FAA-77-3

Report No. FAA-AEM-77-6

REQUIREMENTS FOR FLIGHT TESTING AUTOMATED TERMINAL SERVICE

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MAY 1977

INTERIM REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Office of Systems Engineering Management
Advanced Concepts Staff
Washington DC 20590

Technical Report Documentation Page

1. Report No.
FAA-AEM-77-6

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
REQUIREMENTS FOR FLIGHT TESTING AUTOMATED TERMINAL SERVICE

5. Report Date
May 1977

6. Performing Organization Code

7. Author(s)
Joseph S. Dumas

8. Performing Organization Report No.
DOT-TSC-FAA-77-3

9. Performing Organization Name and Address
U. S. Department of Transportation
Transportation Systems Center
Kendall Square
Cambridge MA 02142

10. Work Unit No. (TRAIS)
FA734/R7141

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
U. S. Department of Transportation
Federal Aviation Administration
Office of Systems Engineering Management
Advanced Concepts Staff
Washington DC 20590

13. Type of Report and Period Covered
Interim Report
June 1976-January 1977

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report describes requirements for the flight tests of the baseline Automated Terminals Service (ATS) system. The overall objective of the flight test program is to evaluate the feasibility of the ATS concept. Within this objective there are two categories of specific ATS flight test objectives: (1) the objectives concerned with verifying the basic advisory capabilities of ATS and (2) the objectives concerned with evaluating pilots' responses to ATS messages. The flight testing is broken down into three parts. Part I will consist of system checkout flights. Part II will consist of validation and some pilot evaluation tests and will be conducted at NAFEC. Part III will consist primarily of normal airport operations at a selected general aviation airport. The requirements for the Part II and III evaluations of each of the ATS services to pilots are presented. For each service, there is a listing of the major issues involved in the evaluation and a discussion of the methods to be used in the evaluation. The description of the test methods for each service presents the type of missions that will be required, along with a table showing the measures to be taken and the sources of data where these measures can be most easily obtained.

17. Key Words
Automation, Air Traffic Control, Flight Testing

18. Distribution Statement
DOCUMENT IS AVAILABLE TO THE U.S. PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)
Unclassified

20. Security Classif. (of this page)
Unclassified

21. No. of Pages
38

22. Price

Form DOT F 1700.7 (8-72)

Reproduction of completed page authorized

PREFACE

This document was prepared under the sponsorship of the Office of Systems Engineering Management, Federal Aviation Administration, as part of the Automated Terminal Service (ATS) program. ATS is one of a number of advanced, automated air traffic concepts being developed to serve the future needs of the national aviation system. The contents of this document reflect comments from various reviewers on previous draft versions. The author wishes to give special acknowledgement to Charles O. Phillips and Alan Robertson for their extensive contributions to early draft versions and to Robert Reyers, NAEFC, and Richard Telsch, MITRE Corp., for their helpful comments on the final version.

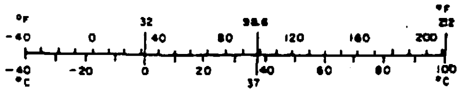
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

1.1 BACKGROUND

The FAA/OSEM has generated a description* of the baseline Automated Terminal Services (ATS) concept. The primary emphasis of this concept is to provide airport services to pilots via an unmanned, automated system. The baseline ATS system has three potential areas of application. First, its primary role will be as a substitute for a control tower at those airports just reaching the criteria for tower installation. Second, the system could be installed at uncontrolled airports where a manned tower is not yet justified, but where additional safety is required. Third, the system could be used as a shift reliever during off-peak hours at some airports that have a manned control tower. The ATS concept has been subjected to analysis and simulation by the MITRE Corporation. As with any major system under development, it is desirable to conduct tests in a live environment in order to fully characterize and refine system performance. There is an additional motivation for conducting flight tests. The ATS concept relies in large part upon the ability of a pilot to gain access to the system, to communicate with the system through various transponder codes, to comprehend the system messages, and to choose an appropriate course of action when advised of a conflict. The human responses to these situations are, therefore, important elements affecting the operation of ATS. The most realistic method for studying these responses is flight testing.

1.2 ATS FLIGHT TEST OBJECTIVES

The overall objective of the flight test program is to evaluate the feasibility of the ATS system. Within this objective there are two categories of ATS flight test objectives: (1) those concerned with verifying the basic advisory capabilities

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*Office of Systems Engineering Management, "A Description of the Phase I Automated Terminal Concept," U.S. Dept. of Transportation, Federal Aviation Admin., Washington DC, November 1976, FAA-EM-76-6.

of ATS and (2) those concerned with evaluating pilots' responses and reactions to various ATS messages and their ability to use the information conveyed in the messages in an effective way. The first objective seeks primarily to assess how well the system generates messages when it is operating with data from a live environment. These objectives are concerned with the mechanical and electronic aspects of the ATS system operation and have been termed ATS Validation Objectives. The second category of objectives deals with pilot responses and opinions and is referred to as Pilot Evaluation Objectives.

1.2.1 ATS Validation Objectives

The most important validation objective is to evaluate and improve, if necessary, the message generating capability of the ATS system. The basic ATS algorithms provide for the delivery of messages depending on aircraft speed and position, aircraft ATC status, and pilot intention; e.g., departure versus touch and go. During the flight tests the system will be presented with these situations, and its performance will be measured and evaluated.

1.2.2 Pilot Evaluation Objectives

The principal objective is to evaluate how well all of the elements of the ATS system work together to provide for the safe and efficient flow of aircraft in an airport environment. The ability of the pilot to use the advisory information to his benefit is to be assessed. Another objective is to characterize the pilot's perception of the timing and content of the ATS messages. Pilot evaluation of all aspects of system operation is to be collected and analyzed to reveal any unacceptable aspects of system operation that may warrant modification either to the ATS concept itself or to some detail of message delivery.

1.3 TEST METHOD

Since flight testing is at best an inefficient process for obtaining engineering data, it is important to provide an adaptive and flexible test program as part of the system development and refinement process. Every attempt should be made to avoid flight test exploration of issues that can be studied by analysis or simulation. The flight tests should focus upon gathering data unattainable by other means and uncovering problems that may have been overlooked during other evaluations of the concept.

1.3.1 Mission Types

The flight tests will use three types of missions. First, there will be Professional Pilot Missions (PPM's). During these missions trained professional pilots will fly planned patterns, variations in pilot behavior will be minimized, and the automated system will receive concentrated attention. Second, there will be Subject Pilot Missions (SPM's). During these missions general aviation pilots will fly general aviation aircraft through specially planned patterns. For reasons of safety and coordination, a professional pilot will be in command of the subject pilot's aircraft and will have ultimate responsibility for the aircraft, although the subject pilot will fly the aircraft. Every effort will be made to provide a normal cockpit environment for the subject pilot. Subject pilot testing is expected to lead to valuable insights concerning pilot use of the advisory messages of the system in both conflict situations and routine flight operations. Third, there will be Normal Airport Missions (NAM's). During these missions the primary emphasis will be on having general aviation pilots use the airport where ATS is located in normal flight activities. While some pilots may be asked to fly certain types of operations, such as missed approaches or touch-and-gos, the aim will be to mimic the activities of a typical general aviation airport.

1.3.2 Flight Tests

In order to accomplish both the System Validation and the Pilot Evaluation objectives, flight testing will be accomplished in three parts.

Part I will consist of checkout flights. The function of these flights is to debug the major components of the system. The objective of this phase is to get the surveillance, tracking, message generation, and message delivery subsystems in working order in preparation for the fine tuning to be done in subsequent phases. This will be accomplished through PPM's.

Part II will consist of validation tests and some pilot evaluation tests. These flights will occur at NAFEC. Most, if not all, of the flights designed to meet the validation objectives will be flown during this part of the test. This will be accomplished with PPM's. Any major bugs in the subsystems will be fixed at this time. In addition, the objectives dealing with the pilot's ability to interact with the system will be accomplished primarily with SPM's. Pilot opinions of the system will also be measured during the SPM's. Some NAM's will also be carried out during this part of the test to measure system and pilot performance under a wider variety of conditions. An interim report, which will be written following the NAFEC tests, will describe the major results of those tests and detail plans for the Part III tests.

Part III will consist of NAM's at a general aviation airport. This part of the flight test constitutes the final evaluation of the concept. The primary emphasis will be on pilot reactions to and evaluations of system characteristics under the variety of conditions encountered at a general aviation airport. An interim report describing the results of the Part III tests will be written at their conclusion. In addition, a final report on all ATS flight test activities will be prepared.

The present document presents the requirements for the Part II tests at NAFEC and the Part III tests at a general aviation airport. The flight test requirements for the evaluation of each of the ATS services are presented in sections 2 through 7. In each section there is a short description of the service, a listing of the major issues involved in its evaluation, and a discussion of the methods to be used in the evaluation. The description of the test methods presents the types of missions that will be required along with a table showing the measures to be taken and the sources of data where those measures can be most easily obtained.

Although the services are described separately, it should not be assumed that they will be evaluated separately. It may be possible to gather data on several services during the same missions. The schedule of missions that yields the most efficient evaluation of the services should be used.

2. SYSTEM ENTRY

2.1 VFR OPERATIONS

In order for a pilot flying VFR to gain access to the services provided by the ATS system he must carry out a system entry procedure called Login. The purpose of the Login procedure is to establish a communication link between the pilot and the ATS system. Use of the Login procedure confirms pilot intent to cooperate with ATS procedures and provides a means for the ATS computer to acquire an aircraft identification to be used in directing voice messages to that pilot. Since the benefits the system provides cannot be obtained without a successful Login, insuring the smooth coordination between the pilot and the system the procedure requires is one of the top priorities of the flight test program. If Login errors occur frequently, either because of system malfunction or pilot performance, acceptance of the ATS will be jeopardized.

The ATS concept description presents two alternative Login procedures. In both, the pilot begins Login on arrival by tuning to the airport's Login frequency about 15 miles from the airport and squawking the airport's assigned transponder code. On departure the pilot squawks the code when he is on the ramp. In both cases the system then broadcasts a message giving the aircraft's position. From this point on the two Login procedures differ. In the Transponder ID procedure the pilot is given a unique transponder code to be used as his ID. Once the pilot squawks that code, the system sends a message that the aircraft is logged in. All subsequent messages to that aircraft will be prefaced with that transponder code.

In the Voice ID procedure, the pilot squawks the airport code and the system sends a message giving the aircraft's position. The pilot is asked to "say your ID." The pilot broadcasts a description of his aircraft, which may include a portion of the tail number. The system then records the description. The description may be up to 5 seconds long. However, it is expected that on the average it will be shorter. The ID is then broadcast back to the pilot along with a discrete transponder code. Once the pilot squawks the code he receives a message that he is logged, and all subsequent messages are prefaced with this Voice ID.

One of the major issues to be resolved during the flight test is whether the Voice ID procedure will allow relatively error-free Login. Despite the fact that the Voice ID procedure takes more time and requires closer coordination between the pilot and the system, it has the following advantages over the Transponder ID procedure:

a. Messages sent with a Voice ID are similar to those normally received from controllers. This should allow the pilot to recognize more easily messages directed to him. Since the pilot has other cockpit duties to perform, listening for an arbitrarily assigned code that may differ by only one or two numbers from another aircraft's may be more difficult than listening for his own voice.

b. The Voice ID allows pilots to identify other aircraft receiving messages. Since the aircraft type and tail number may be part of the ID, a pilot would often be able to locate another aircraft receiving a message and thereby get a better picture of the traffic situation around him. This could only be done by inference with the Transponder ID.

c. Another potential benefit is that there may be fewer requests for repetition of a message with the Voice ID. Although some form of message repetition service is contemplated for ATS, its form will not be determined until the flight test. If pilots are allowed to request a repetition of a message they did not understand, the higher intelligibility of the Voice ID should produce fewer requests. This means that although the Voice ID procedure would take more time on the Login channel, it would result in fewer messages being sent on the operational channel.

These advantages to the Voice ID make it important to thoroughly test and debug the procedure and expose it to pilots with varying levels of experience. Although some preliminary testing of the Transponder ID procedure should be planned, a full evaluation of it will occur only if the Voice ID procedure is unacceptable.

In addition to the type of ID, there are two other aspects of Login to be tested. First, the ability of the system to deal with two pilots attempting to log in simultaneously will be evaluated. When two aircraft squawk the airport code at nearly the same time, ATS requests the first aircraft to log in by including the aircraft's position in the request. However, if the aircraft are near each other or one pilot is not sure where he is, they may both attempt to log in. The system is capable of dealing with this situation in several ways. It can request that a pilot restart Login, and it can recognize which aircraft is squawking the transponder code it has given, even if it is the wrong aircraft, and request that the other pilot log in. What is not clear is how pilots will react to this situation or how long the Login process will take. Second, the feasibility of an ATS system with one frequency for both Login and tactical messages will be tested. This single-channel system has the advantage of allowing pilots to hear each other log in and thereby increase awareness of traffic in the area. However, the point at which the number of messages saturates the channel or becomes unacceptable to pilots must be determined.

Once Login has been successfully completed, an Automatic Terminal Information Service (ATIS) message is broadcast. This message includes the active runway, weather, number of aircraft logged into the system, the frequency of the ATS tactical channel, and special information such as that found in NOTAMS. As traffic density increases it may not be necessary to broadcast the ATIS message after every Login. This would increase the capacity of the system. However, the point at which the message need not be broadcast after every Login must be established during the test as well as the acceptability of this procedure to pilots. In addition, the single channel version of ATS does not broadcast the ATIS message after Login but on a regular (e.g., every 3 minutes) schedule. How well this procedure works with high density traffic must be established during the tests.

2.2 IFR OPERATIONS

The system entry procedure for a pilot flying IFR is somewhat different from the procedure for VFR flights. How different will depend on the equipment available at the particular ATS airport. Basically there are three possibilities:

1. The airport has no RCO and no digital interface with the nearest ATC facility. On arrival into the airport area the pilot is given an IFR transponder code for ATS by the approach controller over the approach control frequency. The pilot then switches to the ATS tactical frequency 10 miles from FAF and squawks the code. The system recognizes the code and requests that the pilot log in. From this point on the procedure is the same as for a VFR flight. On departure the pilot receives his clearance by telephone. It contains the discrete transponder code assigned under the National Beacon Code Allocation plan for his IFR flight. When the pilot is on the ramp ready to depart he squawks this code. When ATS sees a transponder on the ramp with any of the codes allowable for IFR flights, it assumes an IFR departure is ready and requests the aircraft initiate Login. The rationale behind having the IFR aircraft log in on the tactical frequency is to avoid requiring the pilot to make two frequency changes.

There are two aspects of this IFR Login that need to be probed during the tests. The first is the timing of the handoff to and from ATC. On arrival once the pilot switches to the ATS frequency 10 miles from FAF the approach controller cannot talk to the pilot. Furthermore, until the pilot is logged he cannot receive ATS services. The smooth functioning of this handoff and its acceptability to pilots and controllers must be demonstrated during the tests. Second, the impact and acceptability of Login on the tactical frequency must be assessed, especially as traffic density increases.

2. The airport has an RCO. On arrival the procedure for pilots is the same as described above. However, the approach controller will be able to monitor, and if necessary break into, the ATS channel all the way to touchdown. On departure, the pilot can

receive his clearance over the RCO but otherwise the procedure is the same as above. However, the departure controller can monitor and if necessary break into the ATS channel.

3. If the airport has a digital ground link to ATC the procedure is greatly simplified. Here the transponder code and ID are sent directly to the ATS computer. The pilot simply squawks his IFR code. He is already logged into the system. In addition, the ATC controller receives surveillance data on the aircraft until touchdown. On departure, ATC tells the ATS computer the transponder code and departure route of the aircraft. Again, the pilot does not have to log in, and the handoff to ATC can be done automatically. The major issues to be investigated here are the timing of the handoff and the acceptability of the procedures to pilots.

In all three of these cases the pilot has two other options he may wish to take at this time. First, he may wish to make a practice IFR approach. He does this by simply informing the approach controller. The controller then gives him an appropriate transponder code. When he logs in the system, it notes his intention in its initial message to him. Otherwise, the Login procedure is the same as for a full stop landing. Second, the pilot may wish to cancel his IFR flight plan. He does this by informing the approach controller and then switching frequencies and squawking the regular VFR Login request code.

2.3 SYSTEM ENTRY EVALUATION ISSUES

During the flight tests, data will be gathered to answer the following questions about system entry:

1. What proportion of ID Logins are erroneous for both professional pilots and subject pilots with both high and low density traffic? Does experience with ATS reduce the number of errors? What is the source of errors? Can errors be reduced with pilot training or a change in the system?

2. Are Voice ID's intelligible to pilots? How long are they? Is there a preferred content for Voice ID's?

3. When two aircraft attempt to log in simultaneously, how long does it take to resolve the conflict. How often does this occur?

4. Do pilots prefer the Voice ID over the Transponder ID?

5. At what level of density does the single-channel ATS saturate? Is it acceptable to pilots? It is preferable to pilots?

6. What sources of error are there in the IFR Login procedures? Can pilots complete the handoff smoothly? Is the timing of the handoff acceptable?

7. Is the Login on the tactical frequency for IFR flights acceptable to pilots? How much are Logins delayed under high density conditions?

8. What information should be included in the ATIS message? Will pilots accept a reduction in the frequency of its broadcast with heavy traffic?

2.4 SYSTEM ENTRY TEST METHODS

Most of the data needed to answer the evaluation issues for VFR operations can be gathered from PPM's and SPM's during the Part II tests. PPM's with two general aviation aircraft can be used to generate data about the timing and intelligibility of Login messages, system malfunctions, and system performance with simultaneous Login. These missions will also reveal how experienced pilots can handle the Login procedures. Questions about the handling of IFR handoffs and Logins can also be evaluated with PPM's during Part II. However, the data needed to evaluate issues with low density traffic about acceptability of procedures to pilots and Login errors as a function of pilot experience should be gathered using SPM's. Data on message repetition requests and acceptability with high density traffic should receive a preliminary evaluation during Part II.

It is expected that the Part II tests will allow a choice to be made between the ID procedures and the single versus double channel option. A version of ATS containing one of these options will then be installed at the operational site selected for the Part III tests. The primary emphasis of the Part III tests should be on two types of evaluation. First, the system should be exposed to a large sampling of pilots, aircraft types, and communications equipment. The measures taken through a questionnaire or interview form will be especially important here. Second, the evaluation of the system under high density traffic conditions should be completed during Part III.

Table 1 lists the measures that will be needed to evaluate the system entry issues. Also shown are the mission types during which data will be gathered and the sources where the data can be most easily found. Also, the table breaks the test into high and low density flights. The low density flights will require two, or at the most, three aircraft. The high density flights will require at least six aircraft in the airport area. The measures that are listed for the low density tests will generally also be taken during the high density tests. Note that most of the data can be found on either the audio recorder or the pilot questionnaire. Some software hooks will be needed, however, to allow detailed analysis of system performance.

TABLE 1. MEASURES, MISSION TYPES, AND SOURCES OF DATA FOR SYSTEM ENTRY EVALUATION

MEASURES		MISSIONS	SOURCES
Low Density	Time to Login	PPMs, SPMs	Software
	Number and Source of Login Errors	PPMs, SPMs	Software, Questionnaire
	Intelligibility of Voice ID	PPMs, SPMs	Questionnaire
	Aircraft Position at Login	PPMs, SPMs	Software
	Pilot Preference for Type of Login Procedure	PPMs, SPMs	Questionnaire
	Pilot Experience	SPMs, NAMs	Questionnaire
	Pilot and Controller Acceptance of IFR Handoff	SPMs, NAMs	Questionnaire
	Pilot Acceptance of Single Channel Option	NAMs	Questionnaire
High Density	System Response Time to Login Request	NAMs	Software
	Tactical Channel Loading	NAMs	Audio Tape, Software
	Interruptions to Login	NAMs	Audio Tape, Software
	Number of Message Repeat Requests	NAMs, SPMs	Software
	Pilot Acceptance of Reductions in ATIS Messages	NAMs	Questionnaire

3. SEQUENCING AIDS

Once a pilot is logged into the system, he gains access to the services provided by the ATS. During normal VFR operations the most basic services the system provides are sequencing aids. The aids are intended to make the pilot aware of the traffic in the vicinity of the airport and his position in that traffic. The history of accidents at uncontrolled airports shows that the majority occur in the traffic pattern area and that pilots do not see each other in time to make an evasive maneuver. The sequencing aids were designed with this history in mind. They were also designed to improve traffic flow at the entry-downwind merge point.

In normal VFR traffic the ATS system is designed to give each pilot advisories at two points:

1. As an aircraft approaches the downwind leg of the traffic pattern the pilot receives an advisory message giving the position of all other logged aircraft in that vicinity. This message is broadcast to aircraft entering the traffic pattern by way of a 45° entry to downwind and to aircraft transitioning to downwind from a crosswind leg.

2. As an aircraft flying the downwind leg flies abeam of the runway threshold ATS sends a message announcing the number of logged aircraft ahead in the landing sequence.

3.1 SEQUENCING AIDS EVALUATION ISSUES

One of the major questions to be addressed (in addition to testing whether or not the system sends traffic advisories at appropriate times) is the impact of non-transponder-equipped aircraft on system performance and acceptability. Even though the proportion of equipped general aviation aircraft is increasing, there will always be aircraft with malfunctioning transponders. Current plans call for pilots of these aircraft to make self-reports of their position over the ATS frequency. It is unclear at present whether these reports will degrade system performance or annoy or confuse other pilots. This should not happen if pilots use good communication techniques. A potentially more serious problem, however, may be that pilots do not make reports, and some of the other aircraft in the pattern are not aware of their presence.

For the test of the sequencing aids service, data should be gathered to answer the following questions:

a. Are the sequencing messages broadcast at the appropriate times, namely just before pattern entry and abeam of the runway threshold?

b. Are the messages delayed or omitted in high density traffic? According to pilots are the messages received on time to be helpful? Do they facilitate the flow of traffic?

c. Do pilots consider the messages useful despite the presence of unequipped aircraft? Do pilots prefer that the number of messages be minimized in low density traffic?

d. Do the messages increase the pilots' awareness of traffic?

e. Will pilots without working transponders give self-reports?

3.2 SEQUENCING AIDS TEST METHODS

The data needed to answer the issues about whether the messages are being sent at appropriate times in low density conditions can be gathered from PPM's during the Part II tests. All of the other issues, however, require medium to high density traffic; i.e., more than three aircraft flying in the pattern. Data on these questions could be gathered using SPM's, but NAM's with a questionnaire would be most efficient. If the messages are received on time, even under high density conditions, the gathering of evidence on whether the messages increase pilots' awareness of other traffic will be essential to the flight test. If the system is going to help prevent accidents at uncontrolled airports it must be able to increase awareness. Although the issues involving the impact of unequipped aircraft on system performance and acceptability should receive some preliminary test during the Part II flights, the questions can best be resolved during the Part III flights. This is especially true of the question of whether pilots of unequipped aircraft will give self reports.

Table 2 lists the measures, mission types, and sources of data that will be needed to evaluate the sequencing aids issues. As can be seen the sequencing aid evaluation relies more heavily on the pilot questionnaire and the software hooks than the system entry evaluation.

TABLE 2. MEASURES, MISSION TYPES, AND SOURCES OF DATA FOR SEQUENCING AIDS EVALUATION

MEASURES		MISSIONS	SOURCES
Low Density	Intelligibility of Messages	PPMs, SPMs	Questionnaire
	Aircraft Track at Time of Message	PPMs, NAMs	Software
	Delay or Omission of Messages	PPMs, NAMs	Software
	Pattern Classification at Time of Message	PPMs, NAMs	Software
High Density	Number, Length and Intelligibility of Unequipped Aircraft Reports	NAMs	Audio Tape
	Channel Loading	NAMs	Audio Tape
	Pilot's Awareness of Traffic Before and After Messages	NAMs	Questionnaire
	Opinions of Timing, Content and Frequency of Advisories	NAMs	Questionnaire
	Acceptance of Unequipped Aircraft Reports	NAMs	Questionnaire

4. THREAT DETECTION SERVICE

If the sequencing aids service works as designed and if it could be assumed that all pilots fly flawlessly, there would be no need for a threat detection service. When a pilot approaches the traffic pattern area he is made aware of other traffic in the vicinity, and as he passes abeam of the runway threshold his place in the landing sequence is noted. Conflicts should never occur, but unfortunately, they will. Even at airports with skilled and disciplined pilots and a tower controller conflicts occasionally arise. In fact, one of the primary functions of a tower controller is to assure separation between aircraft. ATS incorporates this function by providing warnings to two or more conflicting aircraft. The service is designed for the ATS traffic area (5-mile radius, 3000 ft AGL) and is geared toward alerting pilots to conflicts. However, threat detection for the rest of the ATS radar coverage area will be extended to logged aircraft. The detection logic examines each aircraft pair and compares their relative positions and velocities. The criterion used in determining that a conflict exists are time to collision, miss distance, and range.

The most difficult service to set flight test requirements for is threat detection. There are three reasons for this. First, there are an infinite number of combinations of encounter geometries, pattern locations, aircraft performance characteristics, and pilot experience variables. Obviously, some subset of these must be chosen for planned tests. Second, the conflict warnings given to pilots are not commands. They inform the pilot of a conflict but do not tell the pilot to take a specific action to avoid a collision. At the present time it is unclear how pilots will react to such messages. Some pilots, however, may react to a message by making maneuvers that put them into another and more serious conflict. The variety of such reactions obviously cannot be anticipated in advance to allow specific requirements to be set. Third, the exact timing of the conflict messages is not constant.

Normal variations in the surveillance and tracking systems produce variations in the timing of messages.

The basic problem with setting requirements, then, is to specify a set of conflict situations to test, while at the same time leaving the test schedule flexible enough to further explore situations that may appear during the tests. A reasonable solution to these problems is to plan to test the conflict situations explored by the MITRE Corporation and at the same time be ready to further explore other serious conflict situations that appear during the test phases. This strategy has the additional benefit of providing some validation for the simulation. If the simulation proves to be accurate, it can be a tremendous aid to intensive investigations of new conflict situations.

The conflicts selected by MITRE to simulate are those which have a history of occurring at uncontrolled airports. The following four scenarios and their variations were simulated:

1. Overtake on downwind.
2. One aircraft entering the pattern and another on downwind.
3. One aircraft entering the pattern and another on crosswind.
4. One aircraft on final approach and another turning from base to final.

With the addition of a conflict with an enroute aircraft the most frequently occurring conflicts are covered by these situations. The test plan, then, should include planned flight scenarios to explore these five types of conflict.

4.1 THREAT DETECTION EVALUATION ISSUES

The major issues to be evaluated during the threat detection tests are (1) whether alarm messages are sent on time to enable pilots to resolve conflicts and (2) whether pilots react to alarm messages by putting themselves in further conflicts. An important related issue is whether false alarm messages are sent. It is common practice to have aircraft with different performance characteristics fly in the pattern not only with horizontal separation, but also with vertical separation. Higher performance aircraft tend to fly higher and wider patterns. If aircraft do not have Mode C transponders but are vertically separated, the system may broadcast an alarm message. This may be annoying to pilots and cause delays in other service messages. Since the ATS algorithms give the highest priority to alarm messages, having false alarms in heavy traffic conditions could disrupt the other services.

There are, then, three major areas that must be explored during the threat detection tests:

1. Are the timing and order of the alarm messages sufficient for pilots to avoid collisions? Are they acceptable to pilots? Do false alarms occur frequently?

2. How are conflicts resolved? Are some conflicts more difficult to resolve than others?

3. Do pilot-generated avoidance maneuvers produce additional conflicts?

4.2 THREAT DETECTION TEST METHODS

All tests involving planned flight scenarios will be conducted during the Part II tests. The system validation issues involving the determination of whether the alarm messages are being sent as designed should be conducted using PPM's. Most of the basic tests can be done with two aircraft. The questions about pilot acceptability and pilot avoidance maneuvers must be done with subject pilots flying planned scenarios. The flight experience of the subject pilots chosen for the tests should vary widely. It is important to measure the reactions of both new and experienced pilots to the alarm messages.

Perhaps the most difficult issue to resolve during the flight tests will be the impact of conflicts or false alarm messages during heavy traffic. Because the ATS algorithms put the highest priority on conflict alarms, a series of conflict or false alarm messages during heavy traffic could seriously disrupt the other ATS services. However difficult it is to set up conflicts in heavy traffic (six or more aircraft in the pattern), they must be conducted before the system is moved for the Part III tests.

Some very important data on threat detection can be gathered during the NAM's during both the Part II and the Part III tests. Unplanned conflicts will arise. System performance and pilot reactions during these conflicts should be carefully scrutinized for clues to potential problems. If any appear, further tests at NAFEC or an intensive simulation effort may be called for.

Table 3 lists the measures, mission types, and sources of data for the threat detection evaluation. Note that the evaluation of this service relies heavily on software hooks.

TABLE 3. MEASURES, MISSION TYPES, AND SOURCES OF DATA FOR THREAT DETECTION EVALUATION

MEASURES		MISSIONS	SOURCES
Low Density	Aircraft Track at Time of Alarm	PPMs, SPMs	Software
	TAU, Range and Miss Distance at Time of Alarm	PPMs, SPMs	Software
	Pattern Classification at Time Alarm	PPMs, SPMs	Software
	Message Intelligibility	PPMs, SPMs	Questionnaire
	Pilot Opinion of Ordering and Timing of Alarm	PPMs, SPMs	Questionnaire
High Density	Channel Loading	SPMs	Audio Tape
	Status of Visual Acquisition at Time of Alarm	SPMs	Questionnaire
	Pilot Response to Alarm	SPMs	Software and Questionnaire

5. IFR SERVICES

Once a pilot flying IFR is logged into the system, he gains access to the services given to pilots flying VFR. In addition, he receives services specifically designed for IFR aircraft. These are of three basic types:

1. IFR announcements - IFR arrivals will be announced when they first enter the ATS traffic area. An announcement is also broadcast when the aircraft is 3 miles and 1 mile from the center of the runway. One final announcement will note the IFR aircraft's sequence to land. IFR aircraft departing the airport will receive similar messages at 1, 3, and 5 miles from the airport.

2. Approach monitoring - During the entire approach the system will compute deviations from the approach centerline and broadcast significant deviations. If the aircraft has a Mode C transponder a message will be broadcast if the lowest minimum descent altitude is penetrated. The pilot will also be informed when he has passed the missed-approach point.

3. Outbound handoff - At an appropriate outbound handoff range, a message will prompt the pilot to change frequencies and contact ATC.

5.1 IFR SERVICES EVALUATION ISSUES

To a large extent the success of the IFR services will depend on the cooperation of ATC facilities in the vicinity of the ATS airport. However, the flight test should concentrate on whether the messages are broadcast at the correct time and whether they are acceptable to pilots. Basically, there are only two issues in the evaluation of the IFR services:

1. Are the IFR announcements and approach monitoring messages broadcast at the appropriate times? Are these messages delayed or omitted under heavy traffic conditions? If so, is this acceptable to pilots?

2. Is the outbound handoff completed smoothly? Is the message delayed in heavy traffic? Is the timing of the procedure acceptable to pilots and ATC facilities?

5.2 IFR SERVICES TEST METHODS

The questions involving the timing of messages in low density traffic can be answered with PPM's during Part II. Evaluating the approach-monitoring messages will require flying planned patterns with deviations from normal apprаches. The timing and acceptability of messages in heavy traffic should receive a preliminary test with NAM's during Part II. The complete evaluation can be done during Part III. Evaluating this service does not require using SPM's.

Table 4 lists the measures, mission types, and sources of data for the evaluation of IFR services.

TABLE 4. MEASURES, MISSION TYPES, AND SOURCES OF DATA FOR IFR SERVICE EVALUATION

MEASURES		MISSIONS	SOURCES
Low Density	Aircraft Track At Time of Message	PPMs	Software
	Pilot and Controller Opinion of Handoff Sequence	PPMs, NAMs	Questionnaire
High Density	Delay or Omission of Messages	NAMs	Software
	Pilot Opinion of Content And Timing of Messages	NAMs	Questionnaire

6. PATTERN MANAGEMENT SERVICES

The functions of the pattern management services are to maintain a standard traffic pattern, to keep control of pattern density, accommodate special operations, and reduce waiting time on departure. Basically there are three types of messages:

1. Messages to maintain the traffic pattern - Pilots will be required to fly a standard right or left pattern with standard entry and departure procedures. A pilot attempting to enter the traffic area in other than the entry corridor receives a warning that he is making an improper entry. Pilots who are in the traffic pattern and not conforming to the standard pattern will also receive a warning that they are flying a nonstandard pattern. These messages will not be given to IFR aircraft, and they are not designed to be restrictive. They will, however, require some discipline on the part of pilots using an ATS airport. In addition to attempting to maintain a standard pattern, the ATS system will also draw special attention to runway changes. Messages to announce the opening, closing, or reversal of a runway will be given at 1-minute intervals and continue for a sufficient period to allow the aircraft to alter their flight paths. The major issues to be explored during the flight test are the acceptability of these messages to pilots and the establishment of special conditions under which the criteria for generating these messages should be made either more strict or more lax.

2. Messages to reduce delay — A large fraction of the operations at a general aviation airport are practice flights. This can result in significant delays to aircraft waiting to depart. ATS has two procedures for dealing with this problem. First, it requests individual aircraft that have been executing multiple touch-and-gos to join the departure queue, thereby creating a break in the circulation around the pattern. If delays are still too long. ATS can request that all touch-and-go operations be stopped for a fixed length of time. There is also a special message to request cessation of practice operations on a crossing runway. Second,

ATS can attempt to open a "slot" in the pattern to enable the departure of several aircraft. It does this by requesting that an aircraft passing the runway threshold extend his downwind 1 mile. During the flight tests the major issues to be explored will be adjustments of the timing of these messages to effectively reduce delay and the acceptability of these messages to pilots.

3. Messages to accommodate special operations – ATS allows a pilot to use an alternate runway as long as the pilot makes known his intention by using a special transponder code at Login. The system provides announcements to alert the rest of the traffic to a crossing runway operation or a nonstandard departure. Again, the major issue to be evaluated during the tests is the acceptability of these messages to pilots. In addition, some further service messages for crossing runway, taxi, and takeoff operations may be explored during the tests.

6.1 PATTERN MANAGEMENT SERVICES EVALUATION ISSUES

During the flight tests, data will be gathered to answer the following questions about pattern management services:

a. Are there special conditions under which criteria for generating nonstandard pattern messages should be adjusted? Are the timing and content of the nonstandard pattern messages acceptable to pilots?

b. Are changes in runway status accomplished smoothly? If not, should the timing and content of these messages be changed?

c. Are the messages that are designed to reduce delay effective? Should the criteria for their generation and order be adjusted for special conditions? Are the timing and content of these messages acceptable to pilots?

d. Does the system effectively accommodate alternative runway operations and nonstandard departures? Will additional services be requested to increase the flexibility of the system? Do pilots consider these messages an asset to the system?

6.2 PATTERN MANAGEMENT SERVICES TEST METHODS

For the most part, the pattern management services will have to be evaluated during the Part III tests. The variety of situations that have to be flown to adjust the criteria for messages and to measure delay under high density traffic conditions can be achieved most effectively at an operating airport. In addition, the evaluation will be made to a large extent on the basis of a sampling of pilot opinion. This can be more easily gathered at a general aviation airport. Professional pilots flying planned missions during Part II could be used to insure that the non-standard pattern messages and the runway status message are delivered on time in low density traffic. However, even here the final evaluation will be completed during Part III.

Table 5 lists the measures, mission types, and sources of data for the evaluation of the pattern management services.

TABLE 5. MEASURES, MISSION TYPES, AND SOURCES OF DATA FOR PATTERN MANAGEMENT EVALUATION

MEASURES		MISSIONS	SOURCES
Low Density	Aircraft Track at Time of Message	PPMs, NAMs	Software
	Pattern Classification at Time of Message	PPMs, NAMs	Software
	Message Intelligibility	PPMs, NAMs	Questionnaire
	Pilot Opinions of Management Messages	NAMs	Questionnaire
High Density	Number of Aircraft Waiting to Depart	NAMs	Software
	Number of Aircraft In Traffic Pattern	NAMs	Software
	Pilot Acceptance of Criteria for Touch-and-goes and Crossing Runway Operations	NAMs	Questionnaire
	Pilot Opinions of Management Messages	NAMs	Questionnaire

7. PILOT AND EMERGENCY AIRCRAFT SERVICES

The function of the pilot services is to provide assistance to a pilot operating in the radar coverage area in addition to those services already described. At the present time two services have been developed, although additional services may be investigated during the flight tests. The two services are:

1. Position fix - To obtain a position fix from ATS the pilot squawks a separate published transponder code. Only logged aircraft can utilize this service. On request the system will broadcast the number of miles and the direction in degrees to the airport. The pilot then returns to his assigned code. This message has a low priority in the system and it may be turned off in heavy traffic. It is not meant as an emergency service but as an added convenience that can be obtained if the channel is free. The major evaluation issue is the adjustment of the criteria for terminating the service in heavy traffic.

2. Message repetition - A pilot may miss a portion of a message which was broadcast on the tactical frequency. This service is intended to allow the pilot to receive that message. However, at the present time it has not been decided specifically how the pilot will signal the system that he wants a repetition, or whether all messages can be repeated rather than just the general messages to all aircraft. These issues will be decided during the tests.

In addition to these pilot services there is one other service that has not been discussed: a service for 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 that aircraft. When the aircraft departs from the traffic area or lands, a final message will be sent. The major issue to be resolved during the tests is whether ATS recognizes the code and broadcasts the messages.

7.1 PILOT AND EMERGENCY AIRCRAFT SERVICES EVALUATION ISSUES

During the flight tests, data will be gathered to answer the following questions about pilot and emergency aircraft services:

a. Does ATS give accurate position information on request? At what level of channel saturation and/or traffic density should the service be omitted? Is this point acceptable to pilots?

b. How should pilots request repetition of a message? Should a pilot be allowed to request a repetition of all messages or only general messages? How many requests are normally made? Can some change be made in the system to reduce the number of requests?

c. Does the system respond at 1-minute intervals to an emergency code? Is this procedure acceptable to pilots?

7.2 PILOT AND EMERGENCY AIRCRAFT SERVICES TEST METHODS

All of these services should be evaluated during both the Part II and Part III tests. During Part II PPM's can be flown to gather data on the accuracy of the position fix message, the generation of emergency aircraft messages, and the procedure for message repetition. The Part III tests would then be used for adjusting the criteria for omission of the position fix message, assessing pilot acceptance of the emergency aircraft messages, and evaluating the message repetition service with a variety of pilots and equipment and at high traffic levels.

Table 6 lists the measures, mission types, and sources of data for the evaluation of the pilot and emergency aircraft services.

TABLE 6. MEASURES, MISSION TYPES, AND SOURCES OF DATA FOR PILOT AND EMERGENCY AIRCRAFT EVALUATION

MEASURES		MISSIONS	SOURCES
Low Density	Aircraft Track at Time Message	PPMs	Software
	Message Timing and Intelligibility	PPMs, NAMs	Audio Tape, Questionnaire
High Density	Types of Messages Generating Requests for Repetition	NAMs	Software
	Channel Loadin	NAMs	Audio Tape
	Number of Aircraft in Pattern	NAMs	Software
	Pilot Opinion of Content and Timing of Messages	NAMs	Questionnaire
	Pilot Acceptance of Delay or Omission of Messages	NAMs	Questionnaire

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