., both speak at the same time, the "wrong pilot" squawks the assigned discrete code, both squawk the assigned code).

ATS contains recovery logic which will resolve the above situations. Also, a pilot can restart the login process at any time simply by squawking the restart login code.

The recovery logic for the login process is discussed in the following paragraphs. These cases are unusual events.

If the ID as recorded by the computer is garbled, the pilot should restart the login process by squawking the restart login code of Table 3-1. The restart will be almost immediate since ATS attempts to complete a login procedure for an aircraft before starting one for another.

Pilots who fail to respond to a computer request within a suitable time limit will receive the request again. (The lack of a recorded voice ID is indicated by the carrier monitor function of the VRS and the code change is detected by the tracking software). After the second request, the aircraft is marked uncooperative and the pilot must squawk the restart login code to reinitiate the login procedure.

If two pilots attempt to log in at the same time, ATS will attempt to resolve the confusion. If only one pilot responds to the ID request and his ID is successfully recorded, he will continue the login process and be assigned a discrete code. Now suppose two aircraft are observed to be squawking a login code at the same time:

1. Normally, the geometry information included in the request for "Say ID" will uniquely identify an aircraft. That is, the aircraft "7 MILES NW" will respond and an aircraft "five miles east" will not. After the first aircraft is completely logged in, the second will be handled by the ATS computer.

2. Now suppose the computer requests the "7 MILES NW" aircraft to say ID and does in fact receive audio, but when the unique discrete code is assigned, the

"five miles east" aircraft is observed to transition to the code. In this case the logic will recognize that the "wrong" pilot of the two has responded (and now has both a recorded ID and assigned code). The computer will simply mark the responding aircraft as if it were the one that was originally intended and go on to handle the remaining aircraft.

3. If both pilots speak at the same time, the recorded ID will be garbled and both pilots will have to restart the login.

4. If both squawk the assigned code, ATS will respond with the following message:

AIRCRAFT SQUAWKING
CODE 1527
RESTART LOGIN

It would be possible for a pilot to force an improper action through intentional improper behavior, but this is true of any air/ground communication.

3.3 Services in Overview

Given the ATS environment of aircraft under surveillance and a capability for generating variable content voice messages, a broad range of services can be imagined. Several points are important in motivating the design of individual services:

1. There should be a considerable payoff in simply providing traffic surveillance information to the pilots. Historical accident data [13] indicates that accidents in and near the traffic pattern usually occur with neither pilot being aware of the other aircraft at all.

2. The operation of the traffic pattern provides a considerably ordered traffic environment, but with naturally close proximity of aircraft in a maneuvering state [12]. This places a limit on how conservative the automated system can be in terms of the minimum traffic spacings that cause messages and warnings to be generated. It is important that the services not saturate the voice channel or disturb operations normally deemed safe by the pilots.

3. As a completely automatic system, ATS is limited by its sensors and by the "problem solving" capability of the computer. The ATS computer does not have all the information on ground operations, weather conditions, aircraft type, pilot proficiency, etc., that a controller may take into account in managing traffic. The services must be designed not to rely heavily on decision rules that may be difficult to implement with computer logic.

Since the services are implemented in software, it is expected that considerable enhancement and extension will occur in the field. Specific adaptation to the needs of a particular site is also anticipated.

The design and evaluation of the baseline ATS services will be the primary emphasis of the early phase of the feasibility test bed program (Appendix B). Initially, the services will be extensions or modifications of current ATC practices (such as uncontrolled airport procedures and terminal radar traffic advisories). Various alternatives will be evaluated for technical feasibility and pilot acceptance and a final system description prepared.

To focus analysis and test bed efforts, a specific set of services has been defined to illustrate the range of capability of the ATS system. (These are all within the scope of the "Baseline ATS" and do not involve actual control of traffic). This set will be used as a starting point in testing the ATS concept..

Table 3-2 provides a summary of the ATS services. The services are listed along with their principal function, the events which can trigger ATS messages, and sample messages which could be produced by the service. A detailed description of each service appears in Section 5. The presently defined services include:

1. ATIS - The system provides information similar to present Automatic Terminal Information Service (ATIS) recordings at some tower equipped airports. These messages include active runway, weather, general traffic count and special information such as that found in notices to airmen (NOTAMS).

TABLE 3-2
EXAMPLE ATS SERVICES

SERVICE	PURPOSE	MESSAGE TYPES	EVENT TRIGGERING MESSAGE	TYPICAL PHRASEOLOGY
Automatic Terminal Information Service	Provide important information on airport conditions and available services.	ATIS	Successful completion of a login procedure. May be triggered periodically if channel utilization is high.	MANASSAS LANDING 34 ALTIMETER 29.92 WINDS 030 AT 10 KNOTS 9 AIRCRAFT IN TRAFFIC AREA TUNE TO ATS FREQUENCY 122.9
Threat Detection	Assure separation of aircraft in the traffic pattern by advising pilots of conflict situations.	Threat Detection	A conflict situation is defined by a conflict detection logic which uses time to collision, predicted miss distance, range, and altitude separation as criteria.	CONFLICT!!! <RED AND WHITE CESSNA 35 TANGO> TRAFFIC AT 9 O'CLOCK ON CROSSWIND <BLUE CHEROKEE 29 ECHO> TRAFFIC AT 12 O'CLOCK ON DOWNWIND RANGE IS 3000 FEET
Sequencing Aids	To improve traffic flow in the traffic pattern and provide additional information at strategic points in the traffic pattern	Announce Observed Sequence	Aircraft on downwind passes abeam of the runway threshold	<YELLOW CESSNA 92 QUEBEC> YOU ARE NUMBER 4 TO THE RUNWAY LONG FINALS IN PROGRESS
		Announce Important Traffic to Aircraft Entering the Pattern	Aircraft on entry and within 3/4 mile of nominal turn to downwind.	<YELLOW CESSNA 92 QUEBEC> TRAFFIC AT 11 O'CLOCK NEAR YOUR POINT OF ENTRY TO THE PATTERN
		Announce Important Traffic to Aircraft Turning Downwind	Aircraft on crosswind turning to downwind leg.	<YELLOW CESSNA 92 QUEBEC> ENTERING TRAFFIC AT 2 O'CLOCK DOWNWIND TRAFFIC AT 10 O'CLOCK
Special Aircraft Status	Alert aircraft of a potential threat in the traffic pattern.	Emergency Aircraft	An aircraft is squawking an emergency transponder code (7600 or 7700)	EMERGENCY AIRCRAFT 3 MILES NW OF MANASSAS EASTBOUND
		Unlogged Aircraft Reports	Unlogged aircraft operating in the ATS traffic area.	UNLOGGED AIRCRAFT 4.5 MILES NW OF MANASSAS SOUTHEASTBOUND
IFR Operations Support	Provide special services to IFR aircraft operating in the ATS traffic area and announce their presence at strategic points in their flight plan.	Announce IFR Traffic	IFR aircraft operating in the ATS traffic area	IFR ARRIVAL, <COLGAN 107> 3 MILES NE OF MANASSAS
		Approach Monitoring	IFR aircraft is "handed off" for an approach to the airport. (Aircraft squawks IDENT with appropriate IFR arrival code).	<COLGAN 107> AT MISSED APPROACH POINT NDB-A
		Outbound Handoff	IFR aircraft taking off from ATS airport and passing the defined outbound handoff range.	IFR DEPARTURE <COLGAN 107> CONTACT DULLES APPROACH 126.1
Pattern Management Services	Maintain a standard traffic pattern, control traffic pattern density, accommodate special operations, and reduce waiting time on departure.	Nonstandard Pattern	Aircraft cannot be classified in a standard traffic pattern state for a number of scans	<COMMUTER 19 ALPHA> NONSTANDARD PATTERN 1.5 MILES NE
		Touch-and-go Operations	Large departure queue and/or increased traffic density.	TOUCH-AND-GO OPERATIONS SUSPENDED UNTIL 1400 HOURS
		Crossing Runway Operations	High traffic density, alternate runway departures	VFR PRACTICE OPERATIONS SUSPENDED ON RUNWAY 27 UNTIL 1400 HOURS.
		Departure Management	Large departure queue	<YELLOW CESSNA 25 ECHO> EXTEND DOWNWIND 1 MILE
		Announce Runway Status	Operator input due to changing weather and/or runway conditions.	ACTIVE RUNWAY IS CHANGED TO RUNWAY 34
Pilot Services	Provide additional assistance to pilots on request	Request Position Fix	Aircraft squawking special transponder code	<YELLOW CESSNA 25 ECHO> POSITION IS 5 MILES SW OF MANASSAS BEARING TO AIRPORT 227 DEGREES
		Message Repeat	Aircraft squawking special transponder code	<YELLOW CESSNA 25 ECHO> LAST MESSAGE YOU ARE NUMBER 4 TO THE RUNWAY

2. Threat Detection - The computer projects the surveillance track data of the aircraft and provides warning when a traffic conflict may occur. This would be short lead time threat detection to backup the pilot's normal vigilance in the pattern.

3. Sequencing Aids - Various messages are generated at appropriate points in the pattern to assist the pilot in sequencing himself within the total traffic flow.

4. Special Aircraft Status - Certain aircraft, such as those declaring an emergency, are announced to the traffic pattern.

5. IFR Operations Support - IFR operations discuss in Section 4 are supported by particular messages.

6. Pattern Management - Various strategic decisions can be made by the computer to better manage the traffic pattern operation. While it is not planned to perform actual vector-like control of aircraft in the advisory level of ATS, some messages do affect the aircraft's flight path (e.g., recommending to aircraft in the pattern that they extend downwind leg to give a departure aircraft a takeoff slot).

7. Pilot Services - The pilot can interrogate the ATS system (using transponder codes) for information about his position. For example, there is the equivalent of the present "DF steer" service available at some FSS's in which the pilot is given his bearing to the airport.

Section 5 discusses the services further and Section 6 is an example of operations with the services in context.

3.4 Service Areas, Partial Avionics, and Improper Procedures

The services which the system can generate are directly related to the avionics in the aircraft, conformance to the ATS login procedure by each pilot, and the airspace areas defined in Figure 3-2. Equipage falls into three categories (it is assumed that all aircraft have a two-way radio): Mode C altitude encoder equipped, Mode 3 transponder only, and unequipped (no transponder). Note that login is normally completed prior to entering the ATS traffic area.

3.4.1 Mode C Altitude Encoder Equipped

Mode C equipped aircraft which log into the system will receive all of the services provided by ATS since full information on their position is known and an ID is available. This is true both in the coverage area and the ATS traffic area.

Those which do not log in but penetrate the ATS traffic area will be considered uncooperative. Uncooperative aircraft will not receive any sequencing aids or management services (we have no reason to believe that the pilot is monitoring the proper VHF frequency since he did not log in). However, they will be included in the threat detection tests and will be called for nonstandard pattern operation to assist other aircraft. Their position will be announced at airport entry (5 mile range), pattern entry (turn to downwind), turn to base, and turn to final approach. Since uncooperative aircraft do not have a recorded ID, they will be referred to as "UNLOGGED AIRCRAFT" in all ATS messages.

Unlogged Mode C equipped aircraft beyond the ATS traffic area are tested for threat detection with logged in aircraft but receive no other services.

3.4.2 Mode 3-Only Transponder Equipped

Aircraft equipped with Mode 3-only transponder which log into the system will receive all of the services provided by ATS. Aircraft altitude will be determined by the ATS computer according to position of the aircraft in the traffic pattern and nominal traffic pattern altitudes since the pilot has declared his intention to cooperate at login.

Unlogged Mode 3-only aircraft will not receive any services and will not be included in threat detection or other messages to the rest of the traffic pattern. This is true since their altitude is not determinable and any particular Mode 3 target may in fact be an overflight.

3.4.3 Unequipped

Unequipped aircraft (i.e., those without a 4096 transponder but equipped with a two-way radio) cannot be "seen" by the ATS computer. Therefore, they cannot log into the system, receive any services, or be included in threat detection.

Provision is made, however, to handle the occasional unequipped aircraft or transponder failure. The pilot of the unequipped aircraft can still add to the safety of the traffic pattern by announcing his position over the ATS tactical frequency at strategic points in the flight: pattern entry and turn to base (as in current recommended practice). Position reports should be brief to maintain a low channel utilization:

e.g. RED AND WHITE CESSNA 35 TANGO
TURNING BASE

The ATS computer can detect the presence of a carrier on the VHF frequency and delay a computer generated message until the pilot's transmission is complete.

All pilots must be aware that the ATS services cannot account for the presence of unequipped aircraft.

4. IFR OPERATIONS AND ATC INTERACTION

An aircraft operating at an ATS airport under an instrument flight plan is served by the same ATS automation described in the prior sections. The primary new factors are that the aircraft is under control of the responsible ATC facility and may be executing different procedures than the general VFR traffic. ATS extends the additional safety benefits of automated tracking and service message generation to the IFR aircraft while requiring minimal modification to normal uncontrolled airport procedures. The workload of the responsible air traffic controller is not increased but, in fact, additional flexibility of traffic management is provided.

This section will describe three modes of operation with basic ATS (see Figure 4-1 for overview):

1. ATS with Remote Communications Outlet and Digital Interface to the ATC Facility - This is the "complete" implementation of ATS and would be appropriate for sites where the volume and character of IFR traffic require full service.

2. ATS with Remote Communications Outlet - Those sites with the RCO equipment can operate with several special procedures to expedite IFR traffic. Radar coverage may or may not be available from the facility's own radar systems.

3. Standalone ATS - An ATS system with no hardware links to the facility accommodates IFR traffic with somewhat less flexibility. However, at sites with low IFR operation rates and uncomplicated overlying ATC route structure, this may be completely adequate.

Various hybrid operations could exist in special airspace (for example, an ATS site with two feeder facilities).

The decision to implement one of the three modes listed above would be strongly influenced at any given airport by three factors:

1. ATC route structure and traffic levels - High density traffic in a complex terminal arrival area will impact the way a controller can manage arrivals and departures at the uncontrolled airport.

	ATS	ATS AND RCO	ATS WITH RCO AND REMOTED SURVEILLANCE
CLEARANCE DELIVERY	• TELEPHONE	• VIA RCO	→ SAME
DEPARTURE COORDINATION	• LOGIN, USE IFR FLIGHT PLAN ASSIGNED CODE • VOID-TIME CLEARANCE	• ATC RELEASES PILOT FOR TAKEOFF AT HIS DISCRETION	→ SAME + • POSSIBLE DIGITAL COORDINATION WITH FACILITY
OUTBOUND HANDOFF	• PILOT CONTACTS ATC WHEN ATS PROMPTS FREQUENCY CHANGE	→ SAME	→ SAME + • AUTOMATIC HANDOFF ACTION ON CONTROLLER'S DISPLAY (FORCE FDB)
INBOUND HANDOFF	• CONTROLLER ASSIGNS ATS-IFR DISCRETE CODE • ATS PROMPTS ID LOGIN	→ SAME	• AUTO-LOGIN (PILOT RETAINS IFR CODE AND ALPHA ID TRANSMITTED DIGITALLY)
CONTROLLER INTERFACE	• NONE	• CAN MONITOR ATS CHANNEL, OVERRIDE IN EXCEPTIONAL CIRCUMSTANCES	→ SAME + • SURVEILLANCE (POSSIBLY CERTIFIED FOR RADAR SEPARATION) • DIGITAL COORDINATION WITH ATC FACILITY COMPUTER

FIGURE 4-1

SUMMARY: IFR OPERATIONS WITH AUTOMATED TERMINAL SERVICE

2. Radio coverage - Whether the ATC facility has existing radio contact to the surface will affect clearance delivery, use of void-times, etc. The facility may already have a remoted transmitter/receiver to extend coverage (with benefits similar to the ATS RCO).

3. Radar coverage - Full coverage permits greater controller flexibility in accepting departures and managing the airspace. Uncontrolled airports that are satellites of TRACONs at large hubs may have existing coverage to low altitude. At ARTCC's, the coverage is likely to be less extensive. For example, only 12% of airports given approach control service from Indianapolis and Minneapolis ARTCCs had existing coverage below 2000 feet AGL [14].

These factors will impact the way ATS can improve operations at any given site. The computer software will be "adapted" for a given ATS site in the same sense that manned facilities develop internal procedures and "letters of agreement" with adjacent facilities to accommodate the local situation.

The following discussion will apply to two common cases:

1. En Route Center control - In this case, the ATS airport is under the control of a low altitude en route sector at the ARTCC. The facility computer complex is the National Airspace System (NAS) Model 9020 class of hardware.

2. TRACON control - In this case, the ATS site is assigned to an approach or departure position of a terminal facility. Facility equipment is an ARTS III system.

The technical details of connecting ATS to each type facility would be different, but the roles of pilot and controller remain the same in each case.

This description will use the following approach: A brief overview of current IFR operations at uncontrolled airports will first be given as background (ATS procedures will be seen to be an extension of these existing practices). Next, ATS operations in the "complete" system case will be reviewed. Inbound and outbound handoff will be described in some detail. The description will then be specialized to the case of no digital interface (Section 4.3) and finally to the standalone system (Section 4.4). Section 4.5 outlines the IFR services which will be explored in the feasibility test bed. Section 4.6 discusses practice IFR operations in the context of ATS.

4.1 Current Procedures at an Uncontrolled Airport

To provide a background for discussing IFR operations with ATS, it will be useful to briefly review present uncontrolled airport procedures. These are summarized in Figure 4-2 where we have attempted to show only the most common situation (many special cases exist depending on local conditions). The various phases of IFR operations include:

1. Clearance delivery can be supplied by telephone from the Flight Service Station (FSS) that accepted the flight plan or by phone directly from the en route center (ARTCC) or terminal approach facility (TRACON) responsible for the airport. If VHF coverage is available, (with or without RCO) the clearance can be received directly via radio from the facility. Another common method is to depart VFR and then pick up the IFR clearance while airborne.

2. When radio coverage is not available, departure coordination is accomplished by specifying a clearance void-time (usually allowing approximately a 20 minute departure window). It is the responsibility of the pilot to be airborne within the time window or to recontact ATC for a new clearance. The controlling facility must block appropriate airspace until contact is made with the aircraft and procedural or radar control established.

   If suitable voice and radar coverage is available, the controller may release the aircraft when ready for takeoff without using a void-time. This enhances airspace utilization and is more convenient for the individual pilot.

3. Ground control is completely the responsibility of the pilot, with various standard operating practices and customs to assist orderly operations. The airports of concern to ATS do not normally include complex ground operations.

FUNCTIONS	UNCONTROLLED AIRPORT PROCEDURES*
CLEARANCE DELIVERY	TELEPHONE TO FSS OR OTHER CLEARANCE POSITION, RCO, PICK-UP AIRBORNE
DEPARTURE COORDINATION	VOID-TIME CLEARANCE, RCO
GROUND CONTROL AND RUNWAY OBSTRUCTION CHECK	PILOT SELF MANAGEMENT
TRAFFIC PATTERN MANAGEMENT	•SEE AND BE SEEN •STANDARD OPERATING PRACTICES •PROCEDURAL SYSTEM OF ANNOUNCING POSITION OF UNICOM
FINAL APPROACH SPACING	•NO RADAR COVERAGE PROCEDURAL - RESERVE AIRSPACE UNTIL LANDING ASSURED OR MISSED APPROACH •COVERAGE (RADAR AND VOICE) RADAR SEPARATION
WEATHER OBSERVATION	•USE NEAREST SEQUENCE REPORT PLUS PIREPS •LIMITED UNICOM INFO

* THERE EXIST VARIOUS EXCEPTIONS AND SPECIAL CASES. THE INTENT HERE IS TO DESCRIBE THE MOST COMMON SITUATION.

FIGURE 4-2

PRESENT IFR OPERATIONS AT AN UNCONTROLLED AIRPORT

4. Traffic pattern management is based on the "see and be seen" principle while in visual conditions. A key factor in the environment is that during actual Instrument Meteorological Conditions (IMC), the traffic level drops considerably as VFR operations are suspended. IFR aircraft departing the airport normally climb away from the traffic pattern without significant interaction, even in visual conditions. Approach operations are of more concern since:

a. The IFR aircraft is arriving on an instrument approach that may involve a nonstandard entry (e.g., circle to land via a right base while left hand traffic is in force).

b. The IFR aircraft may often be higher performance than the other aircraft in the pattern.

c. If there is considerable VFR traffic operating below a ceiling, the approaching IFR may have limited time to plan his entry into the traffic flow after breakout.

Another area of concern is IFR practice operations occurring in visual meteorological conditions (VMC). This is a common activity at the ATS class of airports.

5. Final approach spacing where radar coverage does not exist is procedurally based and requires the ATC controller to reserve approach airspace from the time of final approach fix (FAF) inbound until the approach is complete. The controller gives a frequency change to the local UNICOM or aeronautical advisory station (AAS: an on-site FSS) during the approach. The approach is complete when:

a. The pilot cancels IFR (a common procedure).

b. Radio or telephone contact is made to report landing.

c. The pilot recontacts ATC while executing a missed approach.

6. The only available information on weather and status of aids (NAVAIDS) at the airport is available through the ATC facilities (e.g., the sequence report for the nearest reporting station).

These procedures are effective at uncontrolled airports because of the generally low IFR operation rate and the fact that VFR operations are greatly reduced in marginal weather conditions.

4.2 ATS with Remote Communications Outlet and Digital Interface to the ATC Facility

The use of hardware interfaces between ATS and the facility can enhance safety, improve IFR capacity, and make operations more convenient for both the pilot and controller. These interfaces are a voice link to the pilot (the Remote Communications Outlet) and a digital link between the ATS system and suitably computer-equipped ATC facilities.

The RCO permits the controller to maintain voice contact with the pilot to the surface. Clearance delivery and departure release can be given directly to the pilot, eliminating the need for void-time clearances. The controller can use the normal ATC frequency, monitor the messages generated by ATS, or break into the ATS channel to reach an IFR aircraft already transitioned to the local frequency.

With the digital link between the ATS system and the ATC facility computer, several additional features can be implemented to improve support of IFR operations:

1. Surveillance data transfer (target positions and beacon codes) can be remoted to the facility and integrated with data from other facility radars. If this data is certified for radar control, the requirement for blocked airspace during approach can be relaxed.

This local airport radar data might be activated only on controller request, when IFR operations are in progress. It would be presented on the normal plan view display used by the radar controller to handle other non-ATS traffic (the display would continue to be generated by the existing facility computer).

2. Inter-computer data transfers can be used to simplify the login process since aircraft ID and intent can be digitally transmitted to ATS from the flight plan data at the facility. The alphanumeric ID can be used to construct the voice ID and the login process becomes simpler than that of Section 3.

3. Automatic handoff, including forcing of full data block to the appropriate controller display, can be used to simplify coordination with the traffic in the ATC en route structure.

4. ATS control and data exchange - Various functions of ATS (runway selection, touch-and-go status, etc.) could be selectable by the controller and various data (weather, etc.) read out on command.

The following sections describe the handoff process in the case of both digital interface and RCO. Neither the pilot's nor the controller's actions are more complicated than with current procedures.

4.2.1 IFR Departure Procedures

When an ATS airport has both voice and data interfaces to the ATC facility, a flexible set of departure procedures are available (summarized in Figure 4-3). Consider the steps a pilot must follow.

First, the IFR flight plan is filed with the appropriate Flight Service Station by telephone or using a pilot entry terminal (currently being developed in the FSS automation program). This flight plan will be processed by the ATC system while the pilot pre-flights and loads his aircraft.

Next, when ready to taxi, the pilot contacts ATC on the frequency available through the RCO. He will receive an IFR clearance which includes a discrete transponder code that will be used for the entire IFR flight (as given by the national beacon plan [6]). The pilot maintains contact with ATC until he is ready for takeoff and has received his departure release (note that void times are unnecessary).

POINT	OPERATION	FREQUENCY MONITORED BY PILOT
Preflight	• File IFR flight plan with FSS	Telephone
Ready to Taxi	• Receive IFR Clearance	ATC RCO Frequency
Ready for Takeoff	• Receive departure release from ATC	↓
	• Squawk Flight Plan IFR Code, e.g. 2217	ATS Tactical Frequency
	• ATS Confirms Track: "Ozark 107, Depart at Your Discretion, Direct Casanova"	↓
Outbound Handoff	• ATS Prompts:* "Ozark 107, Contact Dulles Approach 126.1"	ATC Frequency

* No transponder code change occurs.

FIGURE 4-3

IFR DEPARTURE PROCEDURES
(WITH DIGITAL INTERFACE AND RCO)

Now the pilot activates his transponder with the assigned discrete code (given in the IFR clearance) and tunes to the ATS tactical frequency. At this point, the ATS computer has received several pieces of information directly from the ATC facility via the digital link:

1. The IFR discrete code that the aircraft will be using.

2. The runway to be used and any needed departure details.

3. The aircraft's alphanumeric ID. With this data, the ATS system can speak the aircraft ID without requiring the pilot to record his voice as described in Section 3. For example, the characters "OZ 107" sent from the facility to ATS could be used to compose the ID: "Ozark One Zero Seven" from prerecorded alphabetic, numeric, and operator identifiers in the VRS system.

The ATS system, on seeing the transponder target with the unique code, will confirm the track and expected route of flight to the pilot by a message on the ATS tactical frequency:

"OZARK 107, DEPART AT YOUR DISCRETION, DIRECT CASANOVA."

The pilot then clears the arrival airspace and starts his takeoff roll when ready. The ATS computer will also digitally notify the facility that the aircraft is rolling.

With the knowledge that the aircraft is IFR and given an ID available, the ATS system can provide the services highlighted in Section 4.5. This period of flight may be looked at as similar to local control at a manned control tower. The primary service of ATS is providing the IFR aircraft with advisories on the VFR traffic operating at the airport.

At an appropriate point in the departure operation, ATS will prompt the IFR aircraft to contact ATC. Example phraseology is:

"OZARK 107, CONTACT DULLES APPROACH 126.1"

Simultaneously, the ATC facility computer is notified by ATS via the digital link and appropriate handoff symbology appears on the controller's display (e.g., blinking data block). The precise outbound handoff point would be specially determined for each site and departure route. It would be a point where sufficient altitude has been achieved to assure terrain clearance and where the aircraft can be conveniently accepted into the ATC route structure.

Note that, if desired, the controller can break in on the ATS tactical frequency during the period the aircraft is monitoring the ATS VHF frequency. Pilots could monitor both the ATS tactical frequency and the RCO frequency during operations. If the aircraft has dual communication receivers.

4.2.2 IFR Arrival Procedures

Inbound procedures are particularly simple when a digital interface exists: most of the coordination is handled directly on the digital intercomputer link. The pilot procedures are summarized in Figure 4-4.

The point where inbound handoff is to occur is determined by the controller for each arrival. Factors affecting its selection are:

1. Radar coverage of the ATC facility (although in the digital interface case, the ATS surveillance can be remoted).

2. Coverage volume of the ATS site.

3. Terrain.

4. The approach to be executed.

5. Whether other IFR traffic are operating at the airport.

In general, the pilot must stay with the controller until clear of all IFR traffic, but we wish to provide ATS services as early as possible to assist the pilot in separating himself from VFR traffic. Typical handoff points might be from 10 miles to Final Approach Fix (FAF) up to a handoff when inbound on approach.

POINT	OPERATION	FREQUENCY MONITORED BY PILOT
Inbound Handoff	● Controller Instructs "Monitor Manassas ATS 122.9, Squawk IDENT"	ATC ↓
ATS Detects IDENT	● ATS Confirms: "OZARK 107, Logged in at Manassas for NDB-A, Circle to Runway 34"	ATS Tactical ↓
Remainder of the Approach	● Pilot Monitors ATS for Services	↓
Missed Approach	● Pilot contacts ATC for further clearance	ATC

FIGURE 4-4

IFR ARRIVAL PROCEDURES
(WITH DIGITAL INTERFACE AND RCO)

The controller directs handoff to ATS by voice instruction to the pilot and a simple input to the ATC computer (e.g., trackball or keyboard action). The facility computer transmits to ATS via the digital link the appropriate handoff data:

1. The IFR flight plan code being used by the aircraft.

2. The aircraft ID ("OZ 107").

3. The particular approach assigned by the controller (e.g., data representing "NDB-A Manassas, circle to land 34").

4. Track data on the aircraft to assure acquisition.

The ATS system can now identify the particular aircraft that is IFR inbound.

After the pilot tunes to the ATS tactical frequency, he squawks IDENT. This indicates to the ATS computer that the pilot is monitoring the frequency. ATS confirms that the aircraft is known:

"OZARK 107, LOGGED IN AT MANASSAS"

The pilot now receives the services discussed in Section 4.5, with particular emphasis on the advisories on VFR traffic.

The aircraft has three ways of terminating the IFR approach:

1. Landing - ATS will transmit a confirmation to the ATC facility.

2. Cancel IFR - During the approach, the pilot can use the RCO frequency to cancel his IFR flight plan with the ATC controller. The facility computer will notify ATS which will re-label the aircraft as VFR (but retain the ID). The aircraft will then be subject to VFR standard ATS services and be assigned an ATS unique code:

"OZARK 107, SQUAWK 1527 VFR"

3. Missed Approach - On detecting a missed approach, ATS will notify the facility computer which will flag the aircraft on the controller's display. The pilot would transition to the RCO frequency to declare his

missed approach and receive further clearance from the controller.

No special ground control procedures exist for IFR aircraft.

4.3 ATS with RCO and No Digital Interface

In this case, the procedures are slightly different since the intercomputer link does not exist. The pilot must now be requested to record his ID during login and certain approach and departure intent must be communicated by transponder codes. The radar data remoting and control of ATS system status of Section 4.2 is not available in this case.

4.3.1 IFR Departure Procedures (No Digital Interface)

The primary change, as shown in Figure 4-5, is that the pilot must record his ID as the VFR login of Section 3. If the standard active runway is to be used for departure, the pilot squawks his IFR flight plan code. The ATS system (noting a target on the airport surface which is squawking an IFR discrete code appropriate for a departure in this ARTCC) then requests the pilot to speak his ID. ATS stores the ID and the services and handoff go on as before.

If the aircraft will use a special runway or departure routing, one of the ATS IFR departure codes is used to indicate this intent to ATS. The pilot will then be requested to squawk the flight plan code after login, but before takeoff. There would be one code for each special routing (i.e., this may be thought of as similar to named Standard Instrument Departures).

The pilot has transitioned to the ATS tactical frequency at login, and nominally is not on the RCO channel during the departure. With no digital interface, a substitute is provided for the digital indication of takeoff roll and handoff to the controller in Section 4.2.1. The ATS system will generate a voice message (spoken only on the RCO frequency to the controller) to confirm the takeoff. A similar call could be made at handoff.

4.3.2 IFR Arrival Procedures (No Digital Interface)

Without the digital interface, the ATS computer cannot be notified of the transponder code, intent, and ID of the inbound aircraft by inter-computer link. Note that arrivals may be carrying IFR discrete codes issued by other centers and cannot

POINT	OPERATION	FREQUENCY MONITORED BY PILOT
Preflight	● File IFR flight plan with FSS	Telephone
Ready to Taxi	● Receive IFR Clearance	ATC RCO Frequency ↓
Ready for Takeoff	● Receive departure release from ATC	↓
	● Squawk Flight Plan Discrete Code, e.g., 2217 (or ATS Special Departure Code)*	ATS Tactical Frequency ↓
	● ATS Request: "IFR Aircraft Squawking 2217, Say ID"	↓
	● Pilot Replies: "<Ozark 107>"	↓
	● ATS Confirms: "<Ozark 107>, Logged in at Manassas, Direct Casanova" (or "SID Bravo from Runway 04, Squawk Flight Plan Code")*	↓
Outbound Handoff	● ATS Prompts: "<Ozark 107>, Contact Dulles Approach 126.1"	ATC Frequency

* Only if non-typical departure used.

FIGURE 4-5

IFR DEPARTURE PROCEDURES
(RCO BUT NO DIGITAL INTERFACE)

be easily isolated from overflights. Figure 4-6 summarizes the changes in the procedures.

To provide unambiguous approach intent at handoff, the controller assigns to the aircraft one of the ATS IFR approach codes. This code would correspond to the particular approach given by the controller (e.g., "NDB-A, Circle to Runway 34"). If procedures and radar coverage permit several aircraft to be simultaneously on the same approach, a few codes per approach would be available to insure that each aircraft is unique. (The unique code prevents errors due to track swapping or reacquisition.) The pilot retains the code during the rest of the approach.

The recorded ID technique is used to log in the aircraft. Services can be supplied as in the previous case.

4.4 Standalone ATS

The description of the prior section applies to this case except that the RCO connection to the ATC facility is not available. The primary change in procedures is that if alternate radio coverage does not exist, ATC must issue a "void time" departure clearance to control entry of the aircraft into the IFR route structure.

The use of transponder codes to communicate intent remains as described in 4.3.

4.5 Services for the IFR Aircraft in the Terminal Area

Once the IFR aircraft is logged in, all the standard ATS services may be extended. Additional services can address the special circumstances of IFR operations. The IFR traffic problem at the ATS class of airports has two facets:

1. During VFR meteorological conditions, the primary concern is merging the (perhaps high performance) IFR aircraft which is executing a standard instrument approach procedure into the VFR traffic pattern.

2. During IFR meteorological conditions, primary assistance can be extended to the IFR pilot in monitoring the approach and avoiding any residual VFR traffic operating below the ceiling.

POINT	OPERATION	FREQUENCY MONITORED BY PILOT
Inbound Handoff	• Controller Assigns an ATS IFR Arrival Code to the Aircraft (e.g., 1520)	ATC ↓
	• Controller Instructs "Contact Manassas ATS 122.9, Squawk IDENT"	↓
ATS Detects Code & Ident	• ATS Requests: "IFR Inbound Manassas Squawking 1520, Say Your ID"	ATS Tactical ↓
	• Pilot Replies: "<Ozark 107>"	↓
	• ATS Confirms: "<Ozark 107>, Logged in at Manassas, NDB-A Circle to 34"	↓
Remainder of the Approach	• Pilot Monitors ATS	↓

FIGURE 4-6

IFR ARRIVAL PROCEDURES
(RCO BUT NO DIGITAL INTERFACE)

The ATS hardware and software present a capability for implementing a broad range of services. The feasibility test bed will be used to develop a complete definition of IFR services and explore their utility in the total ATC process. A simple baseline set of services messages has been defined as a starting point for development. These will be modified and extended during testing to achieve an operationally acceptable IFR capability.

The portions of the VFR services particularly relevant to IFR operations, along with the special IFR services, are highlighted below to summarize total IFR operations. Service details are provided in Section 5.

1. ATIS (5.1) - At the point of login, the IFR aircraft is provided with an ATIS message. This forms a final approach briefing similar to that provided by standard ATIS service at a manned facility. Information provided includes active runway, traffic conditions, special notices, and the weather information available at the site. The last item can be particularly valuable at an airport some distance from the nearest facility with manned weather observation.

2. Progress Announcement (5.5) - The location of the IFR aircraft will be periodically announced to the traffic pattern on both arrival and departure. This provides a prewarning that the IFR aircraft, perhaps still beyond visible range and executing a nonstandard pattern, is operating at the airport.

3. Threat Detection (5.2) - The conflict warning service considers the IFR aircraft with respect to the remainder of the pattern and provides warnings for significant conflict situations. This is particularly useful for IFR-VFR conflicts that may occur while the IFR aircraft is still in Instrument Meteorological Conditions (IMC) or during a circle-to-land operation.

4. Approach Monitoring (5.5) - Since the particular approach being executed is known to ATS, additional

approach monitoring service can be provided. Example features might be:

a. Final Approach Fix (FAF) - The pilot on a non-precision approach has no altitude guidance and must rely on station passage, distance, or time measurements to determine when descent should begin to the Minimum Descent Altitude (MDA). ATS can call the FAF inbound point based on surveillance data as an input to the pilot's approach planning.

b. Missed Approach Point (MAP) - The MAP is determined by the pilot, usually using time from Final Approach Fix (FAF). The ATS system provides a call at the MAP based on surveillance data as a backup to the pilot's calculations. The pilot still has responsibility for determining a missed approach condition.

c. Deviation Monitoring - Since the published approach course is known to ATS, gross lateral deviations can be observed and reported to the pilot. He may elect to miss the approach depending on the severity of the deviation and point along the approach. Altitude monitoring can be extended to Mode C equipped aircraft in the same sense as the Minimum Safe Altitude Warning (MSAW) under development for the ARTS III system.

5. Departure (5.6.4) - The standard departure management service requests extension of downwind leg by aircraft in the pattern when the departure queue has been significantly delayed. ATS will initiate this procedure whenever necessary to accommodate an IFR departure.

4.6 Practice IFR Approaches

Nominally, practice IFR approaches are made under visual flight rules but under the control of the responsible ATC facility. The ATC controller determines whether they may be conducted safely in relation to ther IFR traffic in the system and then handles the operation in a manner similar to actual IFR traffic.

ATS can support full practice IFR operations with the same services extended to actual IFR traffic. The ATC controller will assign an ATS approach discrete code from the set reserved for practice approaches (see Table 3-1) or a data transfer on the inter-computer link will be used. ATS will then add the phrase "PRACTICE IFR" to messages concerning the aircraft. All other operations remain the same.

A common activity at the ATS class of airports is local practice of portions of IFR approaches without ATC contact. Flight instructors direct students to repeat certain segments of IFR procedures (such as low approaches or procedure turns) while maintaining VFR. ATS will accommodate these operations if traffic conditions permit. The pilot in command indicates the desired operation by use of the appropriate local practice code and then is requested to return to the previously assigned ATS unique code. Service messages (particularly the nonstandard pattern messages) will appropriately adapt to the special operation. If the traffic is heavy, ATS will request the pilot to defer the practice procedures.

5. ATS SERVICES

The purpose of this section is to describe the baseline ATS services in sufficient detail to explain why each message is produced and how it should be interpreted by the pilot. The content of each message is given, along with a suggested phraseology (this phraseology and the service design will be modified as necessary, based on feasibility testing). The services were previously summarized in Table 3-2.

As discussed in Sections 2 and 3, ATS can be operated as either a single or two channel system. In a single channel system, both the login process and delivery of all service messages take place on one frequency. Where traffic permits, a single channel system could be used to conserve frequency allocations. Based on simulations and traffic pattern data [12], it is estimated that login will be a dominant factor in channel utilization at typical aircraft arrival rates. It is possible for service messages to be transmitted during the gaps in login (e.g., after ATS has recorded the pilot ID, but before the aircraft has been confirmed as squawking the assigned unique code) in order to provide timely messages in the single channel case.

With login handled on a separate frequency in a two channel system, the rate of message delivery on the tactical channel is normally small. However, if the instantaneous number of aircraft operating at the ATS airport becomes very large, the message capacity of the tactical voice channel may be exceeded. This is the same problem faced by human controllers in busy traffic, and similar remedies are available:

1. The messages are ranked by a preassigned priority and all pending high priority messages will be spoken before those of low priority. This implies that a low priority message could be postponed until the condition calling for the message has disappeared. In this case the message is not spoken at all.

2. The content of the messages can be shortened during heavy traffic.

3. Usually, ATS will not override a message that is already being spoken to start a new one, even for a new message of higher priority. For the highest priority service - threat detection - overriding will be permitted to assure timely warnings.

At some traffic level, the system may have to reduce the services provided to only the most critical. The feasibility tests will explore the limit of system effectiveness as the services are reduced.

ATS services rely on the concept of "pattern state classification." This process assigns a "pattern state" or label to each aircraft based on the aircraft's geographic location and probable intent in the traffic pattern. A list of the ATS pattern states appears in Table 5-1. A detailed discussion of the process of pattern state classification is included in Appendix A.

As in the prior sections, underlined portions of the message examples indicate items which are variable under computer control. Items in parentheses are phrases which are transmitted only if logically required. Angle brackets enclose the pilot recorded IDs.

5.1 Automatic Terminal Information Service (ATIS)

This service is similar to the ATIS recordings broadcast over navigation aids at certain airports today. The ATIS message will consist of pertinent weather information, altimeter setting, active runway (and traffic direction if not the standard left hand pattern), traffic density, the ATS tactical frequency (if different from the login frequency), and other supplementary information recorded by the airport operator.

e.g. MANASSAS LANDING 34
ALTIMETER 29.92
WINDS 030 AT 10 KNOTS
9 AIRCRAFT IN TRAFFIC AREA
(NO TOUCH AND GO'S UNTIL 2100)
(.... Airport Operator NOTAM...)
(TUNE TO ATS FREQUENCY 122.9)

The information could be obtained from weather sensors (preferred if available), or from the Sequence Report of the nearest reporting airport (via the digital data link from the ATC facility if available), or from the System Control Console (most likely source in initial implementations).

TABLE 5-1

AIRCRAFT PATTERN STATES

STATE NAME	DESCRIPTION
LOF	LIFTOFF, aircraft has rolled for takeoff but is not above 200' AGL.
TOF	TAKEOFF, aircraft on the takeoff leg of the pattern.
XWD	CROSSWIND, aircraft on crosswind leg.
DEP	DEPARTURE, aircraft declared to be departure.
ENT	ENTRY, aircraft making entry to the traffic area.
DWD	DOWNWIND, aircraft on downwind leg but prior to reaching a point opposite to threshold.
DWB	DOWNWIND NEAR BASE, aircraft on downwind, has passed threshold, and could turn base.
BSE	BASE, aircraft on base leg.
BSF	BASE NEAR FINAL, aircraft on base leg at a point where it will shortly turn final.
FNL	FINAL, aircraft on final approach.
LDG	LANDING, aircraft on final which has gone below 200' AGL.
ZZZ	UNKNOWN, cannot be certain as to his intent.
ERA	EN ROUTE AIRCRAFT, aircraft beyond the traffic area.

GROUND STATES

RMP	RAMP, on ramp or taxiways
DPQ	DEPARTURE QUEUE, waiting for departure
LRL	LANDING ROLL
TRL	TAKEOFF ROLL

Depending on channel utilization, the ATIS will be broadcast at the successful completion of each login procedure or group of successive logins (when login channel is in use). It would be repeated periodically on the ATS tactical channel in a single channel system. (ATIS is always provided to IFR aircraft on the tactical channel.)

In the event of an ATS hardware failure, an ATIS message of the following form will be broadcast periodically over the voice channels:

> MANASSAS ATS IS INOPERATIVE
> FOLLOW STANDARD UNCONTROLLED
> AIRPORT PROCEDURES

Supplemental information might be added by the airport operator.

5.2 Threat Detection

One of the primary functions of a control tower or a traffic pattern at an uncontrolled airport is to assure separation between aircraft. The ATS system assists the pilot in separating himself from other traffic by increasing his traffic awareness through a hierarchy of messages. The messages, given when appropriate in the total pattern context, include:

1. ATIS information on the total number of aircraft in the pattern (Section 5.1).

2. Sequencing aids to assist in locating traffic at entry, on downwind, and crossing into the base leg area (Section 5.3).

3. Special aircraft status messages on aircraft using the pattern in nonstandard ways (Section 5.4).

4. Threat detection and warning for aircraft in imminent conflict.

The less critical messages should assist the pilot in maintaining normal separation. The threat detection message is operationally an exceptional case rather than a routine event. The ATS threat detection service provides warning to conflicting aircraft. Primarily this service is designed for the ATS traffic area (5 mile radius, 3000 ft. AGL) and geared toward alerting pilots to pattern conflicts. However, threat detection for the rest of the ATS radar coverage area will be extended to logged in aircraft.

The detection logic examines each aircraft pair and compares their relative positions and velocities. The criteria used in determining that a conflict exists are predicted time to collision, predicted miss distance, current range, and current altitude separation when available. (The detection logic is described in detail in Appendix A.) This detection process is based on knowledge of the traffic pattern and does <u>not</u> alert on normal traffic pattern activities.

The content of the conflict message is both pattern dependent and conflict dependent. Conflicts are classified into four categories:

1. overtake,

2. pattern aircraft vs. an entry, departure, or unknown,

3. pattern aircraft with an en route aircraft, and

4. general (see Figure 5-1).

The message is worded to suggest the aircraft which should take action to resolve the conflict. The four conflict categories are discussed below with sample messages for each conflict geometry.

An overtake conflict is defined as an aircraft conflict pair in which one aircraft is behind the other in the pattern. For example, a crosswind aircraft could be overtaking a downwind aircraft as well as a downwind aircraft overtaking another downwind aircraft. This category does not include conflicts in which one of the aircraft is classified entry, departure, unknown, or en route.

The message will be directed at the trailing aircraft in the pair. The text of the message would be similar to the following:*

CONFLICT!!!
<ID> ON <u>DOWNWIND</u>, YOU ARE
OVERTAKING <ID> ON <u>DOWNWIND</u>
RANGE IS <u>1200</u> FEET.

* Note -- If the aircraft ID has not been recorded, the phrase, "UNLOGGED AIRCRAFT", will be substituted.

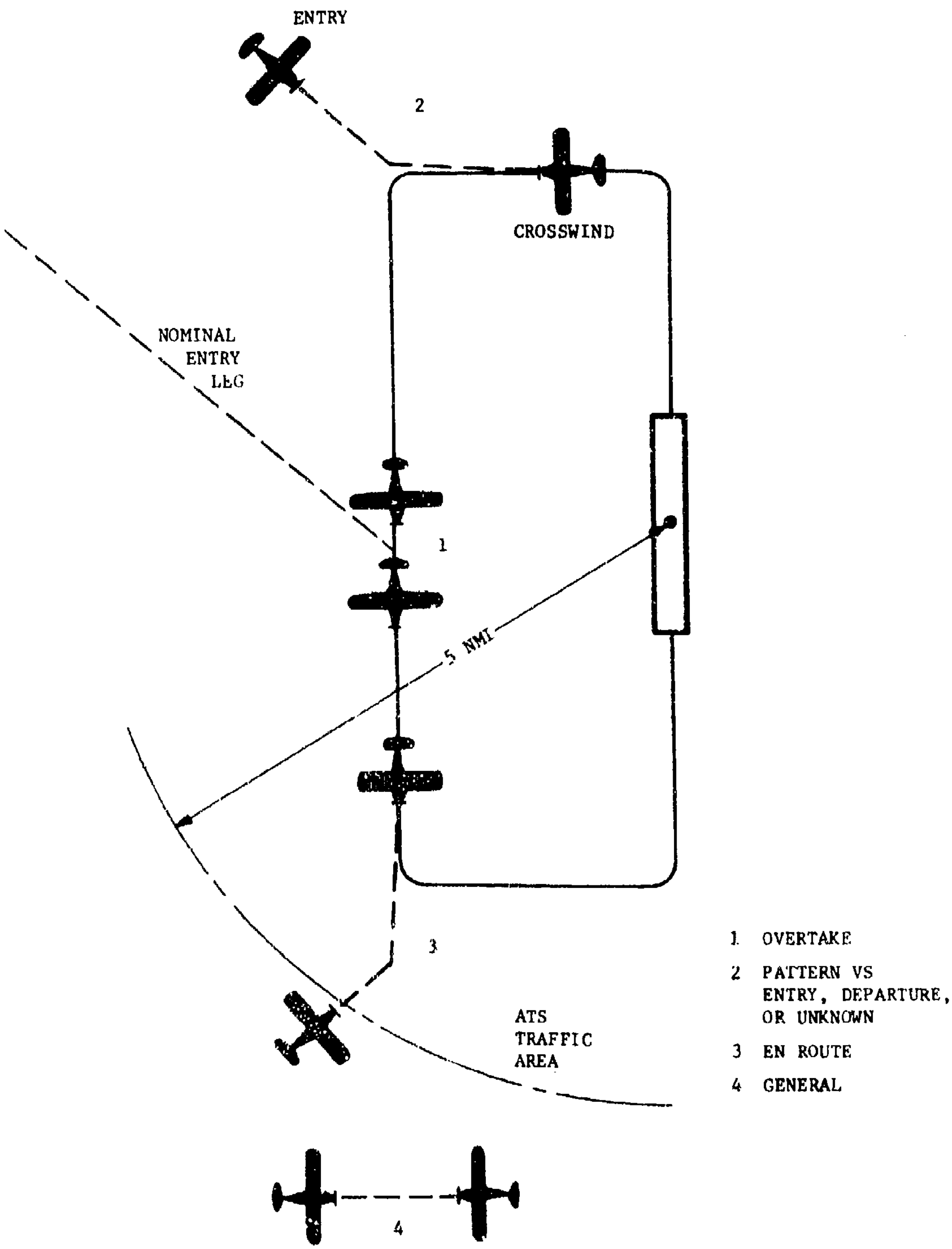


FIGURE 5-1
CONFLICTS IN THE TRAFFIC PATTERN AREA

If a pattern aircraft is in conflict with an aircraft classified entry, departure, or unknown, the message is directed to the latter and would be similar to the following:

CONFLICT!!!
<ID> ON ENTRY, YOU ARE IN
CONFLICT WITH <ID> ON DOWNWIND
AT 9 O'CLOCK. RANGE IS 1800
FEET.

When a pattern aircraft is in conflict with an en route aircraft (i.e., one beyond the ATS traffic area), the message is directed to the en route aircraft if it is logged in (i.e., the aircraft is cooperating with ATS procedures) or to the pattern aircraft if the en route is not logged in.

CONFLICT!!!
<ID> ON DOWNWIND, YOU ARE IN
CONFLICT WITH AN EN ROUTE
AIRCRAFT AT 5 O'CLOCK. RANGE
IS 2500 FEET.

OR

CONFLICT!!!
<ID> FLYING EN ROUTE, YOU ARE IN
CONFLICT WITH <ID> ON DOWNWIND
AT 1 O'CLOCK. RANGE IS 2500 FEET.

All other conflicts fall into a general category where it is suggested that both take action to resolve the conflict. The message would be similar to the following:

CONFLICT!!!
<ID>: TRAFFIC AT 9 O'CLOCK ON CROSSWIND
<ID>: TRAFFIC AT 12 O'CLOCK ON DOWNWIND.
RANGE IS 3000 FEET.

5.3 Sequencing Aids

This service is designed to improve traffic flow within the pattern, particularly at the entry-downwind merge point and the turn to final approach. Important traffic is announced to the pilot at strategic points in his flight. These messages are available only to logged aircraft.

5.3.1 Announce Observed Sequence

An observed landing sequence is announced to the pilot as he flies abeam of the runway threshold on downwind (see Figure 5-2). The announcement consists of the number of pattern aircraft "observed" between the aircraft eligible for the message and the runway threshold. The announcement does not assign a specific landing order, and it is not to be interpreted as a clearance. It is used, however, to assist the pilot in visually acquiring all aircraft ahead of him in the pattern. The sequence could change if an aircraft cut ahead in the pattern or be incorrect due the presence of an undetected (i.e., unequipped) aircraft. Once announced, the sequence number will not be revised or counted down as the aircraft ahead land.

As an extension to this service, ATS will announce aircraft observed on a long final approach. This announcement would be appended to the observed sequence message.

The message broadcast by ATS will be of the following form:

<ID>: YOU ARE NUMBER 4
TO THE RUNWAY.
(LONG FINALS IN PROGRESS)

5.3.2 Announce Important Traffic to Entry Aircraft

This announcement is designed to improve traffic flow at the entry-downwind merge point. Entry aircraft become eligible for the message as they approach the traffic pattern. The actual range is a system parameter. ATS examines the pattern for any other aircraft within close proximity. A message is produced only if there are aircraft to report. The message is strictly a traffic advisory and does not represent a threat detection.

The message format will be similar to the following:

<ID>: TRAFFIC AT 11 (AND 1) O'CLOCK
NEAR YOUR POINT OF ENTRY TO
THE PATTERN.

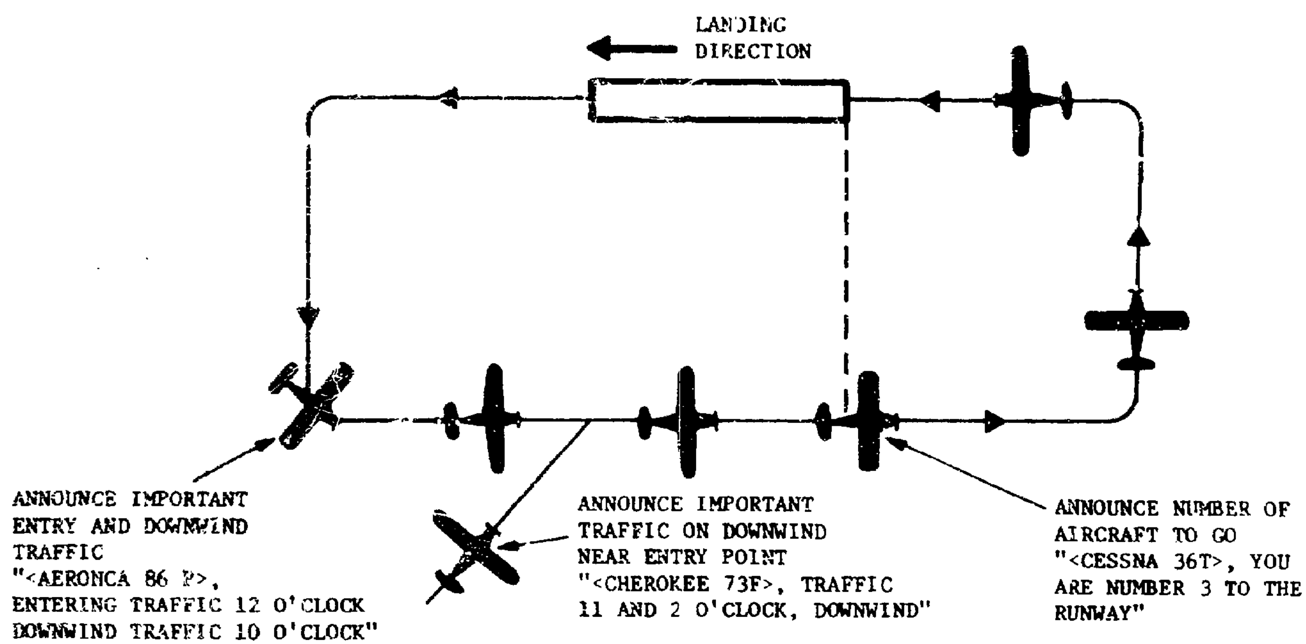


FIGURE 5-2
PATTERN SEQUENCING AIDS

5.3.3 Announce Important Traffic to Aircraft Turning Downwind

This advisory is designed for pattern aircraft transitioning to the downwind leg. It will announce entering traffic and advise on traffic already on downwind. Again, this is only an advisory and does not represent a threat detection.

The aircraft will be eligible for this advisory only once during the time it is classified downwind. If there is no traffic to report, no message is given.

The message format will be similar to the following:

<ID>: ENTERING TRAFFIC AT 2 O'CLOCK
DOWNWIND TRAFFIC AT 10 O'CLOCK

5.4 Special Aircraft Status

Aircraft which fall into the category of special status are considered a potential threat to pattern aircraft. ATS will announce the position of these aircraft both periodically and at strategic points in their flight paths.

5.4.1 Emergency Aircraft

Any aircraft squawking 7600 or 7700 in the airport traffic area will be given emergency status by ATS. Announcements of the aircraft's position will be broadcast at 1 minute intervals and no messages will be directed to the "emergency aircraft." When the aircraft departs from the traffic area or lands, a final message will be sent.

The messages will have a format similar to the following:

EMERGENCY AIRCRAFT 3 MILES N.W. OF
MANASSAS EASTBOUND

EMERGENCY AIRCRAFT DEPARTING MANASSAS
5 MILES N.W.

5.4.2 Unlogged Aircraft Reports

If an equipped aircraft with transponder and altitude encoder fails to log in before penetrating the airport traffic area, ATS will assume that the aircraft is uncooperative and alert the pattern of its entry into the system. This will also act as a reminder for those who simply forgot to log in, but are tuned to the tactical frequency. If the aircraft joins the pattern and remains unlogged, however, announcements at the time he turns downwind and base will be broadcast. Announcements of nonstandard pattern and threat detection messages will still be directed toward these aircraft. The term "unlogged aircraft" will be used in place of the aircraft's ID which, of course, is not available.

The unlogged aircraft reports will have a format similar to the following:

UNLOGGED AIRCRAFT
4.5 MILES N.W.
SOUTHEASTBOUND

UNLOGGED AIRCRAFT TURNING DOWNWIND

UNLOGGED AIRCRAFT TURNING BASE

5.5 IFR Operations Support

Wherever appropriate, the other services make special provisions for IFR aircraft. Certain messages are unique to IFR operations and are gathered here into a single service group. The unique services are:

1. Announce IFR traffic to the rest of the traffic pattern.

2. IFR approach monitoring.

3. Outbound handoff operation.

These services are provided based on adaptation data within the ATS computer that describes individual approach geometry and minima for each approach at the airport.

5.5.1 Announce IFR Operations

IFR arrivals will be announced when they first enter the ATS traffic area. They will also be called when they penetrate a 3-mile and 1-mile range ring from the center of the runway. One final announcement will observe the IFR aircraft's sequence on final approach when he first turns to final. IFR aircraft departing the area will generate similar announcements at 1, 3, and 5 miles from the airport center.

Sample messages are as follows:

"IFR ARRIVAL <ID> IN PROGRESS 3 MILES N.E. OF MANASSAS"

"IFR ARRIVAL <ID> IS NUMBER 2 ON FINAL APPROACH"

"IFR AIRCRAFT <ID> DEPARTING MANASSAS 5 MILES N

5.5.2 Approach Monitoring

Approach monitoring is provided to assist the pilot, particularly during non-precision approaches where altitude guidance is not available. It does not modify the responsibility of the pilot to conduct a safe approach and make his own decision to continue or miss an approach at any point. Several monitoring services will be explored in the test bed. A nominal set is given as follows.

The start of the approach is supported by the ATIS message given at IFR login. This provided weather, traffic situation, and confirmed the particular approach to be conducted. The pilot still uses the approach plate as primary information (see e.g., Figure 5-3). The following first considers the non-precision approach.

The ATS system will call Final Approach Fix (FAF) for the approach:

"<ID> NOW AT FINAL APPROACH FIX
FOR NDB-A, MANASSAS"

The pilot may initiate his descent as he sees fit and is still responsible for determining the minimum descent altitude (MDA) appropriate to his aircraft category.

At the missed approach point (MAP), the ATS system will provide a message based on its surveillance data. The pilot must determine whether to continue the approach, with runway environment in sight, or miss the approach. Phraseology might be:

"<ID> AT MISSED APPROACH POINT NDB-A"

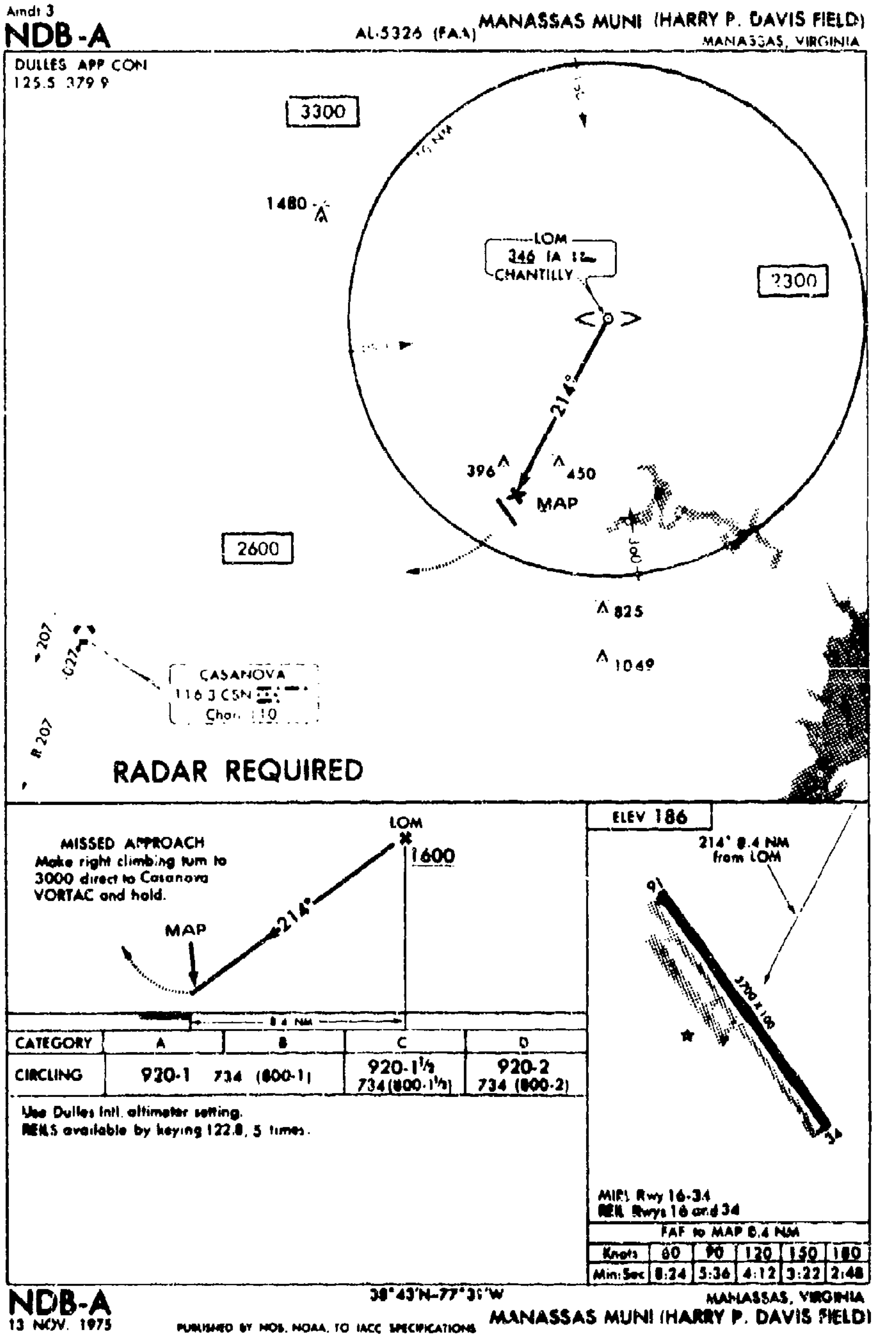


FIGURE 5-3
TYPICAL NON-PRECISION INSTRUMENT APPROACH

During the entire approach from FAF to MAP, the ATS system will compute deviation from approach centerline. When significant, the deviation will be called:

> "<ID> IS 0.3 MILES LEFT OF
> APPROACH COURSE"

For a precision approach, the missed approach call is omitted because glide slope is available. Monitoring will be provided for lateral deviation.

5.5.3 Outbound Handoff

At an appropriate outbound handoff range the aircraft will be prompted to change frequency and contact ATC. Since the flight plan discrete code is already in use, the responsible controller should be able to immediately identify the aircraft when in radar coverage. The message phraseology would be:

> "IFR DEPARTURE
> <ID>: CONTACT DULLES APPROACH
> 126.1"

The ATS system would mark the aircraft as unlogged since it is no longer monitoring the tactical frequency.

5.6 Pattern Management Services

The function of the pattern management services is to maintain a standard traffic pattern, to keep control of traffic pattern density, accommodate special operations, and reduce waiting time on departure. Actions can be triggered by the number of aircraft in the pattern, the number of aircraft in the departure queue, the length of time the aircraft at the head of the queue has been waiting, or other measures of total traffic activity.

The basic automation environment described in the previous sections permits other service features to be added with only software additions. It is expected that services, especially in this group, will evolve during test activities.

5.6.1 Nonstandard Patterns

Pilots will be expected to fly a standard right or left pattern with standard entry and departure procedures when operating in the ATS traffic area. A pilot attempting to enter the traffic area in other than the entry corridor (Section 3.1.1) may be issued a warning that includes information on the active runway and whether it is a left-or-right-handed pattern.

<ID>: IMPROPER ENTRY TO
RUNWAY 36. LEFT-HAND
TRAFFIC.

Pilots who are in the traffic area and not conforming to the standard pattern may also receive a warning:

<ID>: NONSTANDARD PATTERN
1.5 MILES N.E.

This is not very restrictive, however. An aircraft may stray from a nominal pattern direction anywhere within a 45° wedge about nominal before it is classified 'ZZZ' (unknown pattern state). Furthermore, ATS will wait several scans before issuing the nonstandard pattern. However, if the aircraft is consistently classified 'ZZZ', the message will be repeated at 1 minute intervals.

While the message is directed at one aircraft to adjust his flight path to be more consistent with the standard pattern, it also serves as an advisory to the other aircraft that something nonstandard is occurring. These messages can be directed to any equipped VFR aircraft. In the case of low density traffic, these messages would not be generated since the nonstandard activity would not impact other aircraft.

These messages are not generated for IFR aircraft since they may execute instrument approaches and circle-to-land operations independent of the VFR traffic flow.

5.6.2 Touch-and-Go Operations

A large fraction of the operations at many typical general aviation airports consists of touch-and-go landing practice. This can result in a very high operations rate and significant delays to aircraft waiting to depart. Two types of messages are available to ATS:

1. Request individual aircraft which have been executing multiple touch-and-go's to join the departure queue on the next approach, thereby creating a break in the circulation around the pattern.

2. Terminate all touch-and-go operations for a specified period of time.

Of course, some airports do not authorize touch-and-go's at all in current practice (e.g. due to a short runway with obstruction) and this could be continued with ATS.

The first form of message is implemented with a touch-and-go count stored for each aircraft by the ATS computer. The count will be incremented each time the aircraft's pattern state transitions to take-off (TOF). When traffic density increases to an appropriate level or the departure queue becomes large, the touch-and-go count will be compared with a maximum set for the airport. Aircraft surpassing this maximum will be requested to stop touch-and-go operations to allow departures to occur. This message would be spoken when the aircraft's pattern state transitions to take-off (TOF):

<RED AND WHITE CHEROKEE 35 TANGO>:
NO TOUCH-AND-GO ON NEXT APPROACH

The pilot may then choose to leave the airport or land and join the departure queue. The aircraft's touch-and-go count will be zeroed when the aircraft joins the departure queue or is classified as having left the pattern (ERA pattern state).

If periodically stopping individual aircraft is unsatisfactory in reducing traffic density, it may be necessary to eliminate all touch-and-go's.

This action will only be undertaken if the ratio of the rate of touch-and-go's to the total operations rate is high enough so that the action will have an appreciable effect. Touch-and-go's would be restricted for a fixed length of time. If there are two frequencies in use, the message would also appear in the ATIS:

TOUCH-AND-GO OPERATIONS SUSPENDED UNTIL 1400 HOURS

5.6.3 Crossing Runway Operations

A pilot may elect to operate on a runway other than the designated active runway either because of operational conditions (e.g., runway length, braking effectiveness, navigation aids, etc) or in order to practice crosswind operations. Use of an alternate runway is made known to ATS using a special transponder code as described in Section 3.2.5.

However, in high density situations, restrictions may be placed on aircraft performing practice operations. Practice operations would be restricted for a given length of time, and the message would also appear in the ATIS if there are two frequencies.

> "VFR PRACTICE OPERATIONS SUSPENDED ON RUNWAY 27 UNTIL 1400 HOURS"

The pilot requiring a crossing runway for operational reasons would still continue his operation.

The ATS system provides messages to alert the remainder of the traffic pattern to a crossing runway operation. The computer can select the pattern state of the aircraft with respect to the runway being used and provide this data in the messages. The system calls the turn to base and final of the crossing runway aircraft.

> "<ID> IS TURNING BASE FOR RUNWAY 24"

> "<ID> ON ONE-HALF MILE FINAL FOR RUNWAY 24"

The system will also announce departure operations at the point the departure leg is established:

> "<ID> MAKING LEFT DEPARTURE RUNWAY 24"

These messages would occur only if other aircraft are in close enough proximity to benefit by the traffic point out.

5.6.4 Departure Management

If the departure queue is long or an aircraft at the head of the queue has waited a long time to depart, ATS will attempt to open a "slot" in the pattern to enable the departure of several aircraft. The next aircraft that passes the runway threshold on the downwind leg will be requested to extend his downwind leg a finite distance past the runway threshold.

"<ID>: EXTEND DOWNWIND 1 MILE"

To maintain sequence, aircraft following this one will also extend downwind, and a departure slot will thus be formed.

The presence of an IFR aircraft in the departure queue will increase the probability that the extend message will be generated. This is accomplished by adjusting the computer thresholds to favor IFR aircraft.

5.6.5 Announcing Runway Status

While ATIS generally provides information on the airport's active runway, it will be necessary to draw special attention to runway changes. Messages to broadcast the opening, closing, or reversal of a runway will be repeated for a sufficient period to allow the aircraft to alter their flight paths. Runways will be reversed only when traffic density is low and only by manual command of the local airport operator console, similar to the present practice of changing the active runway during a traffic lull.

Messages would be:

"ACTIVE RUNWAY IS CHANGED TO RUNWAY 34 AT 1210 HOURS"

"RUNWAY 18 IS CLOSED TO TRAFFIC"

The messages would be broadcast sufficiently ahead of time to allow aircraft to alter their flight paths. The ATIS message will alert aircraft just entering the traffic area, and all others will hear the announcements over the tactical frequency.

5.7 Pilot Initiated Services

This category of services is reserved for additional assistance which ATS may give, on request, to a pilot operating in the radar coverage area. At the present, only two services are envisioned: to provide a position fix on request, and repeat an ATS message. However, additional services may be tested at the ATS test bed.

5.7.1 Request a Position Fix

To obtain a position fix from ATS, the pilot squawks a separate published discrete code (Position Request, Table 3-1). Only logged aircraft can utilize this service. The ATS computer responds as follows:

<ID>: POSITION IS 5 MILES S.W. OF MANASSAS
BEARING TO AIRPORT 227 DEGREES

The pilot then returns to his assigned transponder code. The message would have a low priority, and the service may be turned off in high traffic density situations.

5.7.2 Message Repeat

A pilot may miss a portion of a message which was broadcast on the tactical frequency. This service permits the pilot to receive the last message directed to him or last general message (e.g., NO TOUCH AND GO'S UNTIL 1400 HOURS) as appropriate. The message will be of the following form:

<ID>: LAST MESSAGE
YOU ARE NUMBER 4
TO THE RUNWAY.

The message is requested by changing to the Message Repeat transponder code (Table 3-1). ATS will regenerate the appropriate message (which may mean, for example, that "TEN O'CLOCK" in the original message becomes "ELEVEN O'CLOCK" in the repeated message). The pilot then transitions back to his assigned transponder code.

6. EXAMPLE OPERATIONS AS SEEN BY THE PILOT

The prior sections have described the messages generated by the ATS system and the conditions which cause them to be spoken. This section will present a brief example of ATS messages in context for a heavy traffic situation.

The following scenario is assumed:

1. The ATS configuration supports two discrete VHF frequencies (one for login and the other tactical channel for ATS messages).

2. All aircraft are equipped with working radios and 4096-code transponders.

3. All aircraft log into the system.

4. During the period of observation, there is heavy traffic at the ATS airport (instantaneous airborne count of 12 aircraft in and near the traffic pattern). The services will be operating at a traffic density where call outs of traffic are occurring frequently. In less active periods, a pilot might login and then receive no messages during his entire operation.

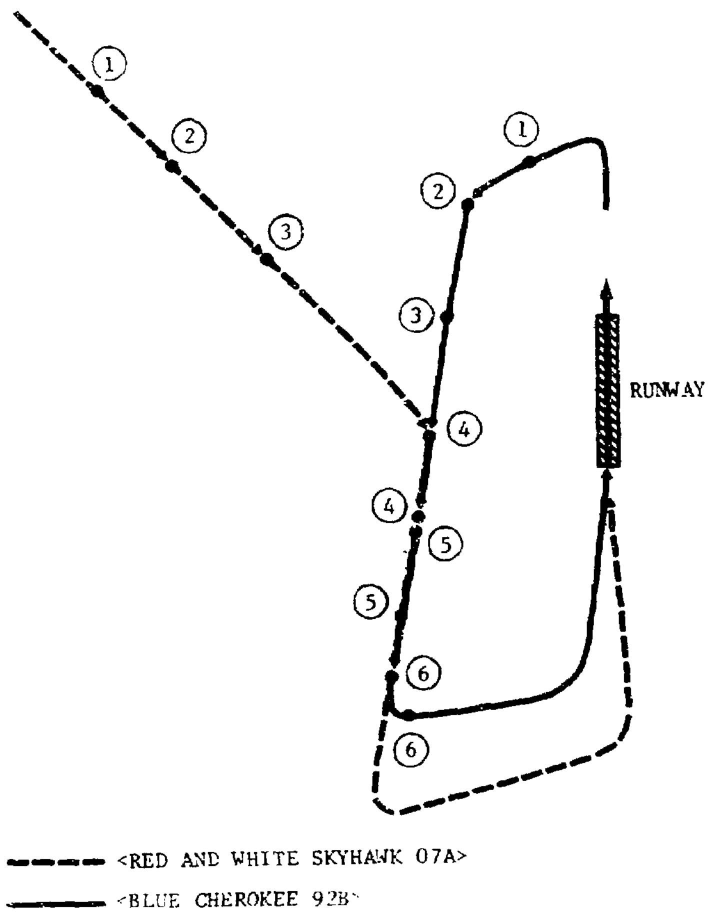
The scenario has been suggested by actual data taken at a typical general aviation airport (Manassas) [12]. This data was fed into an ATS simulation which generated the same messages as an actual ATS system at the airport might have produced.

The progress of two VFR aircraft of the many simultaneously active in the traffic pattern are described in detail in the following paragraphs. The first takes off on Runway 34 and circulates in the pattern. The other is a typical arrival to the airport.

In this example, which covered 5 minutes during a busy Sunday afternoon (150 operations per hour), the channel utilization for the ATS tactical frequency was 45%. Only the messages relevant to the two example aircraft (as shown in Figure 6-1) are discussed in the following sections. Section 6.3 will discuss the complete transcript of messages.

6.1 Aircraft Departing the ATS Airport

The first pilot arrives at Manassas airport at twelve o'clock noon. At 15 minutes past the hour, the pilot starts the engine



- NUMBERS ARE ASSOCIATED WITH THE FOLLOWING MESSAGES:

  (1) 12:21:58
  <BLUE CHEROKEE 92B>
  NONSTANDARD PATTERN
  1 MILE NORTH

  (2) 12:22:14
  <BLUE CHEROKEE 92B>
  DOWNWIND TRAFFIC AT 11 O'CLOCK

  (3) 12:22:34
  <RED AND WHITE SKYHAWK 07A>
  TRAFFIC AT 11 O'CLOCK ON DOWNWIND

  (4) 12:23:10
  <BLUE CHEROKEE 92B>
  YOU ARE NUMBER 4 TO THE RUNWAY

  (5) 12:23:26
  <RED AND WHITE SKYHAWK 07A>
  YOU ARE NUMBER 4 TO THE RUNWAY

  (6) 12:23:50
  CONFLICT!!!
  <RED AND WHITE SKYHAWK 07A>: TRAFFIC AT 12 O'CLOCK ON BASE
  <BLUE CHEROKEE 92B>: TRAFFIC AT 9 O'CLOCK ON DOWNWIND
  RANGE IS 1500 FEET.

- ONLY THE TWO AIRCRAFT DESCRIBED IN THE EXAMPLE ARE SHOWN. OTHER AIRCRAFT ARE ALSO ACTIVE DURING THIS TIME PERIOD.

FIGURE 6-1
TRACKS OF AIRCRAFT PAIR DESCRIBED IN TEXT

of his blue Cherokee and performs his pre-flight checklist. As part of this checklist, he tunes his radio to the ATS login frequency and squawks the general login code for VFR aircraft. At 12:17:30 he receives the following message:

AIRCRAFT REQUESTING LOGIN
ON RAMP AT MANASSAS
SAY YOUR ID...

The pilot then issues a description of his aircraft including part of his tail number over the login frequency for the ATS computer to record.

<BLUE CHEROKEE 92B>

ATS then responds with an assigned discrete code.

AIRCRAFT <BLUE CHEROKEE 92B>
SQUAWK 1527

Observing that the recorded ID is acceptable to him, the pilot squawks 1527 and receives the reply.

<BLUE CHEROKEE 92B>
LOGGED IN AT MANASSAS
FOR RUNWAY 34
SQUAWK STANDBY UNTIL
READY FOR TAKEOFF.

The pilot switches the transponder to standby mode and waits for the ATIS message which follows the login procedure.

MANASSAS LANDING 34
ALTIMETER 29.92
WINDS 030 AT 10 KNOTS
8 AIRCRAFT IN TRAFFIC AREA
TUNE TO ATS FREQUENCY 122.9

The pilot then tunes his radio to the ATS tactical frequency and joins the departure queue. The pilot becomes the head of the queue and observes that base and final approach airspace is clear at 12:20:10. He switches the transponder on and begins his takeoff roll.

The first message is issued to the pilot at 12:21:58 and reflects the fact that he is cutting corners on crosswind with considerable traffic in the pattern:

<BLUE CHEROKEE 92B>
NONSTANDARD PATTERN
1 MILE NORTH

At 12:22:14, the pilot turns onto the downwind leg and receives an announcement about important traffic.

<BLUE CHEROKEE 92B>
DOWNWIND TRAFFIC AT 11 O'CLOCK

This is interpreted as traffic almost directly ahead of you on the downwind leg of the pattern.

At 12:23:10, the pilot is abeam to runway threshold and receives his observed sequency.

<BLUE CHEROKEE 92B>
YOU ARE NUMBER 4
TO THE RUNWAY.

This should be interpreted in the following manner: There are three transponder equipped aircraft ahead of you in the pattern. (Remember, unequipped aircraft will be calling their position in the pattern but not counted in this message.)

At 12:23:50 as the pilot is turning to the base leg, the following message is issued:

CONFLICT!!!
<RED AND WHITE SKYHAWK 07A>: TRAFFIC AT
12 O'CLOCK ON BASE
<BLUE CHEROKEE 92B>: TRAFFIC AT
9 O'CLOCK ON DOWNWIND
RANGE IS 1500 FEET.

At this point, the pilot should look to the left to find the other aircraft and decide if evasive action is necessary.

In the actual data, the other pilot extended downwind to increase separation and there were no further conflict warnings. Meanwhile, the Cherokee pilot turns to final approach and lands the aircraft without receiving any further messages. He turns the transponder off as soon as practical, and ATS automatically removes him from the system.

6.2 Aircraft Arriving at the ATS Airport

The second aircraft is the red and white Skyhawk which was in conflict with the Cherokee in the previous discussion. ATS acquires track on the Skyhawk when it is 15 miles from the airport. The pilot doesn't log in, however, until he is 5-1/2 miles away. He tunes to the login frequency and squawks the general login code for VFR aircraft. At 19 minutes past twelve o'clock he receives the following message:

AIRCRAFT REQUESTING LOGIN
5.4 MILES NW OF MANASSAS
SAY YOUR ID...

The pilot responds with

<RED AND WHITE SKYHAWK 07A>

ATS assigns his discrete code.

AIRCRAFT, <RED AND WHITE SKYHAWK 07A>
SQUAWK 1530

The pilot squawks 1530 and receives the reply

<RED AND WHITE SKYHAWK 07A>
LOGGED IN AT MANASSAS
FOR RUNWAY 34

The pilot then waits for the ATIS message before tuning to the ATS frequency.

MANASSAS LANDING 34
ALTIMETER 29.92
WINDS 030 AT 10 KNOTS
9 AIRCRAFT IN TRAFFIC AREA
TUNE TO ATS FREQUENCY 122.9

At 1.4 miles from the runway, the pilot receives his first message (clock time - 12:22:34)

<RED AND WHITE SKYHAWK 07A>
TRAFFIC AT 11 O'CLOCK
ON DOWNWIND

The message informs him that there is traffic near his merge point to the downwind leg.

The next message occurs at 12:23:36 when the aircraft is abeam runway threshold and indicates the aircraft's observed sequence.

<RED AND WHITE SKYHAWK 07A>
YOU ARE NUMBER 4
TO THE RUNWAY.

This indicates that there are at least 3 aircraft ahead of him to land.

At 12:23:50 he receives the conflict message that the blue Cherokee received in the first example.

CONFLICT!!!
<RED AND WHITE SKYHAWK 07A>: TRAFFIC AT
12 O'CLOCK ON BASE
<BLUE CHEROKEE 92B>: TRAFFIC AT
9 O'CLOCK ON DOWNWIND
RANGE IS 1500 FEET.

The pilot sees the traffic ahead of him that has just turned base leg and realizes that he is closing too fast. He delays his turn to base to increase the separation.

The pilot receives no further messages and turns his transponder off as soon as is practical after he lands.

6.3 Transcript of All Messages on ATS Tactical Channel

The discussion in the preceding sections identified only those messages directed to the two example aircraft. There are messages being generated for other aircraft and for the traffic pattern at large during the same time interval. Figure 6-2 is a summary of all messages on the tactical channel. The columns in the figure (left to right) are:

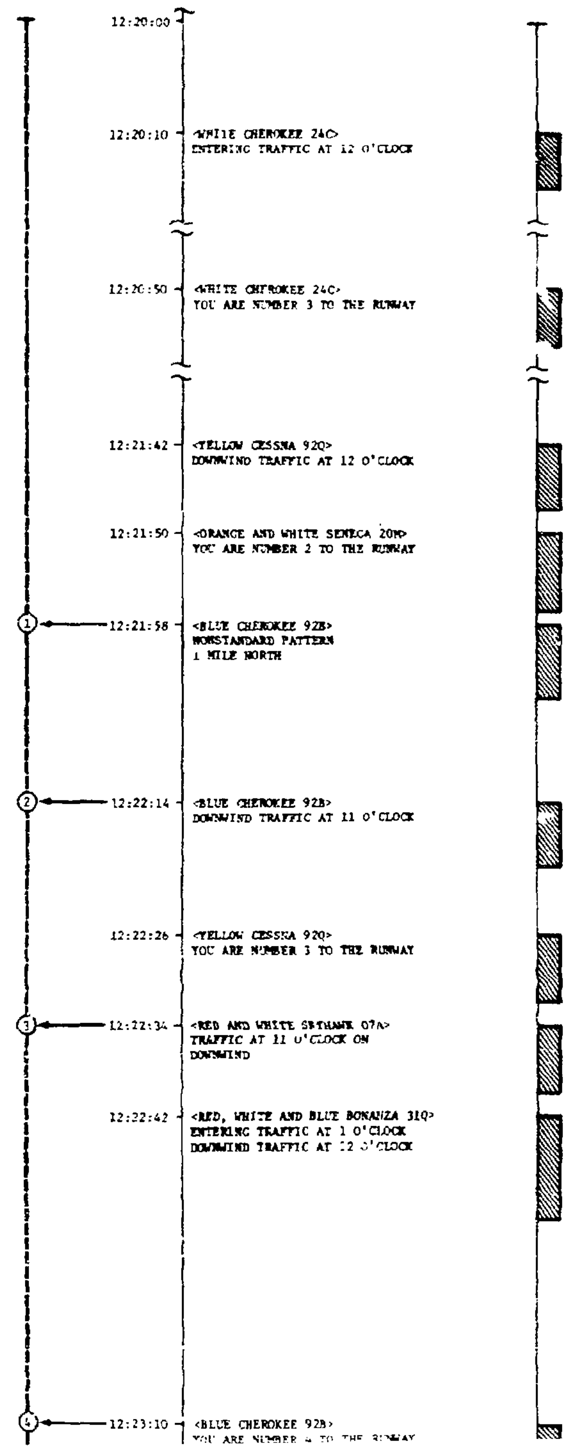
1. A key to the six messages to the example aircraft.

2. Time each message started (in hours:minutes:seconds format).

3. Content of each message.

4. Channel utilization. The shaded segments represent those periods during which ATS is transmitting on the channel.

Figure 6-2 covers the 5 minute period of the examples.


12:20:00
12:20:10
<WHITE CHEROKEE 24C>
ENTERING TRAFFIC AT 12 O'CLOCK
12:20:50
<WHITE CHEROKEE 24C>
YOU ARE NUMBER 3 TO THE RUNWAY
12:21:42
<YELLOW CESSNA 92Q>
DOWNWIND TRAFFIC AT 12 O'CLOCK
12:21:50
<ORANGE AND WHITE SENECA 20M>
YOU ARE NUMBER 2 TO THE RUNWAY
1
12:21:58
<BLUE CHEROKEE 92B>
NONSTANDARD PATTERN
1 MILE NORTH
2
12:22:14
<BLUE CHEROKEE 92B>
DOWNWIND TRAFFIC AT 11 O'CLOCK
12:22:26
<YELLOW CESSNA 92Q>
YOU ARE NUMBER 3 TO THE RUNWAY
3
12:22:34
<RED AND WHITE SKYHAWK 07A>
TRAFFIC AT 11 O'CLOCK ON
DOWNWIND
12:22:42
<RED, WHITE AND BLUE BONANZA 31Q>
ENTERING TRAFFIC AT 1 O'CLOCK
DOWNWIND TRAFFIC AT 12 O'CLOCK
4
12:23:10
<BLUE CHEROKEE 92B>
YOU ARE NUMBER 4 TO THE RUNWAY

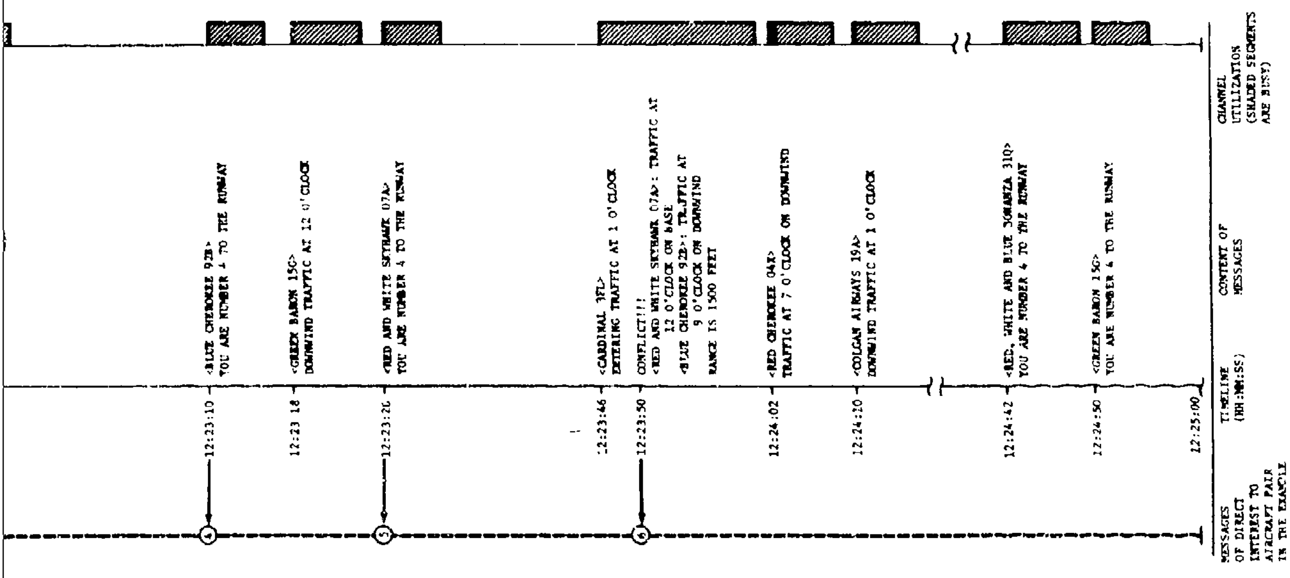


FIGURE 6-2
TRANSCRIPT OF ATS TACTICAL CHANNEL MESSAGES
(HIGH DENSITY EXAMPLE)

This figure is based on estimated message lengths and a simulated scenario. Further study of channel utilization will be done in the feasibility test bed.

APPENDIX A

KEY PORTIONS OF THE COMPUTER DECISION LOGIC

The purpose of this appendix is to explain two key parts of the logic used by the system to generate the ATS messages. The first section examines pattern state classification, a method of establishing a labeling which describes an aircraft's geographic position and its intentions in the traffic area. Most of the services simply examine pattern state transitions to determine when to produce the required messages and therefore, are very simple tests of the pattern state. The second section is a simplified description of threat detection logic concepts. The issue here is effective warning with minimum false alarms in the traffic pattern.

A.1 Pattern Classification

When ATS by virtue of its collision avoidance or management functions makes any tactical or strategic decisions, it needs to know enough about the aircraft to issue commands or advisories in a manner biased toward or compatible with the recommended standard pattern [10]. The aircraft pattern state is central to this concept. ATS assigns to each aircraft a pattern state which is updated each time the radar acquires new data on the aircraft. Ground and transition aircraft are categorized based on speed and position relative to the airport surface. For airborne aircraft, it uses nine basic geographic zones in conjunction with its knowledge of the aircraft's direction of movement to achieve this classification.

A.1.1 Ground State Classification

Aircraft which are below 200' AGL, traveling slower than 47 knots (54 mph), and positioned within a half mile radius of the midpoint of the runway fall into one of the four possible ground states - ramp (RMP), departure queue (DPQ), takeoff roll (TRL), and landing roll (LRL). An unlogged aircraft satisfying the above conditions is classified RMP. Once the aircraft logs into the system, the state is promoted to DPQ and the departure queue length is incremented. As per login procedures, the pilot then squawks standby until ready to roll on the runway. When a firm track again appears for the aircraft, the pattern state is updated to TRL and the departure queue length is decremented. The last state, LRL, is achieved when the above criteria are satisfied, and the aircraft was previously in a landing state (LDG - see transition state classification).

A.1.2 Transition State Classification

Aircraft which are below 200' AGL, traveling faster than 47 knots (54 mph), and positioned within a mile radius of the midpoint of the runway are classified either liftoff (LOF) or landing (LDG). Aircraft are classified LOF if the previous state was TRL or LOF and the above criteria are met. This is also true if the previous state was LDG or LRL and the aircraft has passed the far end of the runway. Aircraft are classified LDG if their previous state was final (FNL - see airborne classification) or LDG.

A.1.3 Airborne State Classification

All aircraft which were not classified into a ground or transition state fall into this category. First, aircraft coordinates are transformed into a standard runway coordinate system. The center of the runway is the origin, and the crosswind and downwind direction in a nominal left hand pattern form the X and Y axes. The aircraft position is classified into one of nine geographic zones and its velocity vector is used to quantize its bearing into one of eight cardinal directions. Finally, this information is used to find the pattern state of the aircraft by a table look-up. This process is described in more detail in the following sections. The diagrams illustrate pattern classification for a left hand pattern. The diagrams for a right hand pattern would simply be the mirror image.

A.1.3.1 Geographic Zones

The zone structure for a typical ATS airport is depicted in Figure A-1 and is defined by six horizontal parameters and one vertical parameter (the height of the cylindrical airspace).

Zone 9 defines the ATS traffic area which is 5 miles in radius and extends 3000' AGL. Aircraft in this zone are considered en route aircraft (ERA). Zone 8 extends from the 5 mile boundary to an inner boundary of 3 miles. Aircraft in this zone are classified either as an entry (ENT) or a departure (DEP) based on whether the aircraft's range rate from the airport center is negative or positive. If the aircraft is not in either of these zones, it must lie in one of the seven zones of the pattern area. Of these, zones 7, 6, 5, 4, and 1 are computed by simple X, Y tests, since these zones are bound by lines parallel to the axes. Zones 2 and 3 are formed by translating the origin to the corner point defining the quadrant and comparing the new aircraft range vector with a radius defining the entry sector (Zone 3).

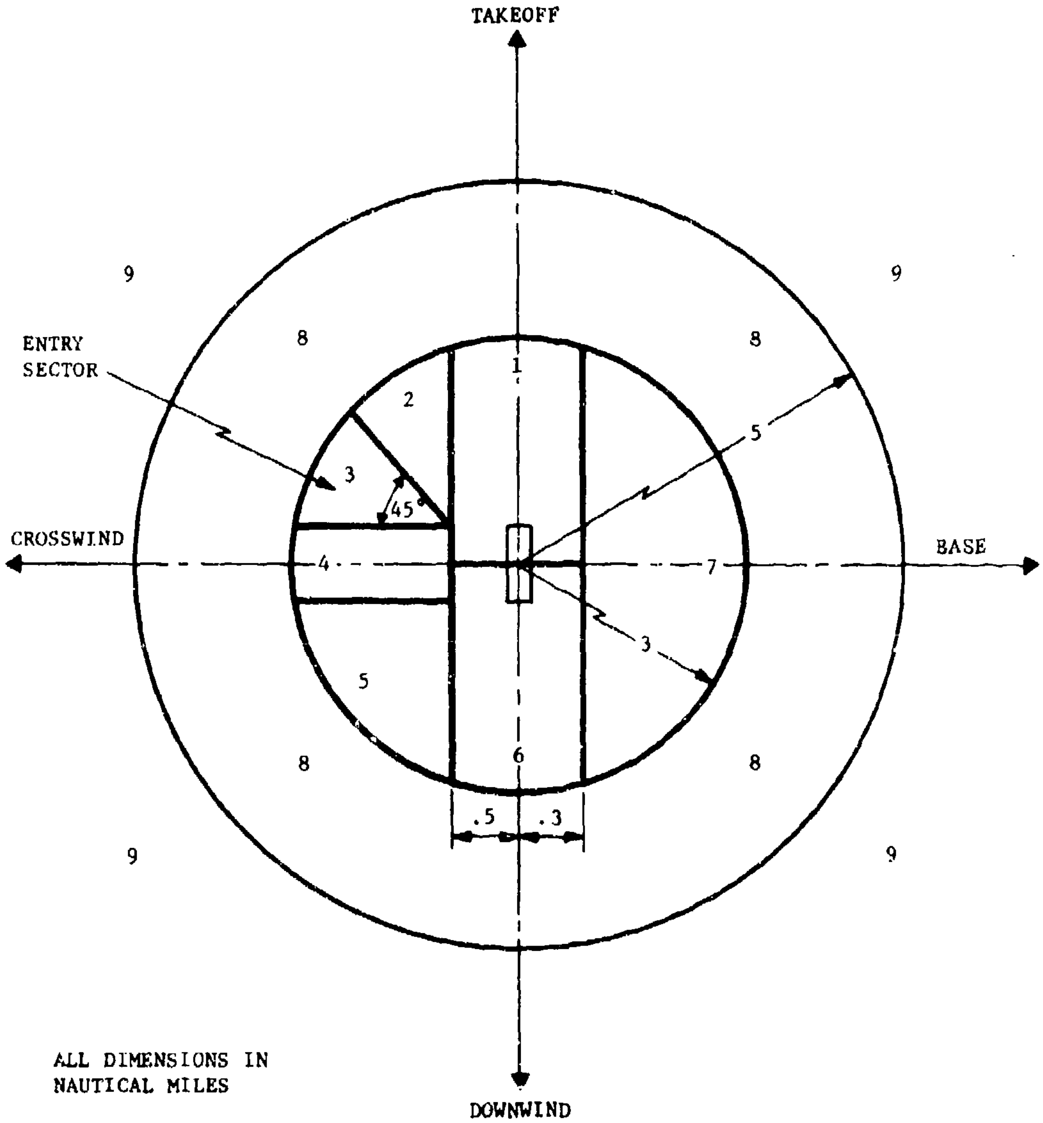


FIGURE A-1
GEOGRAPHIC ZONES

A.1.3.2 Cardinal Directions

The cardinal direction is obtained by the aircraft's velocity vector as referenced to the runway coordinate system. The logic finds the one cardinal direction out of 8 that the velocity vector is closest to. This output, in conjunction with the geographic zone number, is used to determine the airborne pattern state. A breakdown of the cardinal directions with respect to the traffic pattern appears in Figure A-2.

A.1.3.3 Classification Methodology

The remainder of the airborne states are selected by table look-up using the eight cardinal directions and seven remaining geographic zones (pattern states associated with zones nine and eight are independent of the table look-up [section 1.3.1]). The pattern classification table appears in Table A-1. A summary chart of all of the pattern states appeared in Table 5-1. Pattern state changes are delayed by one scan to reduce changes caused by noisy tracks. The delay is increased to three scans if the change is to an unknown pattern state.

A.2 Conflict Detection Logic

Conflict detection in an ATS system was reviewed in system studies [12] which evaluated the effectiveness of using different detection logics in the traffic pattern. The key result of the studies was that a pattern dependent logic (in which detection thresholds are selected based on the pattern state of the aircraft in the conflict pair) will be required to perform effective threat detection in ATS. To be effective, a logic must yield sufficient warning with acceptable alarm rate in the pattern.

A possible approach to the logic can be sketched based on the preliminary data from the above studies. Criteria used in determining that a conflict exists include tau, miss distance, range, and altitude separation. With the exception of altitude separation, these criteria are all in the horizontal plane. A brief description of the criteria follows:

1. Horizontal Tau (TAU) This is a measure of the time to collision in the horizontal plane. Typical estimator are tau (range over range rate), modified tau, time to closest approach, and time to a separation standard. Each has particular advantages in determining conflict status.

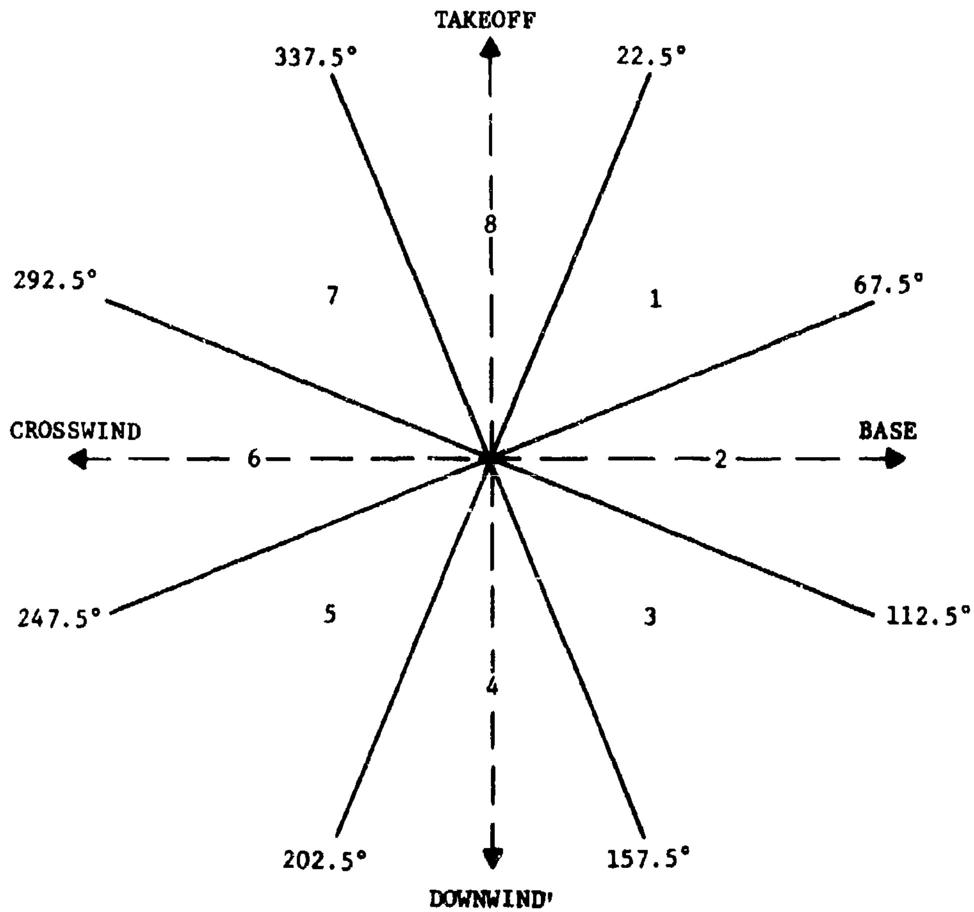


FIGURE A-2
CARDINAL DIRECTION ADDRESSING SCHEME

TABLE A-1
PATTERN CLASSIFICATION TABLE

CARDINAL DIRECTION

HORIZONTAL ZONE	1	2	3	4	5	6	7	8	
1	TOF	DEP	ZZZ	ZZZ	ZZZ	XWD	TOF	TOF	1
2	ZZZ	ZZZ	ENT	DWD	DWD	XWD	DEP	DEP	2
3	ZZZ	ENT	ENT	DWD	DWD	XWD	DEP	DEP	3
4	ZZZ	ZZZ	DWD	DWD	DWD	DEP	ZZZ	ZZZ	4
5	BSE	BSE	DWB	DWB	DEP	DEP	ZZZ	ZZZ	5
6	BSF	BSF	BSF	DEP	ZZZ	ZZZ	FNL	FNL	6
7	DEP	DEP	DEP	ZZZ	ZZZ	ZZZ	ZZZ	ZZZ	7

TOF - TAKEOFF
XWD - CROSSWIND
DWD - DOWNWIND
DWB - DOWNWIND NEAR BASE
BSE - BASE
BSF - BASE NEAR FINAL
FNL - FINAL
ENT - ENTRY
DEP - DEPARTURE
ZZZ - UNKNOWN

2. Horizontal Miss Distance (PMD) - This is defined to be the minimum horizontal separation that will occur between the aircraft in the future if both maintain constant horizontal velocity vectors.

3. Range (R) - This is defined to be the current horizontal separation between aircraft.

4. Altitude Separation (ALT) - This is defined to be the current vertical separation between aircraft.

A conflict is declared if tau is positive and less than a given threshold and the predicted miss distance is less than its corresponding threshold, or the range criterion is below its threshold:

```
  IF ((TAU > 0 & TAU < TAUTH & PMD < PMDTH)|R < RTH) & ALT < ALTTH

THEN

  /*CONFLICT*/
```

where TAUTH, PMDTH, ALTTH and RTH are the tau, predicted miss distance, altitude separation, and range thresholds respectively.

The thresholds are selected based on the pattern state classification of the two aircraft. An example set of thresholds is given in Table A-2. The values in the table are the results of a Monte Carlo study conducted to determine effective threshold levels for a traffic pattern environment. The thresholds were varied to establish a balance between escape effectiveness and the resulting false alarm rate.

Other factors affecting these thresholds might be day/night operations, traffic density, IFR/VFR, or whether either aircraft is uncooperative (i.e., unlogged). The detection logic is not executed when both aircraft in the pair are below 200 feet AGL.

The feasibility test bed will be used to explore threat detection concepts and develop a complete algorithm definition. Key questions include:

1. What warning time does a pilot require in the traffic pattern to successfully use a computer voice message in finding and evading other traffic? How does threat detection modify the pilots visual scanning (if at all)?

2. Should both aircraft receive call outs or only one (the "interceptor" or the "evader")?

TABLE A-2
PATTERN DEPENDENT THRESHOLDS

	TOF	XWD	DEP	ENT	DWD	DWB	BSE	BSF	FNL	ZZZ	ERA
TAKEOFF (TOF)	22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1200	29 1200 1200	29 1200 1200
CROSSWIND (XWD)		22 1200 1200	22 1200 1200	24 1200 1800	22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1200	29 1200 1200	29 1200 1200
DEPARTURE (DEP)			22 1200 1200	24 1200 1800	22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1200	29 1200 1200	29 1200 1200
ENTRY (ENT)				22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1200	29 1200 1200	29 1200 1200
DOWNWIND (DWD)					22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1200	29 1200 1200	29 1200 1200
DOWNWIND NEAR BASE (DWB)						22 1200 1200	22 1200 1200	22 1200 1200	22 1200 1500	29 1200 1200	29 1200 1200
BASE (BSE)							22 1200 1200	22 1200 1200	22 1200 1500	29 1200 1200	29 1200 1200
BASE NEAR FINAL (BSF)								22 1200 1200	22 1200 1500	29 1200 1200	29 1200 1200
FINAL (FNL)									22 1200 1200	29 1200 1200	29 1200 1200
UNKNOWN										29 1200 1200	29 1200 1200
EN ROUTE AIRCRAFT (ERA)											29 1200 1200

TAU (SECONDS)
RANGE (FEET)
MISS DISTANCE (FEET)

3. Is a recommended avoidance maneuver desirable in the message? Is it achievable?

4. Do we need more "strategic" warnings as opposed to warnings when the traffic is already in conflict?

5. Will the rate of false alarms (warnings that pilots feel are superfluous) be low enough to permit successful use at high traffic levels?

A program of test flights will be undertaken to answer these questions, then evaluate the resulting algorithm as a part of the total ATS system.

APPENDIX B

FEASIBILITY TEST BED

The purpose of this appendix is to briefly describe the ATS test bed being assembled for tests during 1977. This semi-trailer mounted system is designed to provide a tool for exploring the feasibility of the ATS concept. Hardware is off-the-shelf or research equipment and is intended to only functionally support the system concept described above: It does not represent production equipment or a production configuration [15].

The hardware integration of the test equipment is being performed by ANA-100 of FAA's National Aviation Facility Experimental Center (NAFEC) in Atlantic City, New Jersey. System design and software development is by the FAA Office of Systems Engineering Management, Washington. Testing will occur in two phases:

1. Checkout, refinement, and special measurements will be done at NAFEC where the traffic can be restricted to research aircraft as needed.

2. The system then will be taken to a typical public uncontrolled airport for tests of pilot reaction and a total evaluation. The public will be invited to exercise the system on a voluntary basis.

This appendix briefly describes the hardware of the test bed and then sketches the test program.

B.1 Test Bed System

A diagram of the hardware configuration appears in Figure B-1. A major component of the system is a Digital Equipment Corporation PDP 11/40 minicomputer with 112K of memory. The 16-bit minicomputer executes the software to compute the ATS logic and controls all peripheral devices. The standard peripheral devices for operating ATS and gathering experimental data include a paper tape reader/punch, DECtape drives, three disk drives, magnetic tape drives, and a Varian printer/plotter. A Tektronix graphics terminal will be used as an input device and system console.

Specially interfaced devices include a beacon radar, a voice response system, and a plan view display for monitoring flight activities.

The radar is a monopulse beacon transmitter/receiver with a directional antenna mounted on a modified Nike Hercules acquisition pedestal. A

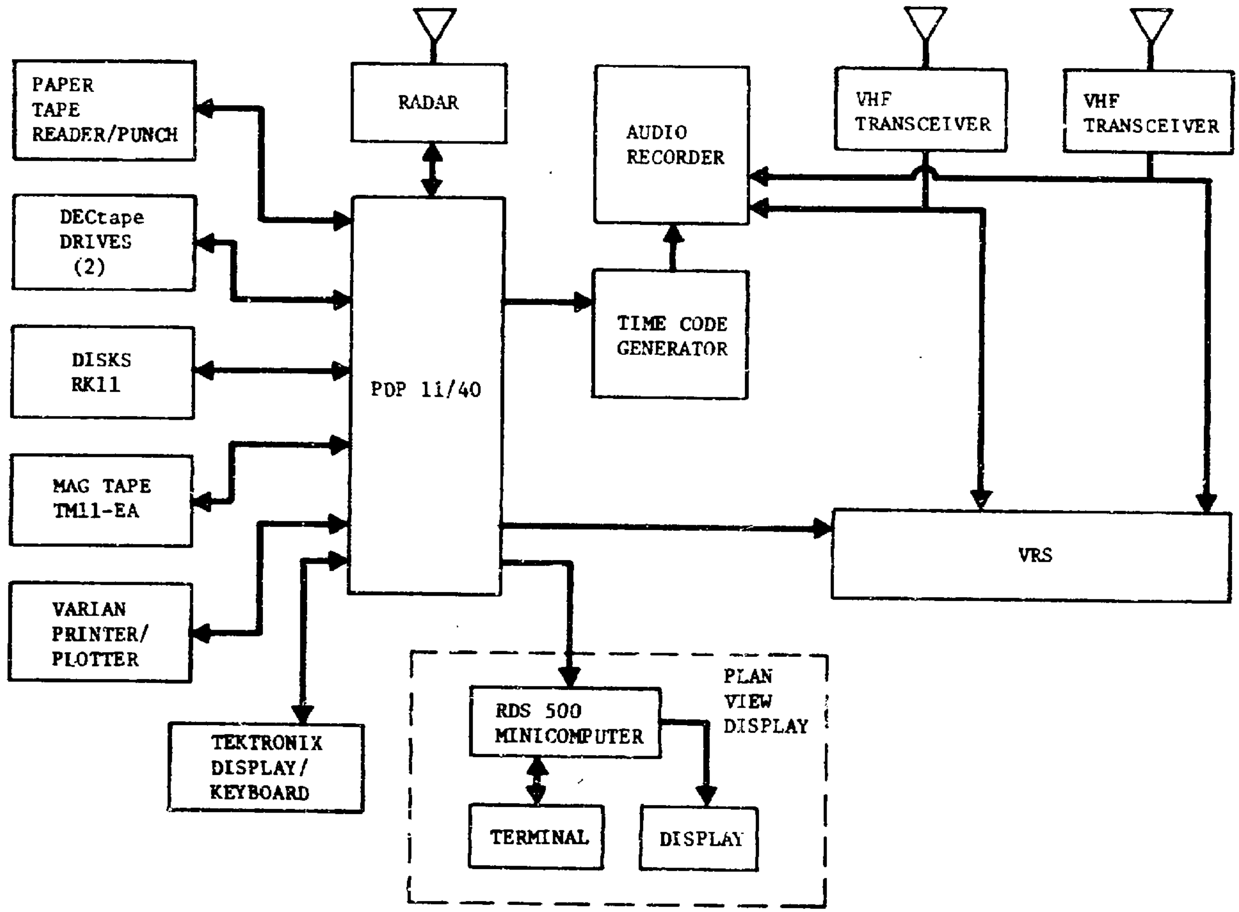


FIGURE B-1
ATS TEST BED CONFIGURATION

special design beacon processor is provided to convert to digital computer data. The radar was assembled by Naval Weapons Center in China Lake, California. Data on acquired aircraft is sent from the radar to the computer by high speed interface and is used by correlation and tracking software.

The voice response system (VRS) constructs ATS messages from a series of pre-stored digitized phrases, for transmission to the aircraft via 720-channel VHF transceivers. Also, the VRS converts received voice messages to a series of samples and stores them for use by ATS. Data transfer to the computer is by direct memory access. The VRS subsystem also includes a DATUM time code generator/translator and an Ampex 4-track tape recorder for storage and playback of ATS messages.

The Plan View Display is a standard National Airspace System R-Console from operational inventory. The display system consists of a Raytheon RDS-500 minicomputer with software for generating images on the Plan View Display (a 20" CRT). It also includes a trackball, pushbutton inputs, and an alphanumeric computer readout display. The PVD will display aircraft symbols with full data blocks, radar trails, and velocity vectors, a fixed background map, and other information pertinent to the ATS system.

The Plan View Display (PVD) in the ATS test bed is used in two modes:

1. As a tool for engineering evaluation of the system and for demonstration of the concept to decision makers. In this mode, both aircraft tracks and internal computer data will be displayed. A complete trace of system behavior - the "why" behind each message - can be produced.

2. As a mock up of a controller position at an ATC facility. An operational ATS site would be under the jurisdiction of a particular facility (En Route Center or TRACON) as discussed in Section 4. In this mode, the test bed PVD will be used to simulate the displays generated at the facility. Thus, IFR services and controller interaction can be simulated without disrupting actual ATC operations or modifying operational systems. The test bed PDP 11 minicomputer simulates the actions of the facility computer as well as performing the ATS functions.

An actual ATS system does <u>not</u> include an on-site plan view display.

B.2 Test Program

The presently envisioned test program consists of two phases:

1. experimental tests, and

2. field tests.

The experimental tests will be conducted at the NAFEC facilities in Atlantic City, New Jersey. The field tests will be performed at a public airport to be selected at a later date. The principle steps in executing the test program are outlined in Figure B-2.

The objectives of the experimental tests will be:

1. establish operational integrity of ATS hardware and software,

2. modify the test bed system based upon observations in a live environment,

3. assess operational acceptance of ATS by pilots participating in testing, and

4. evaluate the performance of the system services.

The first objective will be addressed initially in the laboratory when the PDP-11/40 hardware and software are made operational. After initial system checkout, the equipment will then be moved into the semi-trailer and placed at the NAFEC test site. As services are integrated into the ATS software, each will be checked to determine the integrity and validity of software logic, as well as verifying interfaces (if any) to system hardware. Based upon observed performance, the services will be modified as necessary.

Once a suitable subset of services are available that represent the range of capabilities addressed by ATS, evaluation of the system concept may commence using this "baseline" system. In parallel with an analysis of the baseline system, different service concepts and implementations will be explored. The result of these studies and the evaluation of the baseline will be a revised concept and test bed system. After the revised system is completed, a final evaluation in the experimental test phase will be performed.

The field test activities will be designed to evaluate ATS system performance in the public airport environment in which ATS is expected to serve. Performance measures gathered in this environment and pilot acceptance will be instrumental in making a final system evaluation. Inputs from pilots not involved in pre-planned flight scenarios will be valuable in assessing the response of the user community to the ATS concept. Revisions to the system concept based upon measured performance and response participants at the field site will be incorporated into the ATS system description.

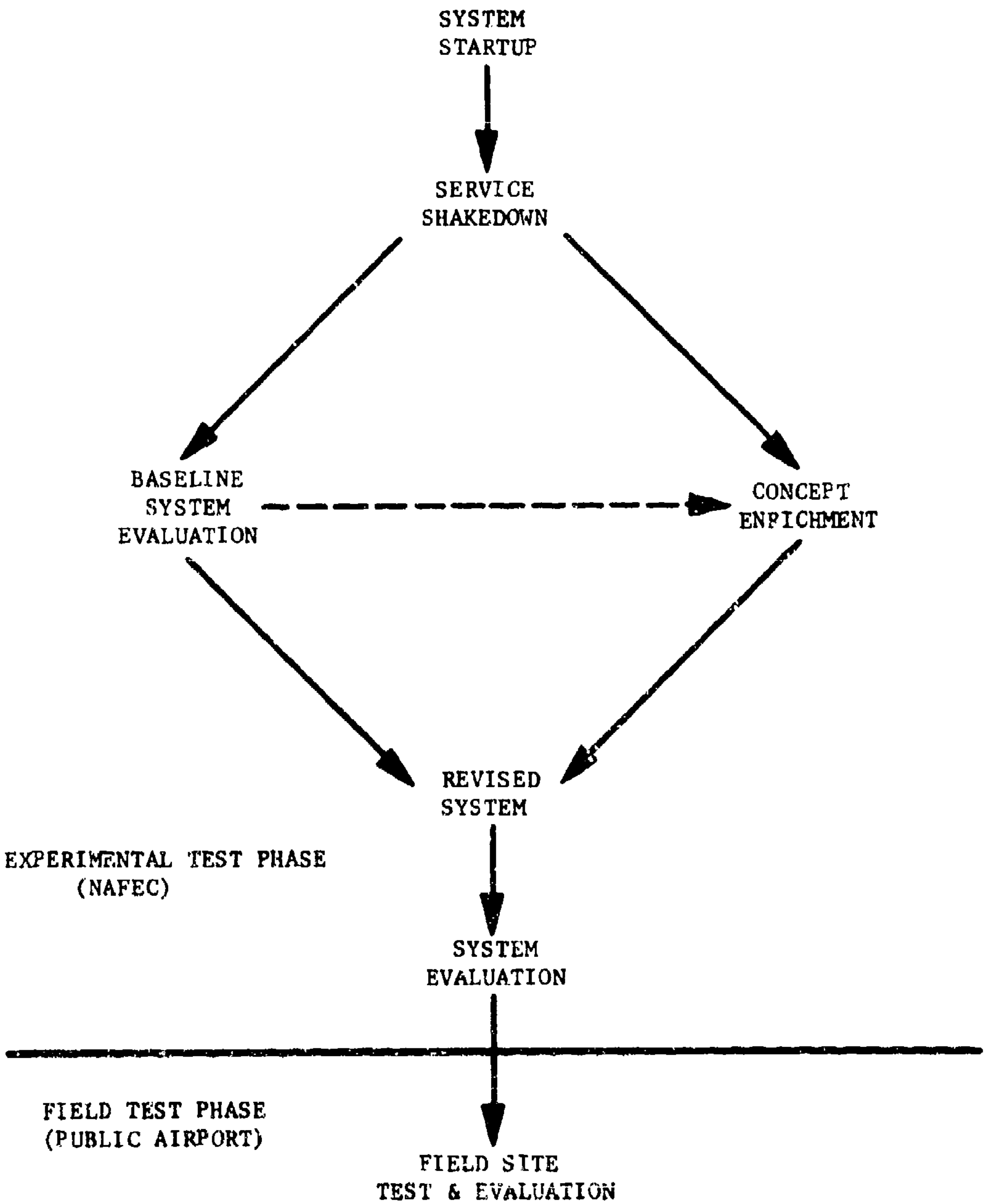


FIGURE B-2
ATS TEST PROGRAM

The results of both test phases will be documented and serve as the basis for an Engineering Requirement and further cost effectiveness evaluation.

APPENDIX C

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