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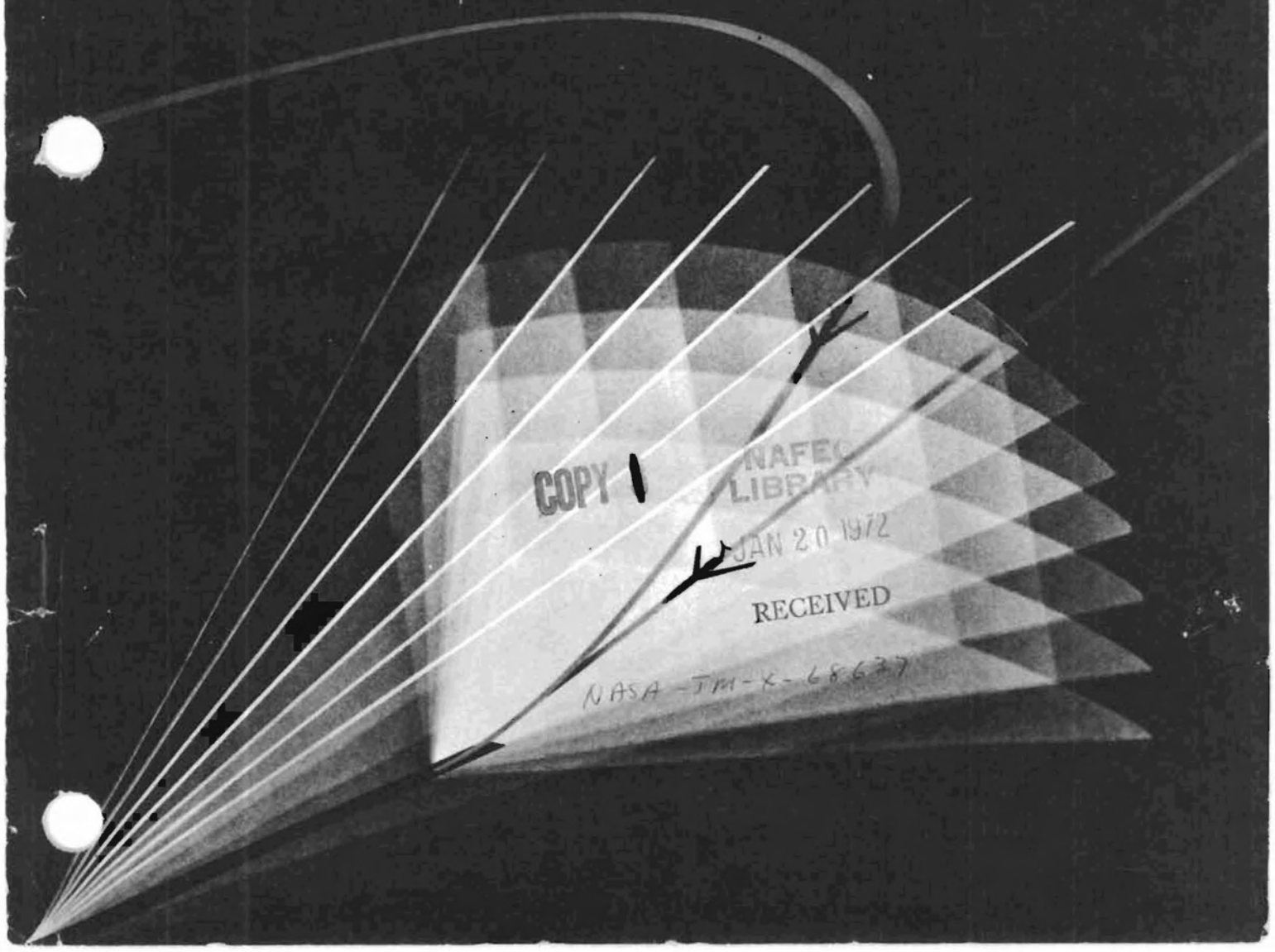
National Plan for Development of the Microwave Landing System

July 1971



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Federal Aviation Administration, Department of Defense and National Aeronautics and Space Administration
National Plan for Development of the Microwave Landing System. Washington, D.C., July 1971.

103 p. (NASA-TM-X68637) AD 733 268

1. Microwave Landing System. 2. Landing Guidance System. 3. Scanning Beam Guidance System. I. Department of Defense. II. National Aeronautics and Space Administration.

COPY

AD 733 268

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Department of Transportation National Plan for Development of the Microwave Landing System		5. Report Date July 1971 6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No. NASA TMX-68637
9. Performing Organization Name and Address Federal Aviation Administration Department of Defense National Aeronautics and Space Administration Washington, D. C.		10. Work Unit No. 11. Contract or Grant No. 13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address Department of Transportation Washington, D. C. 20590		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

A plan for the development of a new civil/military microwave landing system (MLS) is presented. It delineates the five (5) year program of integrated activity deemed necessary to provide a MLS that meets the wide range of user operational requirements set down by RTCA SC-117. Included in the plan are two interdependent and complementary activities: (1) an industry oriented systems development program designed to produce prototype equipments for flight test and evaluation and, finally, production specifications at the earliest possible date; and (2) a concurrent series of supporting government programs, to be undertaken by DOT/DOD/NASA, which will include validation efforts independent of the industry program, investigations of sub-system concepts and techniques, performance of flight tests and system evaluation efforts, and application of the microwave guidance system to the requirements of the individual users. Special emphasis is placed on the need for expeditious development of a MLS basic design that will utilize a standard signal structure and feature highly flexible modular building-block concepts that will facilitate its being appropriately configured to meet the complex requirements for full scale all weather automatic landings on the one hand, and the lesser requirements of general aviation users on the other.

17. Key Words	18. Distribution Statement
Microwave Landing System National Plan for Development of the MLS Scanning Beams; Approach and Landing Doppler Scan	Availability is unlimited. Document will be released by the National Technical Information Service, Springfield, Virginia 22151, for sale to the public.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	103	$3.00 .95

Form DOT F 1700.7 (8-69)

PREFACE

The National Plan for Development of the Microwave Landing System has been prepared by a joint DOT/DOD/NASA planning group.

The plan preparation followed extensive work by the RTCA SC-117, which established that techniques were available for the development of a family of systems that would meet civil and military needs within a compatible and common signal format.

The National Plan delineated herein reflects the five (5) year program of integrated activity deemed necessary, by the Joint Planning Group to provide a microwave landing system (MLS) that meets the wide range of user operational requirements.

The DOT, DOD and NASA strongly support the objectives of the plan and are in agreement that the FAA should proceed immediately with implementation of the systems development effort. Each of the participating agencies and departments agrees that the plan adequately defines a development to satisfy civil and military landing system requirements and agrees to conduct the tasks assigned herein, subject to reconsideration should subsequent events disclose a need for program modification or reorientation. It is to be noted that sources of FY72 funding have not yet been fully resolved and consequently the timing of some of the early tasks is not firm.

The complexity of the basic development program, and the diverse nature of related interdepartmental technical programs, require that a strong integrated program management capability be formed to coordinate and direct the program. To assist the FAA in achieving this over-all capability, actions are being considered to assign DOD personnel to participate on a full-time basis, in the program management office.

As directed in Chapter 4 of the plan, there exists an urgent requirement for the use of interim microwave systems to satisfy particular current and interim needs of various military and civil agencies. To satisfy this requirement, the FAA and DOD will undertake early discussions designed to work out mutually satisfactory solutions to the interim systems problem.

The National Plan will be updated once a year; the next review for the purposes of updating the plan will take place during November 1972.

Under Secretary of Transportation

Department of Defense
Representative to the FAA

Administrator, National Aeronautics & Space Administration

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SUMMARY

This document describes a plan to develop a new, common civil/military aircraft approach and landing system based on recommendations of the Radio Technical Commission for Aeronautics Special Committee 117 (RTCA SC-117). The system is intended to meet the entire spectrum of civil and military needs at domestic and foreign airports until at least the year 2000.

The principal approach and landing systems currently in use are the instrument landing system (ILS) for civil aircraft and the ground controlled approach (GCA) system, used largely by military aircraft. Each of these systems has been used essentially unchanged since its introduction in the early 1940's. Over the last few years, the Navy and Air Force have installed, on a limited basis, tactical microwave landing systems to meet urgent military requirements.

The proposed new landing system will provide appropriate guidance signals so that closely-spaced parallel runways may be used to accommodate high density air traffic. With appropriate airborne processing, the high quality signals will permit the derivation of flexible flight paths as an aid to noise abatement and increased capacity in the terminal area. Accurate guidance signals will be furnished that will be relatively insensitive to weather, terrain, structures, and other aircraft. Low cost versions will be available that will be appropriate for small airfields. Versions will also be available that will be suitable for vertical and short take-off and landing (V/STOL) operations and for the full spectrum of military applications.

The five year development plan includes two major complementary efforts: (1) an industry program designed to produce prototype equipments at the earliest possible date; and (2) a series of supporting government programs that will include independent (from the industry program) validation efforts, investigation of sub-system concepts and techniques, and the application of the microwave guidance system to the needs of specific aircraft.

The industry effort will employ a three-step contracting procedure:

(1) A technique analysis and contract definition phase in which several contractors will provide complete technical, program, and cost data in support of their design approaches, followed by

(2) The development of feasibility demonstration models, as required, to demonstrate the potential of the contractor's technique to meet a wide range of operational requirements, and

(3) The development and evaluation of pre-production engineering prototypes in several different versions, including airborne elements.

The Request for Proposals (RFP) will cover the entire five-year period from issuance of the RFP through the development of prototypes, and subsequent preparation of a set of production specifications. It also will include provisions for initial production quantities as options which may be exercised by the individual participating government agencies.

Multiple contractors (or teams of contractors) will be sponsored initially for the technique analysis and contract definition phase of the work which is expected to last about eight months, followed by four months of government evaluation. This interval of iteration between industry and government will permit intensive early exploration of certain critical issues, including assessment of overall system design for the intended applications.

At the end of this initial period, the contractors' results will be evaluated by the government and a limited number will be selected to continue into the second phase.

At the end of the second phase (feasibility demonstration) of the program, a choice will be made of the specific technique to be used for the development of prototype models. This choice will be based on the results of a comprehensive evaluation of feasibility demonstration hardware.

Then as many as two contractors will be selected to proceed with the third phase of the program (prototype development/flight test and system evaluation). During this phase, prototype systems will be designed, fabricated, and delivered for use in a full flight test and evaluation program to be performed at selected government facilities. This program will involve the various categories of users who will be given an opportunity to participate in flight evaluations using systems and equipments most nearly representative of their needs.

Following the tests, a set of production specifications describing the selected systems (ground and airborne) in terms of performance with complete detailed signal characteristics will be prepared. These specifications and technical characteristics will be in sufficient detail so that ground and airborne elements made by different manufacturers will be compatible. Although this program will result in production specifications, it is anticipated that the military services may require additional engineering development to assure compliance with their detailed requirements.

The government supporting programs will parallel in time the industry effort and will be carried out by the several government agencies participating in the development. These programs will provide the government with an independent means for judging the industry program and will investigate high risk but promising components and techniques which may enhance the system performance and reduce costs should they be successfully developed. It is anticipated that appropriate information concerning such components or techniques will be available for use in preparing the final production specifications. Airborne signal processing, flight control, and cockpit display

techniques and concepts will be explored to determine the means for utilizing the microwave landing system (MLS) in the most efficient manner. It is expected that flight simulation will play a significant role in these endeavors and flight evaluations in various classes of aircraft will be required.

The air traffic control (ATC) interface problems will also be investigated under the government program.

The plan designates the Department of Transportation (DOT), Federal Aviation Administration (FAA) as the agency for managing the industry development effort. Additional technical and engineering support will be provided by Department of Defense (DOD) personnel assigned to the FAA and by an Interdepartmental Advisory Group composed of personnel from the DOD and the National Aeronautics and Space Administration (NASA). The concurrent government programs will be directed by the participating services; however, these efforts will be coordinated through the FAA Program Management Office. Problems such as priorities and funding will be referred to the FAA Office of Systems Engineering Management for resolution. At critical review points, approval at the Secretary/Administrator level of the DOT/DOD/NASA will be sought.

It is estimated that this program will result in a set of production specifications for an MLS with an initial operational capability by 1978.

The estimated five-year cost of the industry development program is $41 million, to be obtained through the DOT/FAA research and development appropriation. The five-year funding requirements for the government programs (DOD, NASA, and DOT/FAA) are estimated at $50 million. This includes the cost of (1) techniques investigations ($15 million), (2) investigations of application to user needs, both military and civil ($20 million), and (3) comprehensive test and evaluation programs, including improved facilities and the operation of test aircraft ($15 million).

The plan also discusses national and international user coordination among the airlines, general aviation, and military aviation. Methods of accomplishing coordination with the RTCA, Aircraft Owners and Pilots Association (AOPA), Airline Pilots Association (ALPA), Air Transport Association of America (ATA), International Civil Aviation Organization (ICAO), and the North Atlantic Treaty Organization (NATO) are outlined. Included are consultation, review, demonstration and information distribution plans.

The international aspects of bringing into use a new landing system are highlighted. The RTCA SC-117 sought international participation from the beginning of its deliberations. The plan continues this effort by encouraging participation of foreign industry in the five-year development program and suggests methods by which this may be achieved.

The plan also discusses the relationship to ongoing programs, both civil and military. The FAA is under heavy pressure to install additional conventional VHF/UHF ILS equipments to meet immediate needs of the airlines and general aviation. The U.S. Navy and U.S. Marine Corps have procured or have initiated plans for procurement of microwave landing systems that will meet the majority of aircraft carrier, tactical operations, and training requirements extending at least through 1980. The U.S. Air Force has procured a number of portable microwave landing systems for special C-130 tactical uses. The Army currently is evaluating a microwave scanning beam landing system to satisfy interim tactical needs. Although procurement and use of interim systems are required until a new microwave landing system has been developed, tested, accepted, produced, and installed, the diversity and numbers of such interim systems should be kept to a minimum. The plan provides guidelines for containing this problem and easing the transition process.

1.0 INTRODUCTION

As an introduction to the development plan for a new landing system, the following topics are discussed:

- The purpose of this document and the development plan;
- The history of present landing systems;
- Reasons for developing a common civil/military system;
- Requirements for a new system;
- Recommendations by the Radio Technical Commission for Aeronautics for a new landing system (Ref. 1); and
- Other major considerations in evolving the plan for a new landing system.

1.1 Purpose

The purpose of this document is to describe a plan for the development and test of a new microwave landing system. The plan was prepared by an interdepartmental planning group established as a result of letters from the Under Secretary of Transportation to the Department of Defense and the National Aeronautics and Space Administration (Refs. 2, 3).

The purpose of the plan is to:

a. Outline the development effort required over the next five years to bring the system into being;

b. Define an approach to resolve the technical issues stemming from the work of the Radio Technical Commission for Aeronautics Special Committee No. 117 (RTCA SC-117);

c. Schedule the work to be accomplished so that objectives can be achieved in an acceptable time frame;

d. Provide data on fiscal, manpower, and facilities resources required;

e. Determine the optimum allocation of significant tasks among the three U.S. government agencies concerned (Departments of Transportation and Defense, and the National Aeronautics and Space Administration), and identify the management group required to coordinate activities;

f. Provide a mechanism for the full participation of industry so that the momentum gained during the RTCA deliberations is not lost;

g. Plan for national and international coordination activities over the five-year development period which will accelerate the acceptance of the new system; and

h. Recommend procedures for accomplishing the transition to the new system, particularly in relation to interim system developments in limited use which are being proposed as partial and immediate solutions to the landing problem.

1.2 History of Present Landing Systems

1.2.1 Instrument Landing System (ILS)

In 1939, the Civil Aeronautics Authority (CAA) demonstrated the first commercial ultra and very high frequency (VHF/UHF) instrument landing system (ILS) at Indianapolis, Indiana. Eight installations were procured in 1940, and in 1941 the system was adopted for national service. System use expanded rapidly in the U.S. toward the end of World War II and then became worldwide, having been adopted as an international standard by the International Civil Aviation Organization (ICAO) in 1949.

The civil VHF/UHF ILS has continued in use, essentially unchanged in basic principles, since its introduction in the early 1940's. The system is limited to a single approach path and for many years has been limited to operational minima of a 200-foot ceiling and forward visibility of one-half mile. To achieve lower minima it has been necessary to add many features, particularly to protect against signal degradation from surrounding obstructions and terrain. The basic technical limitations of the ILS are that (a) it has been shown to be susceptible to interference from nearby terrain, structures, and other aircraft in the air and on the ground; (b) it is dependent on the terrain in the vicinity of the antenna for the creation of its beams; (c) it is limited to providing proportional deviation information within a narrow sector centered about only one approach path; and (d) the size and characteristics of the antennas required do not lend themselves readily to installations at the small landing areas likely to be used by V/STOL aircraft, nor for use on aircraft carriers or highly portable tactical applications.

1.2.2 Ground Controlled Approach (GCA)

The U.S. military services used ILS during the early part of World War II. In 1942, however, the Massachusetts Institute of Technology demonstrated the first radar "talkdown" system invented by Dr. Luis Alvarez. Early in 1944, production testing of the ground controlled approach (GCA) system was completed and quantities became available soon thereafter. Subsequently, GCA became a standard low approach landing aid for the military services. A number of factors such as high initial costs, inefficient spectrum utilization, and the need for highly skilled operators are arguments against continuing the use of GCA indefinitely within the military services despite the numerous tactical advantages inherent in such a system. Furthermore, GCA, even with all known improvements, cannot fulfill the goal of all weather landing.

1.2.3 Other Military Developments

Shortly after the end of World War II, it became clear to the military services that the existing VHF/UHF ILS and GCA systems could not possibly meet all military needs. Development efforts to fulfill such needs began at an early date. A microwave development of ILS was tested by the Air Force as early as 1946, but was found unsatisfactory. The U.S. Navy began work on automatic carrier landing systems in 1950 and has continued such efforts over the past decades. As many as forty separate military developments were either investigated or partially developed, none of which reached the stage of acceptability as a common civil-military replacement for the VHF/UHF ILS and GCA system.

1.2.3.1 Navy and Marine Corps

The Navy has developed and is now implementing its automatic carrier landing system, the AN/SPN-10 and the improved AN/SPN-42, on its large aircraft carriers to achieve a fully automatic "hands-off" approach and landing capability. An extension of this system for Marine Corps use ashore is planned.

The Navy also developed and is now procuring quantities of a microwave scanning beam landing system (AN/SPN-41) for use as an independent monitor for the AN/SPN-42 and as an ILS-type navigation and landing guidance system aboard certain aircraft carriers. Also, a similar version, the AN/TRN-28 is being procured for Navy and Marine Corps use ashore.

The Marine Corps has evaluated but not adopted the simplified tactical approach terminal equipment (STATE) system for its forward area tactical requirements. Also, further investigation and study are being given to a highly portable system known as MRAALS (Marine remote area approach and landing system).

1.2.3.2 Air Force

The Air Force procured and evaluated shore-based versions of the Navy's AN/SPN-10 automatic landing system, which were redesignated as the AN/GSN-5 and AN/GSN-5A systems. However, these systems were not adopted for Air Force use.

The Air Force also sponsored a joint Army, Navy/Marine Corps, and Air Force interim remote area terminal equipment (IRATE) program resulting in an Air Force purchase of TALAR-IV equipment.

In addition, the Air Force sponsored a joint Air Force and Navy/Marine Corps program to replace the GCA system. This has resulted in the AN/TPN-19 modular GCA and radar approach control (RAPCON) equipment, now under development.

1.2.3.3 Army

The U.S. Army is currently sponsoring development of a microwave scanning beam landing system, known as A-SCAN, for helicopter operations.

1.2.4 FAA Developments

In 1959, soon after its establishment, the FAA began to explore the microwave scanning beam technique as the one which appeared to have the most promise of all those previously examined. Initial FAA efforts consisted of a program which led to the development and delivery of an advanced integrated landing system (AILS—a microwave scanning beam system), in 1965, and a recent program to meet V/STOL requirements. The FAA development programs formed the basis for a number of the military systems described above. None of these systems, however, could meet the full spectrum of civil requirements, and therefore the need to formulate a complete system design for the future became evident. Priorities were low but the work continued and together with the earlier military effort formed the data base for the recent RTCA SC-117 technical recommendations.

Although some of these developments were technically satisfactory for meeting unique service needs, no clear mechanism existed for achieving commonality and national acceptance. It became evident that the process of developing separate and incompatible systems for each service of the DOD and different solutions for civil needs was both operationally unwise and wasteful of research and development resources. This factor in itself made the establishment of a common approach and landing system highly desirable.

1.3 Reasons For A Common Civil/Military Landing System

1.3.1 National Policy

The Federal Aviation Act of 1958 charges the FAA with the establishment, operation, and maintenance of a common civil and military system of air traffic control and navigation. This FAA responsibility is also stated in the Code of Federal Regulations, Title 14, Chapter I, and Title 41, Chapter II. Public Law 89-670, which established the Department of Transportation, carries the same requirement.

Military research and development funding in this area was reduced in 1958 as a result of the FAA responsibility for a common civil and military aircraft system. Military developments thereafter have been limited to special environmental applications, such as tactical needs associated with forward areas and aircraft carriers.

1.3.2 Frequency Compatibility

Close coordination must be maintained between the civil and military establishments in order to avoid the development of incompatible civil and military systems. Costly and time consuming conflicts can occur when the civil and military agencies unilaterally develop systems that accomplish the same operational function, but operate either in different parts of the frequency spectrum, or in the same part of the spectrum and use different (incompatible) system characteristics. One example of such a conflict occurred during the years from 1954 to 1956 when the military proposed to implement their Tactical Air Navigation (TACAN) system in the same frequency band occupied by the civilian Distance Measuring Equipment (DME). The conflict was resolved in the U.S. by accepting a system providing VHF azimuth for civil aviation, UHF azimuth for the military, and UHF distance compatible with the TACAN signal format for both civil and military. The ground equipment was provided by co-locating a VHF omnirange (VOR) and a TACAN ground element to form what is called a VORTAC system.

Incompatibilities of this nature are much more difficult to resolve at the international level. In the case of the TACAN-DME conflict, a number of years of intense preparatory work were required prior to International Civil Aviation Organization (ICAO) acceptance of the revised DME characteristics. The MLS program as described will assure that conflicts of this nature are not repeated.

1.3.3 Common Airports

Joint civil and military use of airports is becoming increasingly necessary. Environmental problems such as noise, air pollution, and ground transportation have greatly increased the resistance to construction of new airports in urban areas. Also, the high cost of new airports has directed attention to methods for better utilizing existing facilities. Pressures are now building to permit civil aircraft to operate from existing military airports, particularly in congested urban areas, where the need for additional aircraft capacity is the greatest.

The present military policy of leasing passenger and cargo capacity from civil air carriers requires that civil aircraft operate from military airports.

Military aircraft will continue to fly from civil or joint-use airports for transport of passengers, cargo, National Guard personnel, and reserve training operations.

1.3.4 Standardization

Initial military development efforts for a replacement system to the VHF/UHF ILS considered only individual service needs. It became clear that it would be desirable to strive for a common civil and military design that meets all needs. Joint civil and military agreement will permit a

coordinated development program with the subsequent elimination of unnecessary development activity. Acceptance of the development plan in this document and the associated design goal should result in the saving of substantial future research and development funds. The benefits of eliminating the need for dual ground and airborne facilities are obvious.

1.4 Requirements For A New System

The need for an eventual replacement for the present landing systems, in existence for almost thirty years, has been recognized for some considerable time. Quite recently, shortcomings of the existing systems have been brought into focus, particularly with regard to the effect on airport capacity. A new microwave landing system is needed to:

a. Provide a high integrity precise signal in space, which is insensitive to a physically dense airport environment;

b. Permit all weather operations with an extremely high degree of safety;

c. Provide for a common civil/military system in accordance with national policy;

d. Provide for low cost versions which will permit the extension of service to low density airports on an economical basis;

e. Fulfill the operational needs of V/STOL aircraft for approach and landing services;

f. Provide a flexible guidance system which will aid in noise abatement;

g. Provide the capability for generating curved approaches to runways as a means for increasing airport capacity;

h. Permit less separation (2500 feet) of parallel instrument flight rules (IFR) runways;

i. Provide for tactical military versions of the system on a compatible basis;

j. Provide a system design which will be internationally acceptable as a replacement for the ICAO standard VHF/UHF ILS and will meet worldwide requirements until at least the year 2000.

1.5 Radio Technical Commission For Aeronautics

1.5.1 Special Committee 117

Impetus toward a national solution to the landing guidance problem was provided in October 1967 in a letter from the Air Transport Association to the FAA. This letter established the need for a new landing system for the airlines. As a result, Special Committee 117 of the Radio Technical Commission for Aeronautics was formed in December 1967 to develop ". . .a precision guidance system concept for approach and landing and an associated signal structure. This concept and signal structure shall satisfy, to the maximum extent possible, the various operational needs of the several classes of users."

The committee's work began with its first meeting in February 1968. Participation by representatives of foreign countries and international organizations was encouraged. Widespread interest

was evident by their attendance at many meetings, and the contributions of foreign experts were considered outstanding.

The first task in considering a new landing system was to examine user operational needs and establish a clear and succinct statement of operational requirements. This task, plus a concurrent review of the technical state-of-the art and identification of existing concepts that could satisfy stated requirements, continued for almost one year. This work was completed with the issuance of tentative operational requirements in January 1969.

The next step was to invite the various proponents of new guidance systems to propose techniques that would meet the tentative operational requirements. As a result, twenty-three proposals were received and evaluated by a techniques assessment team made up of experts on the committee who were users and also those who were responsible for implementing facilities. The team was chosen so as to avoid having proposers of a technique be in a position to judge their own or a competitor's technique.

The proposed systems were divided into three categories:

a. Scanning beam systems;

b. Multilateration systems;* and

c. Miscellaneous systems.

The team concluded and the committee agreed in October 1969 that an optimized microwave scanning beam system, combining the best features of several proposed techniques, could best meet most of the operational requirements.

1.5.2 Signal Format Development Team

The next step was the establishment of a signal format development team (SFDT) composed of the industry proposers of scanning beam systems. The team also included representatives from the avionics, general aviation, and airlines industries, as well as several U.S. and foreign government personnel.

The SFDT began its work in December 1969 and completed its activity with the publication of its report (Ref. 1) in September 1970. The team faced a choice between the conventional scanning beam technique or the Doppler scanning technique, since no single, practical signal-in-space format was considered able to accommodate both. Consequently, the team recommended that both techniques should at least be carried through further analysis, and assuming good results, through verification hardware development. The conventional scanning technique was recommended as the first choice for further work. Since the Doppler scanning technique may overcome some of the basic difficulties of conventional scanning systems, however, the team recommended that it should receive concurrent attention.

*Multilateration systems involve computing the position of the aircraft by comparing three or more distances between the aircraft and independent surface points.

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The signal format development team report was presented to the full special committee in October 1970 and accepted by an overwhelming majority. The committee recommended that additional in-depth analytical and experimental work should occur to verify the report.

The RTCA SC-117 technical recommendations form the basis for the development effort described in this document.

1.5.3 RTCA Recommended Design (Ref. 1)

A complete description of the proposed system appears in Ref. 1. It is based on the microwave scanning beam concept as developed over the past ten years. Examples of equipment employing this concept are REGAL, FLARESCAN, C-SCAN, A-SCAN, and AILS (Advanced Integrated Landing System). The latter has been under evaluation by the FAA for the past five years, and although falling far short of meeting the operational requirements formulated by the RTCA, it has provided data which has proved the inherent capabilities of the concept.

The microwave landing system is an air-derived data system operating at microwave frequencies. Ground stations generate electromagnetic signals that enable airborne units to obtain precision azimuth and elevation angles, and range data, referenced to the ground radiating system runway, which are suitable for display to the pilot and/or for inputs to an automated flight control system. Angular position of an aircraft is measured by reference to ground-generated scanning beams that scan across the coverage sector in both azimuth and elevation. The airborne unit extracts the angle data to obtain the line-of-site angle from the ground antenna. Range measurements are made by airborne interrogation of a ground transponder. The use of random interrogation rates allows a particular airborne unit to separate its transponder responses from others by accepting only synchronous responses. The system is capable of providing auxiliary data such as runway identity, equipment status, weather data, and siting geometry, to the airborne units.

Figure 1-1 depicts a block diagram of a typical microwave landing system. The following functional descriptions illustrate only the basic concepts of one simple version of the system. A number of minor variations in the diagram can result from using different antenna scanning techniques, different sitings for the DME equipment, an increased number of antenna systems for more services, etc.

In the case of the conventional scanning beam technique, the angle-scanners transmit narrow deviation angle modulation multi-tone coded signals which include antenna scan angle, identity, and other auxiliary data. The azimuth and elevation scanners operate on a time sequential basis, so that only one transmitter is on at a time. The angle data modulation is precisely synchronized with the antenna scan. The airborne receiver contains narrow bandwidth channels for receiving the signals from the scanning beam antennas. By detecting the sharp slopes of the antenna pattern, beam center detectors find the precise angle value when the aircraft is in the center of the scanning beam.

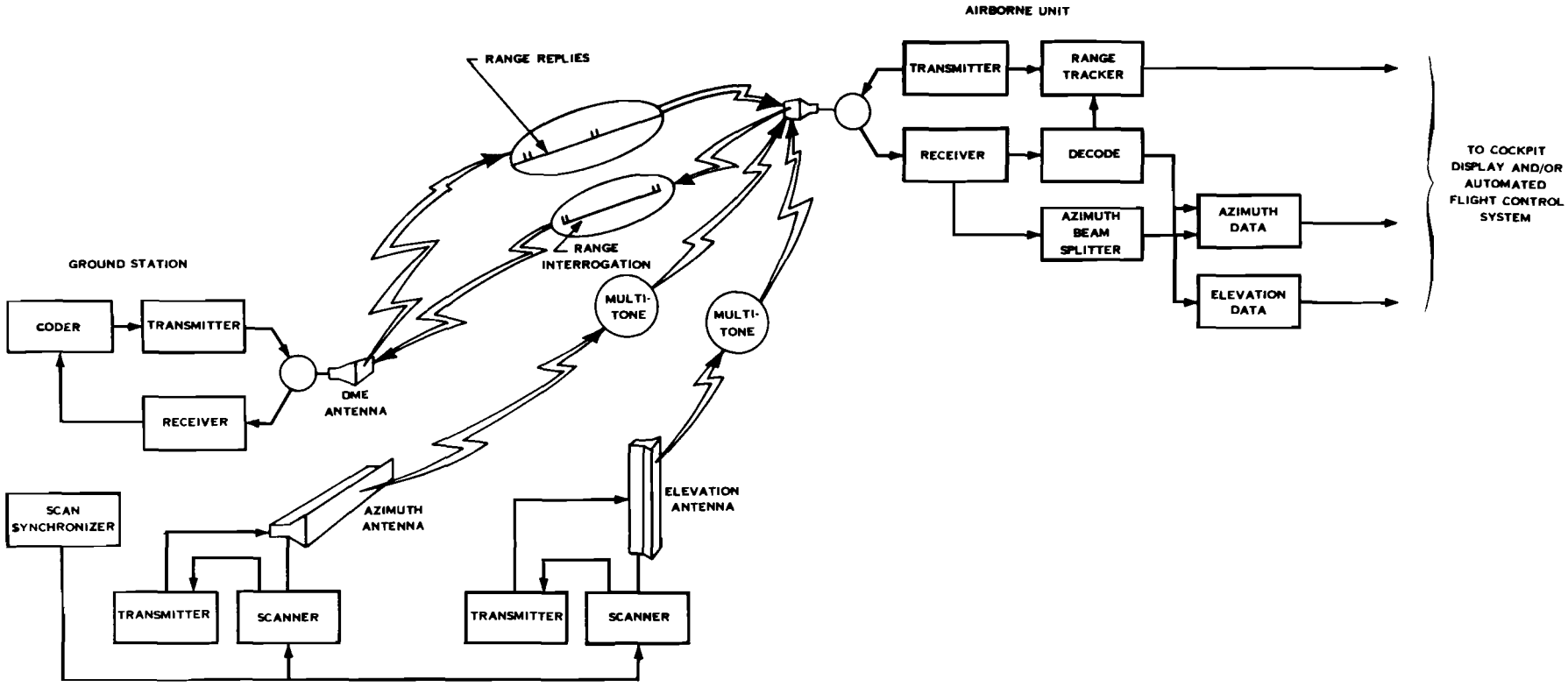


Figure 1-1. Block Diagram of a Typical Microwave Landing System

Aircraft position is recorded by decoding and storing the average value of the angle data during beam transit dwell-time.

In the case of the Doppler scanning technique, the self-encoding Doppler angle scanners transmit carrier-plus-single-sideband signals for the angle data, and amplitude-modulated multi-tone coded signals for identity and other auxiliary data. The azimuth and elevation scanners operate on a time sequential basis so that only one transmitter is on at a time. The airborne receiver contains channels for receiving the signals from the Doppler scanning antennas. By measuring the Doppler shifted frequency with respect to the reference carrier, the precise angular position of the aircraft is determined. Similar measurements are made in time sequence for azimuth and elevation.

To obtain range information, the airborne unit transmitter sends out range interrogation pulse-pairs at a pulse repetition frequency (PRF) nominally of 40 pulses per second (pps). The ground station receives the interrogations and, after a pre-determined time delay, transmits reply pulse-pairs. The airborne receiver accepts and decodes the range replies. A range tracker precisely determines aircraft range and velocity.

The following is a summary outline of the proposed system and provisional signal format:

a. The RTCA SC-117 recommended microwave landing guidance system* is comprised of the following elements:

(1) A C band elevation and a C band azimuth guidance element;

(2) A distance measuring equipment (DME) at C band;

(3) A Ku band elevation element for flare guidance to touchdown;

(4) A Ku band azimuth element for military application (optional).

The C and Ku band elevation elements will make use of compatible signal formats allowing the simplest possible signal processing in the airborne receiver.

b. The DME function, required to be an element of the landing guidance system, is to be in a separate part of C band, spaced at 3 Megahertz (MHz) intervals, channel-correlated but not integral with the angle channels.

c. The beams, both azimuth and elevation, must be capable of yielding planar information.

d. The format will use narrow band channels for angle data, spaced approximately 0.6 MHz apart. Fixed tones will be used for coding, and a tone range for angle data, frequency-proportional to angle. The system will provide for 100 channels initially and will be expandable to 200 channels.

e. Scan rates of up to 5 per second will be available within the signal structure for the C band elevation element and azimuth front and back course guidance, and 10 per second for the Ku band elevation element.

*The RTCA gave limited consideration to the airborne elements of the total system and tended to concentrate on the ground guidance facility. In the context used in this plan, the microwave landing system includes both ground and airborne elements.

f. For the conventional scanning beam system, 0.8 millisecond minimum dwell time is provided. A 0.5 degree beam width for the second elevation element is possible if needed.

g. For the conventional scanning beam, a continuous scan sum pattern beam will be used. Step scan antennas can be accommodated in the system.

h. For the conventional scanning beam, the modulation is likely to be narrow deviation angle modulation; for the Doppler scan, the modulation will be a modified double sideband-AM.

i. The format will accommodate a Ku band azimuth scanner in the event special military needs require it (such as at joint-use airports) as a complementary feature of the basic SC-117 system.

j. The system will be capable of providing discrete data identification plus certain limited data messages, such as indication of the status of the particular aid, the runway served, the identification of the facility and possibly certain other very simple data messages.

k. It will be possible to utilize the system: (1) on a single site basis (such as might be required for simple man-transportable military systems), (2) for V/STOL and possibly general aviation application, and (3) in a multi-site arrangement in which the basic elevation and azimuth scanners would be located at the conventional ILS localizer and glide slope sites. Ku band flare guidance will be located several thousand feet behind the basic C band elevation scanner to provide flare and touchdown guidance.

l. Table 1-1 describes the seven equipment configurations selected by the RTCA to satisfy the various operational and economic requirements of a common civil/military system. These configurations provide the necessary flexibility to adapt the system to the differing requirements for landing fixed wing aircraft, V/STOL aircraft and helicopters, and for military applications such as landing on aircraft carriers. The common signal format will allow users using the simplest low-cost airborne equipment to obtain service from either simple or high-capability ground equipment configurations. Also, users using the most comprehensive airborne equipment will be able to obtain service from the simplest ground equipment configuration, but with reduced capability. Thus, the user can determine the particular hardware that meets his needs. Modular construction and commonality between ground equipment configurations will provide the necessary growth capability to expand the simpler configurations to the most complex configuration as operational requirements increase.

1.6 Other Major Considerations

1.6.1 Transition to A New System

It is recognized that existing urgent requirements for landing systems must be met. The FAA must continue to install the VHF/UHF ILS concurrently with the development of the new microwave system. In addition, the military services will continue to fulfill their tactical needs by

Table 1-1. Capabilities Of Ground Station Configurations

SC-117 CONFIGURATION	B	D	E	F	G	I	K
	Straight Azimuth (Az) Basic DME	Straight Az Straight Elevation (El) Basic DME	Straight Az Select El Basic DME	Straight Az Straight El Basic DME	Straight Az Select El Precise DME	Curved Az Curved El Precise DME Missed Approach	Curved Az Curved El Precise DME Missed Approach
FACILITY PERFORMANCE*	CAT I	CAT I	CAT I	CAT II	CAT II	CAT III	CAT III
MINIMUM GUIDANCE ALTITUDE	150 Ft.	150 Ft.	150 Ft.	50 Ft.	50 Ft.	Touchdown	Touchdown
COVERAGE							
ELEVATION	Not Applicable (NA)	8°	20°	8°	20°	20°	20°
AZIMUTH	±20°	±20°	±20°	±20°	±20°	±40°	±60°
MISSED APPROACH	.....	.....	.....	.....	.....	±40°	±40°
ACCURACY**							
ELEVATION (2σ)	NA	7 Ft.	7 Ft.	1.4 Ft.	1.4 Ft.	1.4 Ft.	1.4 Ft.
AZIMUTH (2σ)	26 Ft.	26 Ft.	26 Ft.	11 Ft.	11 Ft.	9 Ft.	9 Ft.
RANGE (σ)	300 Ft.	300 Ft.	100 Ft.	100 Ft.	20 Ft.	20 Ft.	20 Ft.
DATA RATE (Max)	2.5 Hertz (Hz)	5 Hz	5 Hz	5 Hz	5 Hz	10 Hz	10 Hz

*A CAT I facility provides guidance information from the limits of coverage to the point on the runway centerline extended on the glide path at a height of 200 feet or less above the horizontal plane containing the threshold.

A CAT II facility provides guidance information from the limits of coverage to the point on the runway centerline on the glide path at a height of 50 feet or less above the horizontal plane containing the threshold.

A CAT III facility provides guidance information from the limits of coverage to and along the surface of the runway.

These are facility performance categories and do not in themselves indicate the operational utilization of a particular facility.

**Accuracy values are specified for the minimum height where guidance information is required.

the introduction of an improved GCA system and at least two microwave landing aids. This makes the task of accomplishing the transition to a new common system quite difficult.

To speed operational deployment of the new MLS, it will be necessary to decide what use should be made of interim aids. This subject is discussed in more detail in section 4 of this document.

1.6.2 RTCA Recommendations Versus Others

The RTCA SC-117 recommendations result from more than two years of work by a highly competent group of industry and government experts. The recommended system is designed to meet the operational requirements of all users and these requirements appear to be realistic and capable of achievement. Undoubtedly, it would be possible to postulate a whole series of different signal formats other than the one recommended by the RTCA. In some particular aspect, each of these conceivably would be superior, but perhaps at the expense of not meeting the entire set of common requirements.

The RTCA recommendations, although compromises to some extent, are believed to represent the best technical foundation for undertaking development efforts in an expeditious manner. Critical issues and limitations of the RTCA product are discussed in section 2 of this document. Validation efforts will lead to refinement. The RTCA recommendations have won the acceptance of a large industry segment, and it is essential to use them, with qualifications, as the starting point in the programs outlined in this plan.

2.0 DEVELOPMENT PLAN

There are two major aspects of the MLS development plan:

(1) An industry-oriented five-year program starting with concept validation and continuing through prototype development and preparation of production specifications; and

(2) Supporting government programs to be undertaken by DOT/DOD/NASA which will include: (a) techniques investigations; (b) application to user needs; and (c) flight test and evaluation activities.

The material that follows provides a detailed description of these two interrelated programs. Included are the reasons why certain significant choices for the conduct of the program were made by the interdepartmental planning group.

2.1 Industry Development Plan

2.1.1 Scope

The plan is an industry-oriented systems approach which places on the contractor(s) the full responsibility for undertaking all phases of work. These phases will range from initial analysis and experimentation through construction of prototype equipment and preparation of a set of production specifications.

The plan involves use of a three-part contracting procedure: (1) a technique analysis and contract definition phase, followed by (2) the development and testing of feasibility demonstration hardware, and (3) the development and testing of engineering prototypes. The request for proposals will be available to all of industry, with a strong recommendation that contractor teams be formed.

Up to six contractors (or contractor teams) may be initially sponsored for the technique analysis and contract definition phase of work. Each will engage in analyses, experiments, and laboratory demonstrations to support and validate his proposed technique and signal format, and to define a program including preparation of engineering prototype specifications for the follow-on system development work.

At the completion of contract definition, a comprehensive assessment will be made of each contractor's progress in the refinement of his proposal. Up to four may be selected to proceed into the next contractual phase. Upon completion of the feasibility model demonstrations, the government will select the best technique and signal format and choose one or more contractors to continue into the next phase which involves development leading to delivery of the prototype systems.

The government will test and evaluate the prototype systems to verify that the wide range of user operational requirements can be satisfied.

The selected contractor(s) will prepare a set of MLS production specifications and, at the option of the government, compete (along with others) for the manufacture of limited production quantities for operational implementation.

The plan minimizes the amount of time required for initial validation effort and technique selection and permits the earliest possible start for prototype system development.

The industry development effort is divided into eight tasks (described below). The schedule for accomplishing these tasks is illustrated in Figure 2-1.

2.1.2 Program Tasks

2.1.2.1 Task A–Request For Proposal (RFP)

The RFP will require contractors to respond with their technical and management plans for the complete program–from the initial verification studies and experiments, through prototype development and testing, and including preparation of a set of production specifications. The proposed schedule should be directed at obtaining operational implementation of the system in the 1976-1980 time frame. Appendix A contains more information on the contents of the RFP.

2.1.2.2 Task B–Evaluation Of Proposals

The proposals will be evaluated against the range of civil and military operational requirements specified in the RFP. Emphasis will be placed on a combination of the following elements:

(1) Understanding of the inherent technical problems and validity of proposed solutions;

(2) Corporate/management background and experience; and

(3) Resources and facilities to be devoted to the five-year effort.

Based on this evaluation, a number of contractors will be selected to proceed into the technique analysis and contract definition phase, which will consist of study, analysis, and experimentation efforts to define and verify the proposed system design.

2.1.2.3 Task C–Technique Analysis and Contract Definition

A number of contractors (as many as six) will undertake the work necessary to further develop their proposals by gathering the data necessary to refine the proposed design concepts.

The output of this task will be an updated MLS Development Program Plan containing a full report of the technique analysis effort; an updated feasibility demonstration program plan which includes feasibility demonstration hardware specifications, a feasibility test and evaluation plan, and related schedule and cost estimates; an updated prototype systems development plan; and, an updated limited production option plan.

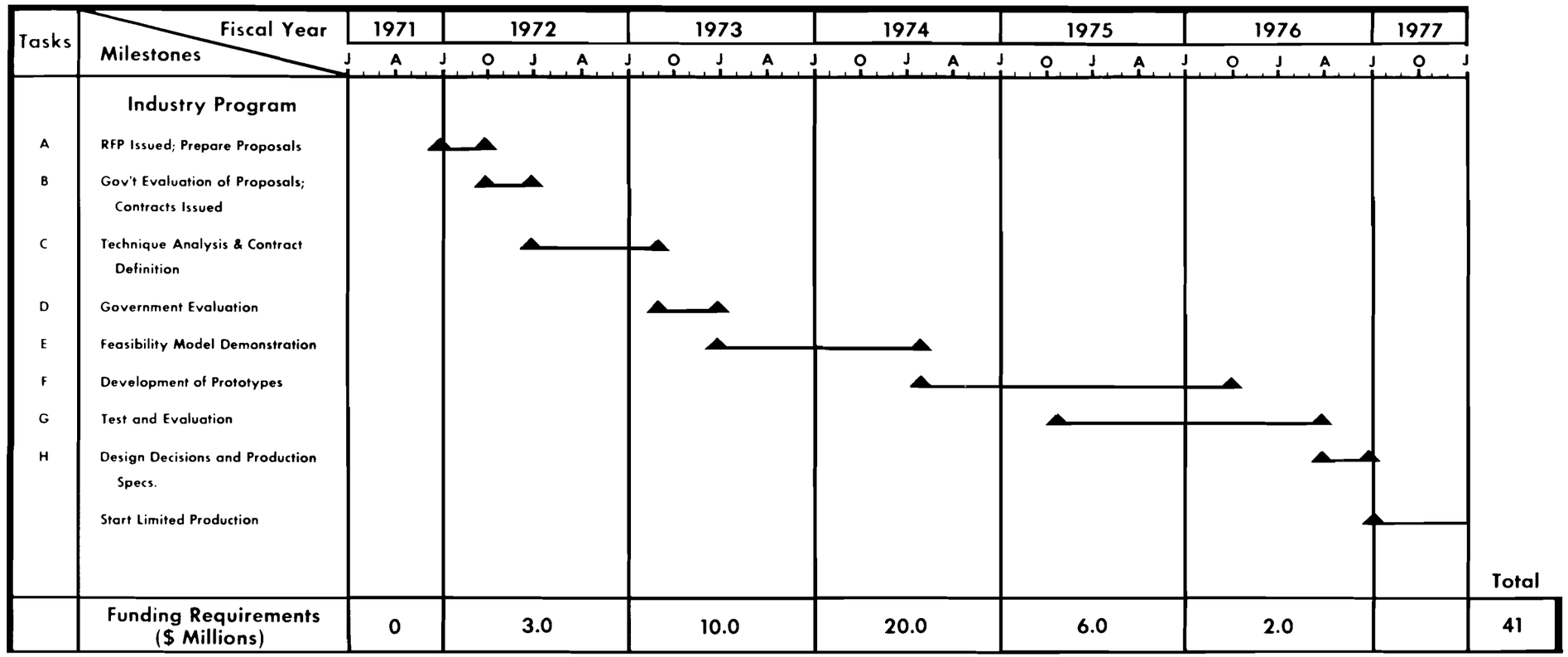


Figure 2-1. Industry Schedule

2.1.2.4 Task D – Government Evaluation

The government will evaluate progress made by the contractors during the initial techniques analysis and contract definition task. This evaluation will consider the extent of analysis completed, engineering specifications, and planning for feasibility demonstrations and prototype production. Several contractors will be chosen to continue into Task E of the program.

2.1.2.5 Task E – Feasibility Model Demonstrations

Feasibility models will be designed, fabricated, and tested during this portion of the program. After a thorough review of the data acquired during the program, the government will select the best system technique/signal format for application in the prototype development task effort which will be performed by up to two of the contractors. The output of the task will be a refined MLS Development Program Plan containing a refined prototype systems development plan; and a refined limited production option plan.

2.1.2.6 Task F – Development Of Prototypes

Selected prototype systems will be designed, fabricated, and delivered to the government for test and evaluation. Each prototype development program will include key decision points at which time a decision may be made to terminate a particular program if the required performance is not attained.

2.1.2.7 Task G – Flight Test and Evaluation of Prototypes

The prototypes will be evaluated and flight-tested at government facilities to verify that the operational requirements for the various types of aircraft and ground sites are met. This will be a series or parallel effort dependent on the availability of the various prototypes. The contractor(s) will prepare a set of production specifications (in terms of performance) with the detailed signal characteristics needed to meet all civil-military requirements in the various configurations, for both airborne and ground systems. Refined cost estimates for limited production quantities will also be made.

2.1.2.8 Task H – Design Decisions and Production Specifications

The evaluation results will be reviewed and the best system (either one complete or the best combination of sub-systems) selected as the common civil-military system.

If a combination of sub-systems is necessary to meet the operational requirements, or if more investigation is required on one system, further verification and system refinement will be accomplished. This information will be required prior to refinement of the production specifications, scheduled to take place as a part of this task effort. (It is to be noted that additional engineering

development of equipment to meet the military environmental requirements may follow, on an individual service basis, prior to exercising the military production options.)

At the completion of the development plan, a contractor may be selected to proceed into production of limited quantities of the selected system configurations to satisfy early operational needs of the various users.

2.1.3 Development Hardware Requirements

2.1.3.1 Feasibility Models

The number of feasibility models to be developed for test purposes will be the minimum required to determine the suitability of a proposed technique to meet the range of operational requirements. Each contractor will designate in his plan the feasibility models to be fabricated and will provide justification for his selection.

2.1.3.2 Prototype Systems

The numbers and configurations of prototype equipments to be delivered; the allocation of these equipments to the various government agencies; and the aircraft to be used in the flight test program are shown in Table 2-1. With respect to the ground equipments, one contractor is to supply one each of configurations G, I and K and one special (modified split site) configuration E. The other contractor is to supply one each of configurations D, E, I (shipboard) and K, and one special (modified colocated) configuration E (see Table 2-1). Selection of these ground configurations should enable the government to evaluate the potential of each contractor's design with respect to all configurations and allow direct comparison tests of each design.

2.1.3.3 Airborne Equipment

The contractors are not to develop prototype airborne equipment, other than that necessary to receive the MLS signal, decode it, and provide outputs that are usable for display and aircraft control. Each contractor is to install, in designated aircraft, the prototype MLS airborne equipment and appropriate hardware and/or modifications to existing airborne equipment necessary to demonstrate that the MLS outputs are suitable for display and automatic aircraft control. This effort will require detailed specifications and close coordination to effectively resolve the interface problems and minimize costs.

Table 2-1. MLS Prototype Equipment To Be Delivered (Including Aircraft Installations)

AGENCY	GROUND EQUIPMENT		AIRBORNE EQUIPMENT		
	SC-117 Configuration	Quantity	Number of Sets	Configuration	Aircraft Type
FAA	K	1	4	K	Airline (CV-880)
	D	1	4	D	General Aviation (Aero Commander)
NASA	K	1	3	K	STOL (C-8A)
USAF	E	1	4	E	T-39
	I	1	8	I	C-135B, F-106B
USN/USMC	I (Shipboard)	1	8	I	F-4J, A-7E
	G	1	4	G	CH-46, AV-8
USA	E (Modified) (Split Site)	1	4	E	Fixed Wing
	E (Modified) (Co-Located)	1	4	E	Helicopter
TOTALS	9 Ground Sets		43 Airborne Sets		12 Aircraft Installations

2.1.3.4 Production Quantities

At the completion of the development effort, it is envisioned that the government could exercise a production option with the contractor whose prototypes most fully satisfy the specifications, for the quantities and configurations of ground and airborne equipments shown in the following table (Table 2-2).

Table 2-2. Production Items To Be Included In Production Options (Funded by Each Agency At Its Option)

AGENCY	GROUND EQUIPMENT		AIRBORNE EQUIPMENT	
	Configuration	Quantity	Configuration	Quantity
FAA	K	5	K	10
	D	5	D	10
NASA	K	1	K	10
ARMY	E (Man-Pack)	1	E	5
	G (Man-Pack)	1	G	5
NAVY/ MARINE CORPS	1 (Shipboard)	1	K	10
	G (Man-Transport-able)	1		
AIR FORCE	I	2	K	10
	E	2	E	10
TOTALS	19 Ground Sets		70 Airborne Sets	

2.1.4 Procurement Approach

This plan involves use of a three-phase contracting procedure: a technique analysis and contract definition phase, followed by a feasibility demonstration phase, and a prototype hardware development/flight test and system evaluation phase. A fixed price contract will be used for the technique analysis and contract definition effort and cost-plus contracts will be employed for the feasibility model and prototype development/flight test and system evaluation efforts.

Fixed price contracts for up to $500,000 will be offered to each contractor for Task C, Techniques Analysis and Contract Definition (Phase I). To assure that the contractors selected at the end of the contract definition effort can continue into the hardware development phase with a minimum of delay, it is necessary that fully negotiated contracts be available as soon as possible after completion of the government's evaluation in Task D. This requires that contract negotiations be carried on with the selected contractors at the earliest date practicable.

Cost-plus contracts will be negotiated with up to four contractors selected for Phase II, Feasibility Demonstration (Task E). Upon completion of the feasibility demonstration program, the government will perform a thorough and comprehensive evaluation of the various MLS designs demonstrated, to determine their potential for meeting the broad spectrum of user operational requirements. Then, cost-plus contracts will be negotiated with up to two contractors selected for Phase III, the Prototype Development/Flight Test and System Evaluation segment of the MLS industry development program. Maintaining two contractors in Task F will provide technical design and cost competition.

The contract procurement approach to be employed in the MLS development program is in full agreement with the procedures outlined in the FAA Contracts Division, Advanced Procurement Plan No. 4400.1-17.71, dated 9 March 1971, "Microwave Landing System (MLS)"

2.1.5 Industry Program Funding Requirements

During the five-year period, Fiscal Years 1972-1976, it is estimated that the industry program for the development of prototype units and subsequent preparation of production specifications (ground and airborne) for the MLS will require $41,000,000. This total was derived as follows:

(1)	Technique analysis and contract definition; six contracts at up to $500K each	$3,000,000
(2)	Feasibility model demonstrations, prototype development, and delivery of nine ground equipments and 43 airborne units over a two-year period	30,000,000
(3)	Installation of prototype equipments (ground and airborne) and support of government test and evaluation programs	6,000,000
(4)	System level verification and preparation of production specifications	2,000,000
Total		$41,000,000

Funds required by fiscal year are listed in Table 2-3.

Table 2-3. Industry Development Program Funding

FISCAL YEAR	$ MILLIONS
1971	0
1972	3.0
1973	10.0
1974	20.0
1975	6.0
1976	2.0
TOTAL	41.0

2.1.5.1 Basis For Estimated Costs

The objective of this development plan is to achieve the desired goal within a five-year time period. In arriving at the approach described, no constraints were imposed by establishment of any predetermined budgetary levels. However, a conscious effort was made to stay within the fiscal bounds of what appeared appropriate in terms of relative priorities and the importance of the MLS to the entire third generation increased capacity ATC system. Therefore, the plan is a compromise, one which calls for a full-scale effort, but one which still recognizes that there must be a relatively well-defined limit to that which will be made available.

Technique analysis/contract definition (for approximately one year) encompassing the work effort for this program may cost potential contractors more than the $500,000 fixed price. While beyond government control, it is anticipated that contractors striving for prominence in this field may expend additional funds to offer a competitive proposal.

The background experience of a number of industry organizations in microwave landing systems, their development of experimental equipments, and their diverse contributions to the RTCA SC-117, clearly show that a comprehensive program should solicit the talents of as many such organizations as sound program management and funds will permit. Therefore, the plan provides for an award of up to six contracts for the technique analysis and contract definition phase, at a total cost of $3,000,000.

The cost of feasibility demonstrations and development of prototypes is estimated at $25 to $35 million. For convenience, this has been charted as $10 and $20 million per year for the two Fiscal Years, 1973 and 1974 respectively. Distribution within that period may vary as a function of exact contractual details. These phases of the effort call for feasibility demonstrations by up to four contractors and the continued development of prototypes by as many as two on a competitive basis. The requirement for nine ground stations and 43 airborne units results in the estimates given.

To attain close familiarity and achieve acceptance of the MLS by the various segments of civil aviation and the different services of the DOD, it is considered necessary to supply prototype units to as many as can profitably undertake evaluation programs. The large number of such prototypes, coupled with the approach of maintaining industry competition, results in the $25 to $35 million estimate given above. During FY 1975, prototype units will be delivered and installed in designated aircraft. The $6 million cost is based on having industry install the prototype ground and airborne equipment (in government aircraft), and provide field engineering and maintenance services.

The estimated final cost of $2 million during FY 1976 is associated with system level modifications which may be necessary and the cost of preparing production specifications plus allied documentation.

The $41 million for the industry program is considered appropriate for funding under the FAA R&D programs under the common interpretation of the 1958 Act; this is consistent with assigning program responsibility to the FAA.

2.2 Supporting Government Programs

The industry development portion of the total five-year plan has been described. Interrelated and interdependent supporting programs will be conducted concurrently by the individual participating government agencies either in-house or with separate contract support.

The supporting government programs will include three areas of effort: (1) techniques investigations; (2) application to user needs; and (3) flight test and evaluation. A series of tasks to be accomplished under each of these areas will be defined and described in this section. Responsibility for funding and accomplishment of each task will be allocated among the participating agencies in consideration of existing and/or planned capabilities and the individual requirements of each agency.

A detailed description of the total government program is contained in Appendix B. A summary of the program follows below. Table 2-4, page 2-13, summarizes the program by general area of effort, government agency, and funding requirements by fiscal year.

2.2.1 Program Content

2.2.1.1 Techniques Investigations

This effort includes analyses, tests, and experiments directed at establishing a knowledge/data base in the government to enable the government to conduct comprehensive technical evaluations of industry proposals and subsequent analytical and experimental efforts. This work not only will assist in the selection of the technique/signal format to be authorized for prototype development, but also will support the required technical validation of the selected technique. Early investigations using existing R&D hardware will address issues such as required data rate, low angle ground effects, C band and Ku band propagation (including multipath effects), and effects of siting geometry on

airborne signal processing requirements. Other investigations will involve encoding/decoding techniques, modulation techniques, the planar/conical antenna design question, and problems associated with a two-frequency-band system. New design techniques or technological developments having potential for improving performance or reducing component costs will also be investigated; for instance, a feasibility study will be conducted on phased arrays to determine their potential for use with the MLS.

2.2.1.2 Application To User Needs

Included in this area of effort are those activities required to assure effective utilization of the airborne receiver's output. This must be done to verify that the selected system technique will satisfy the spectrum of established operational requirements. These activities will provide the technological data base required for the development and evaluation of flight control and display techniques, and will determine the performance requirements for signal processors.

Other studies will be conducted to assure suitability of proposed and selected techniques to meet certain unique military requirements. For instance, the Navy must determine the effects of a moving platform (carrier flight deck) on a Doppler scanning system, and those antenna techniques that are suitable for C band operation from ships. The Army, however, being interested only in Ku band angle guidance, must determine that the MLS C band DME sub-system will be compatible with their requirements.

The interface between the MLS and the ATC/NAS will be analyzed in consideration of system requirements. The most effective means of using and integrating the MLS into the ATC/NAS will be determined. Included here will be the application of the selectable and curved path capability of the MLS to increase operational capacity of an airport and to distribute and control noise levels in airport approach and departure corridors.

2.2.1.3 Flight Test And Evaluation

This effort encompasses those activities necessary to validate the overall adequacy of the selected MLS in meeting the diverse requirements of all users. Extensive flight tests will be conducted not only to determine whether the MLS will meet nominal operational requirements, but also to determine its adaptability to special user requirements. Operational acceptability from the pilots' viewpoint will be given primary consideration. The FAA is responsible for system validation in accordance with the range of operational requirements established for civil aviation.

The effectiveness of the MLS for STOL operations will be evaluated by NASA and the Air Force.

Each of the participating services of the DOD will be responsible for validating the MLS for its unique requirements.

There is no individual government facility equipped to undertake the complete test and evaluation of the MLS. However, it is believed that sharing of facilities by the proper allocation of tasks can accomplish the test and evaluation program without the need for extensive new facilities. Some modification and upgrading of existing facilities will be necessary and costs for such work are reflected in the funding requirements indicated.

2.2.2 Supporting Government Program Funding Requirements

Table 2-4 shows the total estimated funding requirement for the government program during the five-year development period to be $50 million. Of this total, $15 million are required for techniques investigations; $20 million for investigations of applicability to user needs; and $15 million for flight test and evaluation. Individual participating agencies will require funding to accomplish the portion of the total program which has been designated as their responsibility. These funds should be made available through each agency's normal budgeting and appropriations procedures. The funding required by agency per fiscal year is also summarized in Table 2-4.

The detailed description of the government program contained in Appendix B shows funding requirements for each task by agency and fiscal year. (Note: The U.S. Army and the U.S. Air Force will require program adjustments in FY 1972 in order to meet their funding requirements.)

2.2.3 Related Programs

In addition to those efforts that are essential to the development of the MLS, NASA and the Air Force have programs to develop solutions to STOL problems. NASA desires to fund the development of an avionics system for a selected STOL aircraft as part of the MLS program. Since such a development would be required regardless of whether or not there is an MLS program, the cost of developing that avionics system should not be considered as a direct charge in the development of MLS. Since a test bed will be required by NASA, however, it has been decided that the cost of the development of the STOL avionics ($11.6 million) should be identified as a related program. Actual flight tests of a prototype system by NASA will determine the suitability of the MLS for STOL operations; the costs ($1.7 million) associated with evaluation are considered a part of the MLS program, and are treated accordingly in Appendix B.

The Air Force has a STOL technology program which includes efforts ($4.6 million) for STOL flight control and instrument landing development. In addition to the $4.6 million, the Air Force has already spent $2.0 million in equipping a CH-3E helicopter as a STOL flight profile simulator and is currently making data flights using modified STATE (C band) equipment in defining high angle guidance, and control and display problems and solutions. Tests using a synthesized MLS are planned for CY 72 as well as flights in a STOL-type aircraft. Since this program is proceeding regardless of whether or not an MLS program exists, the program cost is not considered a direct charge in the development of the MLS and is treated accordingly in Appendix B.

Table 2-4. Supporting Government Program Funding

Program/Government Agency	Funding By Fiscal Year ($000)						
	1971	1972	1973	1974	1975	1976	Totals
TECHNIQUES INVESTIGATIONS							
1. Experimentation Using Existing Systems							
Federal Aviation Administration	0	300	300	0	0	0	600
Transportation Systems Center	100	200	0	0	0	0	300
U.S. Army	0	250	225	150	150	50	825
U.S. Navy	0	425	300	55	0	0	780
U.S. Air Force	700	3,150	2,300	300	0	0	6,450
2. Advanced Technology Investigations							
Federal Aviation Administration	0	100	100	500	500	500	1,700
Transportation Systems Center	305	500	500	0	0	0	1,305
3. Signal Format Investigations							
Federal Aviation Administration	600	300	300	0	0	0	1,200
U.S. Army	0	260	255	255	210	0	980
U.S. Navy	0	170	80	50	0	0	300
U.S. Air Force	0	250	200	0	0	0	450
Sub-Totals	1,705	5,905	4,560	1,310	860	550	14,890
APPLICATION TO USER NEEDS							
1. Aircraft Control/Display							
Federal Aviation Administration	0	1,700	1,450	1,700	1,450	400	6,700
U.S. Army	0	400*	1,200	525	500	100	2,725
U.S. Navy	0	250	250	200	0	0	700
U.S. Air Force	50	1,250*	700	1,250	1,350	0	4,600
2. U.S. Army Operations	0	400	575	525	475	325	2,300
3. U.S. Navy Operations	0	230	415	100	0	0	745
4. U.S. Air Force Operations	50	400	110	110	110	0	780
5. ATC/NAS Interface							
Transportation Systems Center	0	300	300	300	300	300	1,500
Sub-Totals	100	4,930	5,000	4,710	4,185	1,125	20,050
FLIGHT TEST AND EVALUATION							
1. Provide Test Facilities							
Federal Aviation Administration	0	300	500	200	0	0	1,000
Transportation Systems Center	0	100	100	0	0	0	200
U.S. Army	0	350	1,170	270	245	200	2,235
U.S. Air Force	0	900	500	300	300	0	2,000
2. Flight Test							
Federal Aviation Administration	0	0	100	400	1,500	1,000	3,000
National Aeronautics and Space Administration	0	0	0	200	700	800	1,700
U.S. Army	0	0	100	550	700	0	1,350
U.S. Navy	0	0	100	200	800	700	1,800
U.S. Air Force	0	0	200	500	500	500	1,700
Sub-Totals	0	1,650	2,770	2,620	4,745	3,200	14,985
SUMMARY BY AGENCY							
Federal Aviation Administration	600	2,700	2,750	2,800	3,450	1,900	14,200
Transportation Systems Center	405	1,100	900	300	300	300	3,305
National Aeronautics and Space Administration	0	0	0	200	700	800	1,700
U.S. Army	0	1,660*	3,525	2,275	2,280	675	10,415
U.S. Navy	0	1,075	1,145	605	800	700	4,325
U.S. Air Force	800	5,950*	4,010	2,460	2,260	500	15,980
TOTALS	1,805	12,485	12,330	8,640	9,790	4,875	49,925
Related Programs							
National Aeronautics and Space Administration	(1800)	(4000)	(3500)	(1600)	(700)	(0)	(11600)
U.S. Air Force	(1150)	(1150)	(1150)	(1150)	(0)	(0)	(4600)

*The U.S. Army and the U.S. Air Force will require program adjustments in FY 1972 in order to meet these funding requirements.

2.3 Derivation of The Plan

The details of the development plan were presented above. This section discusses the factors considered in the development of the five-year plan.

2.3.1 General Considerations

2.3.1.1 Guidelines and Constraints

Basic to any program effort are certain reference and boundary conditions which provide broad guidelines about which the program is to be structured. These pertinent factors are:

(1) The development program will cover a five-year time period with time zero being the date of issuance of the RFP;

(2) The analytical and evaluation effort of RTCA SC-117 establishes the reference upon which the program will be based; and

(3) The end product of the program will be a set of production specifications for the various system configurations necessary to satisfy the range of operational requirements set down by RTCA SC-117.

2.3.1.2 System Limitations

In the broadest context, a total system approach could be interpreted to include all sub-systems related to the landing of an aircraft. Even though they may require effort, however, sub-systems such as approach lighting, independent landing monitor, area navigation, various air traffic control terminal area sub-systems, etc., are excluded from this program except to consider their constraints on the system design.

2.3.1.3 Accomplishment Of The Work

The task of developing a complex system in a limited time frame requires the use of available talent wherever it may exist; i.e., industry and government, both national and international.

Industry will be expected to bring in, by teaming arrangements, specialists in avionics and flight control systems as well as the talents of recognized foreign experts.

The government programs will utilize the background knowledge which exists in various DOD laboratories and in the FAA. Efforts to reach international agreement between governments for the conduct of the program will be undertaken by the DOT/FAA. This is discussed in more detail in section 3.0.

2.3.2 Technical Considerations

2.3.2.1 RTCA Deliberations

The long and thorough deliberations of the RTCA SC-117 produced an excellent basis for an orderly and logical development program. The organization of the numerous and sometimes

conflicting requirements into a meaningful set of parameters resulted in the establishment of a family of seven ground-based guidance system configurations covering most user operational desires (with the exception of some unique military requirements).

A signal format common throughout all system configurations was produced which accommodates the known information requirements. The signal format also provides a high degree of flexibility and the capacity to add additional information requirements if they become necessary.

The RTCA deliberations not only selected a preferred concept (microwave scanning beams) from among many candidates, but also made best judgment decisions on the techniques to be used in the design of system hardware. The RTCA realized, however, that the decisions concerning specific techniques needed verification since, in many cases, they were based on incomplete data. Rather than an outstanding single choice, close votes between competing approaches or a lack of a sufficient basis to exclude a suggested approach were the norm. The examination of these critical design areas, including a thorough consideration of the aircraft portion of the system, form a significant part of the necessary development program.

2.3.2.2 Unresolved Technical Issues

2.3.2.2.1 Doppler Principle Versus Conventional Scanning Beam Techniques

Although the RTCA SC-117 was able to reach best judgment decisions on many critical choices, one issue of great significance remains unresolved and will require parallel effort for eventual resolution. Use of the Doppler principle as a means for creating a scanning beam in space was judged to have significant potential and therefore was considered worthy of exploration along with conventional scanning beam techniques. Technical reasons for this decision appear in the report of the RTCA SC-117 (Ref. 1).

The significance of this action is that parallel work will be necessary until the Doppler approach is eliminated or shown to be superior to the conventional one. Since the Doppler approach was proposed by representatives of European industry, it is expected that it will receive international interest and support. For this reason, as well as for the promise that the Doppler approach holds, a prudent plan should encompass the resources needed to carry this effort to a proper conclusion. This unresolved issue may require the building of feasibility models for both the Doppler and conventional scanning approaches before a clear decision can be made.

2.3.2.2.2 Other Critical Design Issues

Analyses and experimental test programs are required to verify the decisions reached by RTCA SC-117 on other critical design choices. Several critical issues requiring effort are outlined below.

(a) Angle Modulation

A CW carrier with a form of constant amplitude phase modulation (narrow deviation angle modulation) was selected over pulse modulation techniques. Verification of this choice is required. Also, laboratory measurements should be used to determine cross-talk limits and to determine which type modulation levels should be assigned to each of the frequency-multiplexed modulation signals of a given function.

(b) Scan Rates

Scan rates of 5 scans/second for the azimuth and number one elevation guidance element and 10 scans/second for the number two elevation guidance element were selected. These rates must be verified as operationally adequate for Categories II and III as well as autoland. Considerable verification is needed to assure that the decision is valid for this is critical to many diverse types of aircraft. Too low a rate can limit the precision of response that may be needed for certain aircraft or for new aerodynamic control systems.

(c) Planar Versus Conical Beams

SC-117 concluded that scanning beams for azimuth and elevation should be of the planar type in standard configurations. It was recognized, however, that conical elevation beams could be employed in specialized applications where the azimuth and elevation sites are co-located. Planar beams are naturally produced by mechanically rotating or nodding antennas, and conical beams are naturally produced by linear, electronically scanned antennas. Analyses and experimental work are needed to determine the feasibility and cost of producing planar beams from non-rotating antennas. Verification is required of the adequacy of elevation coverage, at the edges of azimuth coverage, using planar beams.

(d) C Band DME Pulse Transmission

The provisional signal format provides for the operation of the DME function on separate frequencies within the C band. Verification is required that initially 100 channels and ultimately 200 channels can be achieved by pulse-multiplexing the 10 available frequencies. Also, pulse echoes, C band antenna directivity (air and ground), and other well-known factors that influence the performance of the DME function to the desired tight accuracies of the provisional format need to be evaluated, particularly in multipath environments.

(e) Step Scan

SC-117 concluded that the provisional signal format should be designed to accommodate the continuous scan as the basic choice. Step scan could be employed, however, provided its radiation (when processed by the airborne equipment) meets the performance requirements of the configuration with which it is used. The use of the step scan technique offers the capability of providing electronic scanning at minimum cost. Experimental tests are required to determine whether

the step scan technique can provide low angle coverage without an unacceptable level of low grazing angle reflections. Also, it must be verified that it is possible and practicable to have an airborne processor which can accommodate both continuous and step scan techniques. Analyses are required to determine if the step scan technique offers significant reductions in the cost of ground equipment.

(f) Missed Approach

A departure course (azimuth) scanner located back-to-back with the approach course scanner, and transmitting in a separate time slot with an information bit to distinguish it from the approach guidance, was selected by SC-117 to provide guidance for missed approach and climb-out service. The use of a separate, missed-approach site at the approach end of the runway was also identified as a non-standard installation.

The first solution appears to be the better in terms of simplicity, economy, and reliability. Analyses and experimental tests are required, however, to determine whether the "cone of silence" over the station, which is inherent in this method, can be made small enough to satisfy operational requirements.

The use of the separate site at the approach end of the runway would eliminate the "cone of silence" problem. This solution has numerous disadvantages, however. It is more complex; costlier; has decreased reliability; and requires its own power, control, and monitoring functions. Also, tests are required to determine if a missed approach (back course) signal can be radiated simultaneously with the front course without interference.

(g) Sum Pattern Versus Null Pattern

It was the judgment of SC-117 that the conventional beam shape (sum pattern) is preferred because of the simplicity of the sum beam decoding circuitry. Verification of this choice is required since there is evidence that the null beam may enable operation at significantly shorter ranges due to the null not being defocused, and that smaller errors tend to result when the null is used for beam splitting. Analyses and experimental tests are required to determine whether the use of the null pattern will result in lower equipment complexity and whether equivalent low angle accuracy can be achieved.

2.3.2.3 Need For Design Verification

The RTCA SC-117 recommended system has never been constructed, even in rudimentary form, and there is no extensive knowledge available concerning major components. This is not meant to imply that the recommended system is beyond present day technology; there is little doubt of technical feasibility. The question, rather, is whether or not the RTCA SC-117 approach represents (with a high degree of certainty) the best way to proceed. The remaining unresolved critical issues alone prompted RTCA SC-117 to recommend technical validation and investigations for certain issues.

In addition, since the new MLS will satisfy all civil and military requirements well into the future, and because of the large eventual system investment, the development plan must contain the means by which proof of the design technique can be acquired. This must be done in a manner which will assure the expeditious progress of the development cycle, and at the same time be of sufficient depth to provide high confidence in the wisdom of the design choices.

The need for analyses, experimentation, and verification work is particularly critical in the initial phases of the development program. It must be recognized, however, that evaluation and verification is a continuous process throughout the program and is necessary to minimize technical uncertainties and risks and to provide insight for the inevitable trade-off decisions that are part of any development effort. This work must both precede and overlap prototype systems development.

2.3.2.4 Need For Development Of Several System Configurations

A strong point of the RTCA SC-117 design is its applicability to all classes of users. Many efforts were expended to assure that the signal format would lend itself to the design of a variety of ground equipments meeting general aviation, military, and air carrier needs all in a compatible manner. This capability must be verified; therefore, there is a need for the development of several configurations of ground facilities and airborne elements. Only in this manner can the adequacy of the signal format to meet its objective be proven. This will require delivery to the government of many types of ground facilities with the consequent need for an extensive test and evaluation program. Although this is costly, there is no other way of ascertaining full system capability.

2.3.2.5 Need for Development Of Ground And Airborne Components

As a new system evolves through design, fabrication, test, and evaluation, many modifications and trade-offs between interdependent sub-systems are necessary due to design problems which arise. Quite obviously, then, the development cycle must include both ground and airborne elements of the total system. Prototype airborne equipment is required only to the extent necessary to validate that the MLS will satisfy the range in user requirements; that is, to receive the MLS guidance information, decode it, and provide outputs that are usable for aircraft control and display purposes. The prototype airborne equipment required by the DOD under this program should lead directly to the procurement of equipment meeting military specifications.

An adjunct to basic airborne sensor design is the development work necessary to provide the computational capacity and tie-in to aircraft flight control systems so that the received guidance signals may be used to their fullest operational advantage. This area has been almost totally unexplored, particularly with regard to the generation of curved approaches to closely spaced parallel runways and other concepts associated with increasing airport capacity. This will be a development, test and experimentation effort in parallel with the basic guidance system development; however, a

full capability in this respect will not be realized until the basic guidance system has been developed.

2.3.3 Program Schedule Considerations

2.3.3.1 Urgency And Risk

There is a certain urgency associated with the accomplishment of this program as reflected in the designated time element. Tending to counter the urgency issue is the need to minimize technical risks (the high cost of being wrong) before going into engineering prototype or production phases of the development. Trade-offs between risk, time, and money must accommodate some level of acceptable risk to obtain a product in a reasonable time and at a reasonable cost.

The need for a new approach and landing system to replace present systems has been acknowledged for some time. This need is basically due to the technical limitations discussed in section 1.4. More recently, studies of methods to improve airport capacity have highlighted operational deficiencies associated with existing systems. The rapidly expanding demand for air transportation services has emphasized the urgent need for an improved approach and landing capability.

In order to be responsive to this urgent need, it is essential that the plan be based on techniques which have a relatively high probability of success, to result in production specifications for a new system within a five year time period. To meet this time schedule and permit the earliest possible operational implementation, the time devoted to the development effort must be efficiently utilized; that is, it must be productive in terms of technical progress. This means that time devoted to procurement activities should be minimized, and therefore some approach other than the commonly used classical development cycle is needed. A discussion of possible approaches is contained in the following section.

2.3.3.2 Discussion Of Alternative Development Plans

Although there is a preferred technical approach (conventional scanning beams) in the RTCA SC-117 documentation (Ref. 1), it must be recognized that all of the candidate techniques considered during the deliberations of SC-117 could not be decisively ruled out. The relatively short program time period prior to the development of engineering prototypes must be used to concentrate on those key areas of each technique which permit decisions to be made in favor of a single approach as early as possible.

In consideration of the difficulty experienced by the RTCA SC-117 in trying to eliminate competing techniques and to converge decisively on one and only one technique, two possible alternative development plans may be delineated:

Alternative (1): using the SC-117 recommendations, initiate a full-scale five-year systems development program with industry, starting with concept validation and feasibility model demonstrations prior to the development of prototype hardware, to permit selection of the superior

technique to be employed as early in the program as practical; conduct a parallel supporting government program of analysis, experimentation, and test to provide additional guidance to the system developers and to assist the government in selecting the technique to be implemented;

Alternative (2): direct a program of independently conducted analysis, experiments, and tests to validate and resolve the SC-117 tentative findings; the results of these individual efforts would be compiled, compared, and evaluated by the government to determine whether the scanning beam or the Doppler scanning technique should be implemented; after a firm decision has been made as to the superior technique, and after the prototype specifications are written, contracts would be awarded to industry for prototype systems development.

Alternatives (1) and (2) are similar for each provides a sound mechanism for the selection of a system technique and, in this respect, is responsive to the overall objectives of the national plan. For these two alternatives, the technical approach for selecting the system design is essentially the same. There are some basic differences between the two plans, however, which affect the timeliness of achieving the goal and the timeliness of full-scale industry involvement.

Alternative (2) represents a conventional R&D plan in which the development effort is broken down into three distinct phases; a concept formulation and validation phase; a feasibility model phase; and an engineering prototype phase. These are discussed further below.

To accomplish the first phase, the government would direct a program of independently conducted studies, analyses, and experiments to validate or modify the tentative findings of RTCA SC-117 and to recommend techniques for feasibility model development. These initial efforts would be accomplished by organizations such as government laboratories or non-profit (unbiased) research laboratories which are not hardware manufacturers. Equipment manufacturers would be involved, however, on a limited, discrete task, sub-contract basis. At the end of this phase, the government would compare and evaluate the results and prepare feasibility model specifications for the most promising techniques.

During the second phase, contracts would be let for feasibility models and the government would conduct a flight test and evaluation program which would form the basis for the selection of a single system technique. At the end of this phase, engineering prototype specifications would be written for the selected system.

To accomplish the third phase, contract(s) would be let for prototype hardware, and the government would conduct a comprehensive flight test and system evaluation which would result in refinement of the system design and the preparation of production specifications.

Alternative (1) utilizes the same basic mechanism (i.e., the concept formulation and validation phase, the feasibility model phase, and the engineering prototype phase) in selecting the best technique and developing the prototype hardware. It differs from alternative (2), however,

in that it involves a total systems development approach which encompasses all three phases of the program. This approach provides for full-scale participation of industry from the start of the program and permits the utilization of a contracting procedure which minimizes procurement processing time during the total development program. On the other hand, alternative (2) does not invite full-scale industry participation until the start of the engineering prototype phase, and separate, lengthy procurement action is required for each phase of the program. There does not appear to be any significant difference in cost or technical risk between the two alternatives since the content of the two plans is similar.

In examining the necessary time period to accomplish alternative (2), a six-year period appears to be the best that can be achieved with this plan. It is evident that the primary reason for the plan's inability to meet the five-year development goal is the use of separate competitive procurement actions for the various phases which result in excessive procurement processing time during the total program. Alternative (1) is advantageous in this area, since it permits better use of the allocated time period by utilizing a total systems development approach in which one or more of the initially selected contractors will carry through all three phases of the program, thereby minimizing the time required for procurement processing. Also, alternative (1), by using the full-scale participation of industry from the start of the program, would help to maintain the momentum gained by industry during the RTCA SC-117 deliberations and thus would underscore the government's resolve to develop and implement the new system at the earliest possible time.

On the basis of these considerations, alternative (1) was selected.

2.4 Other Aspects of the Industry Plan

2.4.1 Teaming

A total system development effort involves both the ground and airborne elements of the system. The interrelationships between sub-systems during the development cycle naturally results in design modifications and trade-offs due to problems encountered. To most effectively marry the ground and airborne systems and assure that the total system will be available for procurement at the completion of the development cycle, avionics and flight control systems specialists must be completely involved. Therefore, teaming arrangements between segments of industry are an important requirement in this plan and will be considered by the government in the evaluation of proposals.

The involvement of the expertise available in foreign industry is also desirable. It would help to assure that technically the best system possible will be developed and would be an important step in achieving eventual international acceptance of the microwave landing system. Any proposed arrangements directed at applying the talents of foreign industry in the development cycle will be a factor for consideration in proposal evaluation.

2.4.2 Industry Role in Evaluations

Industry does not have the full capability to conduct the required flight test and evaluation of the new system and will rely upon the government to provide the necessary test facilities. (These are discussed in section 2.6 and in Appendix B.) Industry will have an active role in the flight test and evaluation program as well as in the engineering, installation, and technical support category. This includes the provision of appropriate special test equipment, and the expertise necessary to assure continued, proper operation of both the ground and airborne elements of the total system during test and evaluation.

The government also intends to augment its capability by utilizing the services of expert consultants in microwave landing systems and microwave technology on an as-required basis for technical evaluations and test and evaluation program planning.

2.4.3 Competition

The maintenance of competition throughout the development program is considered necessary to assure that the best system obtainable, within the constraints of time and money, is being developed and that the follow-on initial procurement of limited production quantities will be on a competitive basis. As already discussed, competition is readily maintained through the contract definition and feasibility model demonstration phases. To assure technical competition in the development of prototype hardware and competitive cost proposals for the production options, the government intends to select two contractors to proceed into prototype development. However, the contracts will contain provisions for termination in the event that a contractor becomes deficient either technically or in terms of rate of progress.

2.5 Program Management

Although development of the MLS is addressed mainly to meeting technical objectives, there are many management implications which must be considered as an integral part of the total program plan. Complex interdepartmental relationships, and a determination of how best they should operate to bring a new common civil/military MLS into existence, have to be considered. In recognition of this situation, a management approach has been developed which brings the full talents of government and industry to bear on the problem. The need for concurrent programs to be undertaken by various government laboratories (with the aid of industry) has been established and management responsibility for such effort has been assigned to each of the three major agencies involved (DOT, DOD, and NASA).

Fiscal requirements for the program have been developed and the rationale for the funding provided. As a first iteration, the plan contains all that is necessary to get the program on its way.

The major effort remaining, then, is to execute the plan, and the job of management is to supervise its execution.

From a management viewpoint, there are five basic tasks to be accomplished:

(1) Technical management of the industry development program;

(2) Planning, coordination and integration of concurrent government laboratory programs;

(3) Program progress monitoring and reporting;

(4) Coordination with user groups and international organizations; and,

(5) Resolution of technical and funding priority problems.

The new microwave landing system is considered to be an integral part of the upgraded third generation ATC system, as formulated by the ATCAC. By virtue of its charter, the development of this new microwave landing system is recognized as a basic FAA responsibility. To properly discharge this responsibility, it is essential that the best capability available be applied to perform this effort. To accomplish this, the FAA will, in addition to full application of its own resources, continue to expand previously established capabilities in this area. NASA's ability to manage large-scale programs is recognized, and will be utilized, as appropriate, in support of the overall program. In addition, the technical capabilities of DOT/Transportation Systems Center (TSC) are appropriate for the performance of a variety of tasks to be undertaken by the government concurrently with the industry development program.

The industry system development program, task (1) above, is most critical with respect to time and entails a major expenditure of funds. FAA technical expertise is manpower-limited and cannot do the entire management job, as presently constituted. Even with expansion of the FAA's professional and engineering staff, it is apparent that from a program integration/coordination standpoint, assistance will still be required from the DOD and NASA during the evaluation phases of the MLS development program. Their assistance is especially critical in the early evaluation of industry proposals when the FAA will not have been able to assemble a full staff.

The assignment of technical areas of work for task (2) appears in Appendix B of this document. Task (2) consists of concurrent government laboratory programs undertaken either in support of the industry effort or in fulfillment of individual user needs. The DOT/TSC has been given an expanded role in total systems analysis, exploration of specific critical technical issues, and at a later date, portions of the total evaluation effort. The DOD must carry a major part of both initial signal format verification and flight evaluation during the latter part of the five-year period. It should also be borne in mind that the DOD is responsible for the development of specific military ground hardware and avionics equipment for specific aircraft. The Air Force and the NASA-Ames STOL programs will be an important adjunct of the program, designed to prove system military utility for future STOL aircraft and to demonstrate enhanced ATC capabilities as a result. Task (2) must assure proper coordination and integration of all the above governmental laboratory

activities. It is essential that they be conducted in a proper time sequence and relate properly to the total effort, thereby achieving results which contribute to the industry prototype development effort. Actual technical management of these activities will, quite obviously, be the responsibility of the appropriate organizational groups within DOT, DOD and NASA that will conduct the specific activities. An important level of program coordination will be achieved by the widespread acceptance of this plan, and the firm understanding that it represents the policies of the DOT, DOD, and NASA. Continued coordination is essential, however, to the success of the development program.

Tasks (3) and (4), progress reporting and centralized coordination with user groups, present no unusual management challenges and can be handled readily by the MLS program management office.

To provide program management and direction for the tasks mentioned above, it is planned that a full-time working level Program Management Office will be formed within FAA/SRDS (see Figure 2-2). This office will ultimately (by FY 1973) consist of 21 permanently assigned individuals supported by consultant/technical support services on an as-required basis. Within the cadre of personnel assigned on a full time basis, it is planned that at least four of the engineering positions be occupied (at an early date) by personnel assigned to the office by the DOD (representation to be distributed among the military services). These individuals will be competent engineers with backgrounds in microwave technology, or techniques applicable to microwave landing systems, and have appropriate experience in the technical management of government research and development contracts. The active full time participation of DOD personnel will enhance the timely accomplishment of the overall MLS development program, provide for closer integration of the supporting government programs and the MLS system development activities, and promote more effective interdepartmental relationships.

The FAA Program Management Office (Figure 2-2) will be established as a Branch Office (Microwave Landing System Branch) within the Navigation Development Division of the Systems Research and Development Service (SRDS) and have the necessary authority to accomplish all MLS program activities in a timely manner. The functions of the branch will be as indicated below.

a. The branch will be the focal point and principal element of the Division with respect to development, ultimate deployment, and modernization/modification of MLS equipments in support of national goals to increase the capacity of the National Airspace System.

b. With respect to the foregoing, the branch will:

(1) Plan, program, specify and manage all development effort of the agency on engineering techniques, devices, equipment and systems. These responsibilities will cover the cycle from initial inception through delivery of the first article and issuance of procurement specifications.

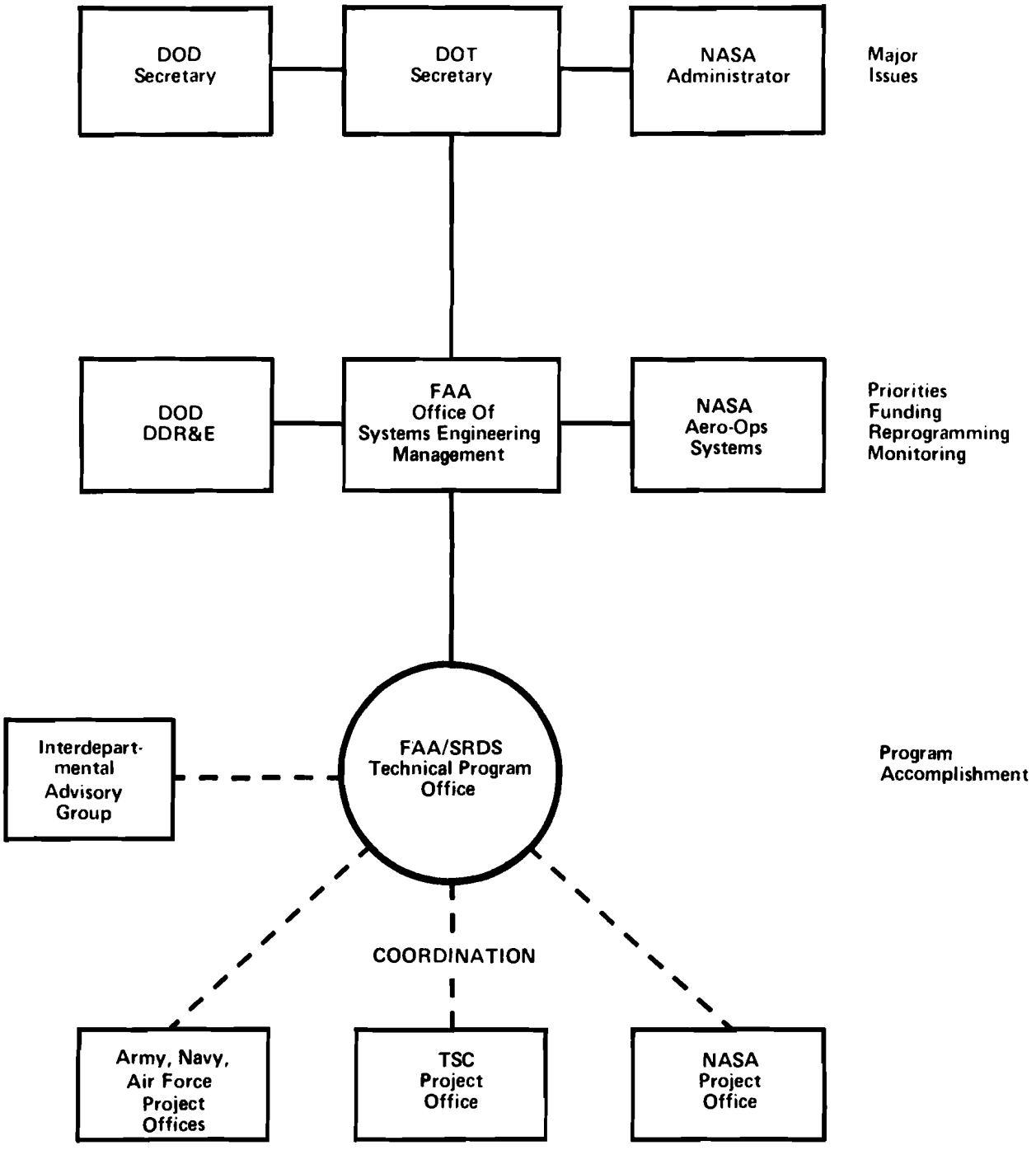


Figure 2-2. MLS Program Management Office

(2) Program and manage all design, development, fabrication and acceptance testing necessary to assure that initial specifications are met. Also, it will establish programs for research, experimentation, evaluation, and will initiate assignments for their accomplishment.

(3) Program, design, develop and manage the acquisition, installation and preparation for operational evaluation of prototype equipments at joint military/civil facilities.

(4) Provide technical consultation and assistance to, and coordination with, offices, services, and regions of the agency, other government agencies, and aviation-user organizations.

(5) Design and develop prototypes, and specify all major modifications required for in-service improvement, and improvement of joint military/civil facilities.

(6) Prepare data upon which final equipment procurement specifications can be based.

c. On a total system basis, appropriate engineering support will be obtained, as required, to assure that the MLS interfaces properly with the concept, procedures, and equipment associated with other all-weather landing programs and the multi-dimensional terminal navigation programs.

To perform the responsibilities of the branch, three sections, with the manning indicated in Figure 2-2, will be formed.

The System Integration Section will perform the branch functions with respect to program planning, documentation, scheduling, reporting, controlling, and carrying out coordination and liaison functions with offices, services and regions of the FAA, other government agencies (both national and international), and aviation user organizations.

The System Development Section will perform the branch functions related to system design, development, technical and operational test and evaluation, and management of acquisition and subsequent installation for evaluation.

The Supporting Engineering Section will perform the branch functions with respect to techniques investigations, test facility development, component development, applications engineering, and the definition of an interim system for V/STOL aircraft.

In addition, it is anticipated that the office will require the assistance and advice of selected consulting contractors in the executive management of this program. This assistance will be critical, especially during the initial phases of the program, when the full engineering staff has not been acquired.

To assist the FAA Program Management Office in the performance of its total MLS program integration and coordination responsibilities, an Interdepartmental Advisory Group, will be formed, consisting of representatives from the DOD services, NASA, and TSC. This group will aid in the coordination of the supporting government programs and provide representation on technical working teams and evaluation teams during appropriate stages of the MLS industry effort.

The management task (5) of resolving possible program conflicts, funding priorities, etc., can only be resolved at a higher management level than that of the group described above. Additionally,

periodic changes to this plan will be required. This management function will be accomplished through the FAA Office of Systems Engineering Management (OSEM). This office is presently responsible for planning, coordination, and management of resources for the total increased capacity effort associated with the upgraded third generation air traffic control system. Interdepartmental coordination for resolution of policy, priority and funding questions, necessary reprogramming action, and overall monitoring of progress, are the types of activity consistent with the responsibilities of the OSEM.

Figure 2-3 illustrates the overall management concept.

2.6 Experimentation and Test Resources

2.6.1 Introduction

An inventory of facilities now available at government laboratories and an indication of their availability will make it possible to determine whether or not additional capital facilities will be required for this program.

In a program of this nature, there are three types of facilities which are basic:

(1) An operational airport

(2) Range instrumentation, and

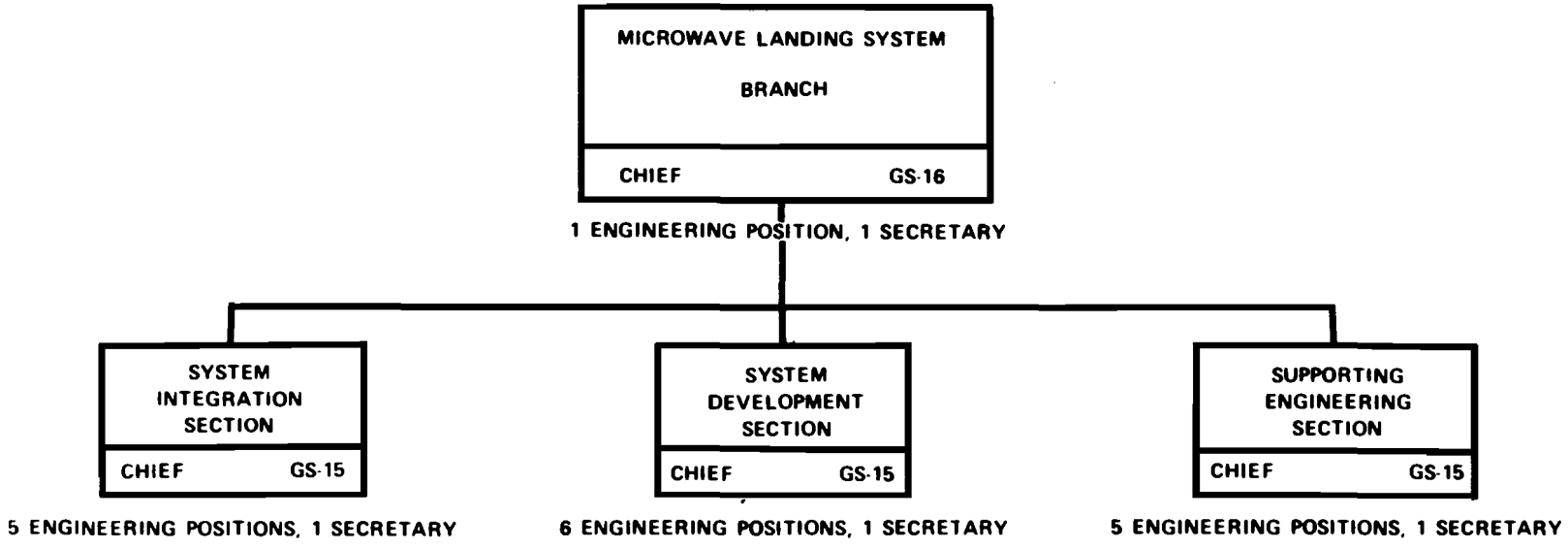
(3) Instrumented aircraft.

In addition to these basic facilities, the following are significant: flight simulators, data reduction facilities, special test laboratories, antenna ranges, etc., and experimental R&D microwave landing systems.

There is no one government facility which is equipped to undertake the complete task of test and evaluation without augmentation. FAA/NAFEC has an excellent airport and range, but is limited in available aircraft. DOD should be in a position to make aircraft available, although range facilities available to the Air Force at Wright-Patterson Air Force Base are not totally adequate. NASA is well equipped at Edwards Air Force Base, but their aircraft availability is limited. At this point, it may be tentatively concluded that a proper pooling of resources can meet program needs without the construction of elaborate new facilities.

The above conclusion, quite obviously, is based on the establishment of adequate priorities for this program. All of the above major facilities are in use and are scheduled for continued use over the next few years. It should be possible to make the facilities available for the microwave program without causing hardship to other activities.

Flight simulators exist at NASA/Ames, Air Force/Wright-Patterson, and NAFEC. Each of these facilities is best suited for particular phases of simulation work and, therefore, all will be required in the program. Unfortunately, none of the facilities have completely adequate visual scene simulation capability for all-weather landing work. This still requires further development



MANNING SCHEDULE

6 POSITIONS · FY-71
10 POSITIONS · FY-72
5 POSITIONS · FY-73
TOTAL: 21 POSITIONS

Figure 2-3. Management Concept

so that all-weather operations can become a reality. Minor improvements will be made at NAFEC so that the limited simulation capability available there can be used in this program without long delays. More elaborate simulation will depend on the facilities at NASA/Ames and at Wright-Patterson Air Force Base. Specialized test equipment, antenna ranges, etc., will have to be augmented over what presently exists; however, these are not considered to be in the category of major facilities. The extent of modification and the need for new facilities are described in Appendix B along with the estimated costs.

Experimental versions of many types of microwave systems developed over the past five years constitute another important resource. These are as follows:

(1) Flarescan (Ku band) elevation only; Air Force, Wright-Patterson Air Force Base

(2) AILS (Ku band) elevation and azimuth; FAA/NAFEC

(3) SPN-41 (Ku band) elevation and azimuth; Navy, Patuxent River, Maryland

(4) A-Scan (Ku band) elevation and azimuth; Army, Ft. Monmouth, New Jersey

(5) MODILS (C band) step-scan elevation and azimuth; FAA/NAFEC

(6) STATE (C band) with fixed glide slope and coarse/fine localizer; Air Force, Wright-Patterson Air Force Base

(7) TALAR IV (Ku band) with fixed glide slope and fixed localizer; Air Force, Wright-Patterson Air Force Base.

Most of these equipments can be readily modified for the gathering of experimental data required for the process of validating RTCA signal format recommendations. These are significant programs which must be started at the earliest possible time.

Although it was mentioned earlier that sufficient aircraft should be available, past history has shown that invariably aircraft shortages occur during large-scale evaluation programs. The flight time available on an R&D aircraft is limited, perhaps 30 hours a month, as an average. The conduct of programs on an expedited basis requires that back-up aircraft be available to meet tight scheduling. Aircraft availability must have high priority for successful conduct of the program. As a minimum, the aircraft listed in Table 2-1 (which are scheduled to receive the initial prototype airborne equipments) will be required in the program. However, R&D aircraft will also be required and at an earlier date. It may be necessary to augment NAFEC's capability so that this work can be conducted on schedule.

2.6.2 Available Facilities

2.6.2.1 NASA

(1) Edwards Air Force Base, California

- Dynamic Test Range

- Control Room and Real Time Plot
- GE-225 Computer
- MPS-19 Radar Modified for C band
- Time Multiplex Station with PCM/FM/FM
- High Accuracy Instrumentation Radar (HAIR), (equivalent to FPQ-6 C band)

(2) Ely, Nevada

- Dynamic Test Range
- Real Time Plot
- Time Multiplex Station with PCM
- MPS-19 Modified for C Band

(3) Wallops Island, Virginia

- GSN-5 X-Band and TV Playback
- MPS-19, S Band
- GE Computer
- Intermediate Focal Length Optical Track (IFLOT)
- FPS-16

(4) Langley Air Force Base, Virginia

- Anechoic Chamber, All Automatic Data Reduction
- Both Inside and Outside Test Facility to Look at Antenna Design

(5) Ames, California

- FSAA 6 Degree of Freedom Simulator and Digital Computer
- Link 3 Degree of Freedom Simulator and Digital Computer
- Motion and Visual Systems are Probably the Best Available

2.6.2.2 Army

(1) Ft. Monmouth, New Jersey

- Two-Camera Portable Linked Tracking System with Timing Under Evaluation
- UH-1H Iroquois Helicopter (A-SCAN Equipped)

2.6.2.3 Navy

(1) Patuxent River, Maryland

- SPN-42 plus A/G Telemetering for Real Time Data Reduction
- Photo-Theodolite Range
- M-33 Tracker

2.6.2.4 Air Force

(1) Wright-Patterson Air Force Base, Ohio

- M-33 Tracker
- Precision Digital-Optical Tracker System (DOTS)
- 6 Degree of Freedom Simulator with Digital/Analog Computer
- Multi-Crew Simulator (MCS) for V/STOL IFR Control-Display Problem
- Flying Laboratories
  - T-39 – manual-on-instruments and autoland
  - C-131 – manual/autoland
  - CH3-E – pilot assist functions, avionics
  - LOH-6 – pilot assist functions, navigation tie-in
  - OV-2 – modified for STOL operation
  - C-135B – landing monitor radar research
  - C-141 – autoland
  - TIFS – Total-In-Flight Simulation: 6°-of-Freedom, Variable Stability
- ECM Tower
- Airborne Data Processors
- Specialized Cockpit Displays

(2) Rome Air Development Center, New York

- Radar Range
- Antenna Range

(3) Eglin Air Force Base, Florida

- Gulf Coast Range
- Climatic Hangar

(4) Holloman Air Force Base, New Mexico

- Range and Computer Facilities

(5) Instrument Pilot Instructor School, Air Training Command, Randolph Air Force Base, Texas

- T-39 – Weather Minimum Investigation Aircraft Flying Zero-Zero Weather
- T-39 – Landing System Research Aircraft
- T-38 – HUD and Landing System Research

(6) Andrews Air Force Base, Maryland

- KC-135 – Manual-Automatic Landing And Navigation Research Aircraft

2.6.2.5 DOT, Transportation Systems Center, Boston

- Computer Facilities

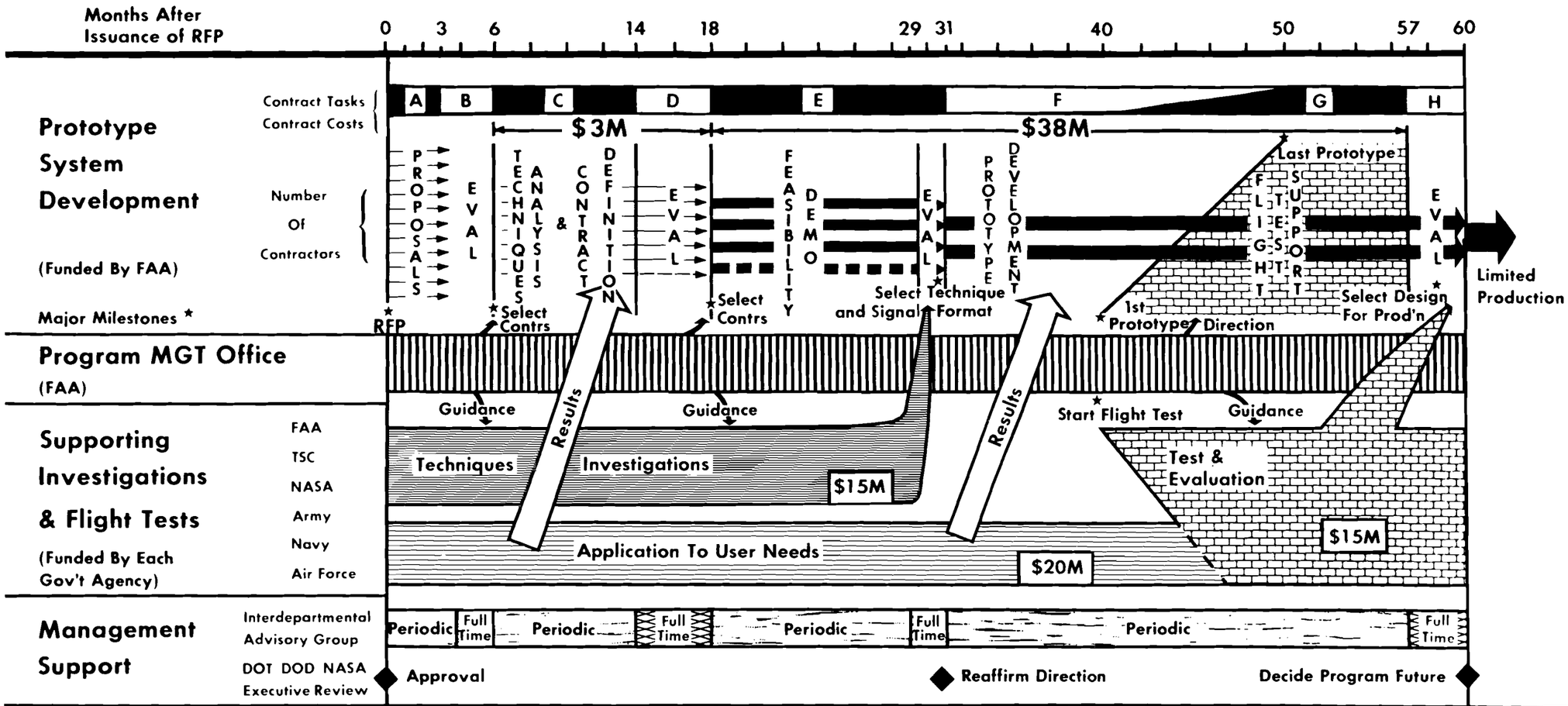
2.6.2.6 Federal Aviation Administration, NAFEC, Atlantic City, N.J.

- Photo-Theodolite Range – 4 Stations
- Real Time 30" x 30" XYZ Plot, Computer Uncorrected Tape Print, Corrected Tape by Reading Film Frames
- Central Timing, Communication, Range Control
- M-33 Radar Tracker with Tape Output, Analog-to-Digital Conversion, Semi-Portable
- Simulator, Approach and Landing with Analog and Digital Computers
- Convair 880, Dual Fail-Passive Autoland System, Head-up Display
- DH-125 Twin Otter STOL Aircraft
- Gulfstream G-152 Twin Turbo-Prop CTOL.

2.7 Relationship Between The Major Programs

The development plan (described above) consists of two major branches of interrelated and interdependent efforts. These are: (1) the development and fabrication of prototype microwave systems by systems contractors, under government direction and supervision by an FAA Program Management Office; and (2) a parallel program of supporting investigations and flight tests directed and accomplished by the individual participating government agencies, either in-house or with separate contract support. The different aspects of the plan have been presented and discussed on an individual basis, with reference to the relationship between the major programs.

Figure 2-4 brings everything together and summarizes the overall development plan. It highlights the significant aspects in both the industry prototype development effort and the government supporting effort and shows not only the relationship between them but the role of the FAA Program Management Office in directing and coordinating the activities of industry and the participating government agencies. The funding requirements by fiscal year and participating agency are given to complete the summary of the overall plan.



R & D Funding ($ In Millions)

Fiscal Year	71	72	73	74	75	76	Total
FAA TSC	1.0	3.8 (3.0)*	3.7 (10.0)*	3.1 (20.0)*	3.7 (6.0)*	2.2 (2.0)*	18 (41)*
NASA	0	0	0	0.2	0.7	0.8	2
Army	0	1.7**	3.5	2.3	2.3	0.6	10
Navy	0	1.1	1.1	0.6	0.8	0.7	4
Air Force	0.8	5.9**	4.0	2.5	2.3	0.5	16
Total	1.8	12.5 (3.0)	12.3 (10.0)	8.7 (20.0)	9.8 (6.0)	4.8 (2.0)	50 (41)
Related Programs: STOL Avionics (NASA)	1.8	4.0	3.5	1.6	0.7	0	11
Related Programs: STOL Program (USAF)	1.1	1.1	1.2	1.2	0	0	5

* FAA funding of main contractual effort is shown in parentheses and is separate from the funding for supporting programs.

** The U.S. Army and the U.S. Air Force will require program adjustments in FY72 in order to meet these funding requirements.

Figure 2-4. Microwave Landing System Development Plan

3.0 NATIONAL AND INTERNATIONAL COORDINATION

This section discusses the following subjects:

- General need for coordination and liaison among concerned government agencies, and users
- National coordination, both civil and military, and
- International coordination and relationships.

3.1 General

The development and implementation of a new civil/military microwave landing system involves various segments of government as well as the users of the system. Coordination activities are required to effectively accomplish the development effort and gain national acceptance of the new system. These activities range from the dissemination of information on the nature of the effort to the technical involvement of industry in the resolution of significant issues and the participation of user groups in operational evaluations and demonstrations.

An equally significant consideration in the development of a new landing system for common civil/military application is the need for its eventual adoption as an international standard. Past experiences in introducing system changes into the international environment have demonstrated difficulties of ratification and have led to the realization that international collaboration starting at the earliest possible stage is highly desirable. This is not to imply that such collaboration should in any way impede the development cycle, but rather that concurrent efforts looking toward international acceptance are significant. Therefore, it is necessary to plan for a well-conceived series of coordination efforts during the five-year development cycle. Additionally, it is desirable to seek the active participation of foreign governments and industry in the development work as a method of facilitating eventual worldwide acceptance.

3.2 National Coordination

Adequate coordination throughout government and industry during the development cycle will build confidence in the program and lead to early acceptance of the new system. In order to lessen the administrative burden involved in coordination activities, regularly planned and scheduled meetings, such as the FAA Annual Planning Review Conference, will be utilized for reporting progress. However, it will be necessary to prepare for specialized technical symposia and demonstrations at appropriate intervals as indicated in this section.

The relationship with RTCA SC-117 may be considered a special one since the basic development program stems from work of that body. The RTCA will be asked to form a small advisory group from the nucleus of SC-117 which will be called upon for advice and guidance prior to and during the review and evaluation periods that have been described in section 2 of this document. In addition, since it is not practical to have actual representatives from the many independent user organizations in the development/test program, the RTCA advisory group will be asked to resolve this problem by periodically reviewing the program and presenting its recommendations to the FAA.

The FAA Annual Planning Review Conference will be used as the forum for exchange of information with a large number of aviation organizations, such as ATA, ALPA, AOPA, and other industry/user groups. A special technical symposium will be planned for the Fall of 1972* where a critical review can take place. Demonstrations for these groups will be scheduled on a yearly basis starting late in 1973.

The Airline Electronic Engineering Committee (AEEC), a part of ARINC, will be invited to monitor the progress of the plan, since it is necessary at the appropriate time for that body to develop airline airborne specifications. The AEEC will be provided with progress reports and briefings at their regularly scheduled semiannual meetings. At a later date, the appropriate AEEC committee assigned to this area will be asked to participate in the scheduled technical symposium and demonstration activities.

As development work progresses, it will be essential to involve military operational commands in technical and operational demonstration activities. As described in section 2, military versions of ground equipment will be developed as a significant part of the program and at the earliest time, possibly during 1974, military user groups will be invited to participate in their evaluations.

The material below summarizes by organization the types of coordination activities planned and the approximate calendar year dates when they will take place.

3.2.1 RTCA SC-117

(1) A technical program review will occur after completion of contract definition and of feasibility demonstration of techniques.

(2) Periodic meetings will occur as required between an advisory group representing SC-117 and the program office charged with technical management of the five-year plan.

3.2.2 RTCA - National Assembly

A brief yearly progress report will be given at the RTCA Annual Fall Assembly Meeting, 1971-1975.

*Note: all dates given in section 3 are calendar years, unless otherwise indicated.

3.2.3 ATA, AOPA, NBAA-ALPA, FSF-AOC, etc.

Yearly progress reports and full discussions will occur at the Annual FAA Planning Review Conferences (1971-76). The above groups may also participate in various technical symposia and flight demonstrations.

3.2.4 ARINC/AEEC

(1) Semi-annual reports will be given at the regularly scheduled AEEC assembly meetings starting in late 1971.

(2) Formation of a special AEEC committee will be requested during 1973 to prepare airline avionics specifications. Continuous coordination activity in this area through 1975 will be required.

3.2.5 Military Commands

Flight demonstrations and operational symposia will be scheduled during 1974-75.

3.2.6 Selected Government and Industry Participants

(1) Technical symposium will occur early in 1973.

(2) Flight demonstrations will occur during 1974-75.

3.3 International Relationships

Close program coordination activities are required to achieve eventual acceptance of the microwave landing system as an international standard. Fortunately, foreign government representatives and international organizations have participated in the preliminary work under the auspices of RTCA SC-117. Coordination activities will encompass methods of encouraging and supporting development programs by foreign industry as well as coordinating progress with ICAO and NATO.

3.3.1 ICAO Relationships

There is full recognition that ICAO is the international body through which system acceptance and international standardization must be sought. Efforts are already in process through the All Weather Operations Panel (AWOP) to provide status information and to achieve agreement on new operational requirements as an initial step. This action will be supplemented by introducing into ICAO suggestions for carrying on the process beyond this first endeavor. This process must evolve carefully since it is unique in the history of ICAO. ICAO has never been asked to participate in the early development of a new international system. Their work has been limited to making a choice among two or

more existing candidate systems and it is believed that this should be their role in the present case as well.

Efforts will be made as outlined in this plan to accomplish the goal of gaining international acceptance of the new system on a step-by-step basis over a five-year period. After agreement on operational requirements, it will be necessary to seek acceptance of the microwave scanning beam or Doppler scan technique as the appropriate way of meeting the stated needs. A final step must be the detailed development of system characteristics for introduction as standards into appropriate ICAO documents. A proposed plan of action is as follows:

1971

(1) Operational requirements for a new system are accepted by the ICAO All Weather Operations Panel (AWOP).

(2) ICAO Air Navigation Commission receives recommendation that operational requirements (after acceptance by AWOP) be transmitted to all states for comment.

(3) AWOP aids the ICAO Air Navigation Commission in review of comments received from states and then makes necessary revisions to operational requirements document.

(4) AWOP prepares criteria for evaluation of concepts proposed by states for meeting the operational requirements.

1972

(1) At the Seventh Air Navigation Conference, propose formal acceptance of revised and tentative operational requirements by all ICAO states.

1972-74

(1) AWOP participates in scheduled technical symposia and flight demonstrations.

(2) AWOP develops evaluation criteria for assessment of specific techniques under development.

1975

(1) Special international technical symposia and demonstrations for all ICAO states will be arranged at high levels with suitable protocol.

(2) Parallel symposia in other countries actually engaged in development programs will be encouraged.

(3) AWOP will recommend a tentative set of system characteristics based on analysis of development programs which have taken place.

1976

(1) U.S. will introduce system technical characteristics derived from this development plan at a special ICAO Com/Ops meeting for eventual approval by ICAO and inclusion in Annex 10 (Standards and Recommended Practices).

3.3.2 International Military Relationships

The NATO groups that are currently involved in discussions and development of new approach and landing systems are (1) NATO Air Force Armaments Group (NAFAG), (2) the NATO Industrial Advisory Group (NIAG), (3) the Committee for European Airspace Coordination (CEAC) and (4) the Advisory Group for Aerospace Research and Development (AGARD).

NATO acceptance, adoption, and implementation of the MLS could be enhanced by early program collaboration with interested NATO nations. NATO cooperative research and development procedures can accommodate joint efforts on projects such as the MLS if such efforts are appropriate.

3.3.2.1 NATO Air Force Armaments Group (NAFAG)

Subgroup 7 of the NATO Air Force Armaments Group (NAFAG) is responsible for the standardization of approach and landing systems within NATO. Due to its charter and current level of activity, it may be useful as an additional forum to promote understanding of a common system program.

NAFAG SG/7 has currently divided its work program into two time phases: interim (1970-1975) and long term (post-1975). Interim systems are limited to those already in production or an advanced state of development. Systems proposed are TALAR IV (United States), SYDAC/ILS (France), SETAC (Germany), and the (MADGE) interferometer (Great Britain). NAFAG will consider the adoption of an interim system during 1971.

The United States has introduced the RTCA SC-117 documentation into the NAFAG SG/7 forum in order to keep military agencies in other nations informed. The United States will report on the U.S. progress through introduction of programming documents, briefings, test results, etc. Additionally, the United States may propose that a collaborative NATO Project Group be formed in the event that this method of international collaboration is deemed useful.

3.3.2.2 NATO Industrial Advisory Group (NIAG)

At its meeting late in 1969, the NATO Conference of National Armaments Directors (CNAD) instructed their NATO Industrial Advisory Group (NIAG), (a group of European and selected American consultants from industry), to advise on a requirement suggested by the NAFAG for an advanced approach and landing system for the post-1975 period. This system would replace current approach and landing systems to enable full blind landing conditions to be met, and would be compatible

between civil and military aircraft. The objective of the NIAG is to recommend a single technique or system to the NAFAG and CNAD which would be appropriate to meet the civil and military requirements.

3.3.2.3 Advisory Group for Aerospace Research and Development (AGARD)

Under its Guidance and Control Panel, AGARD has for some years monitored international activities in the field of approach and landing systems. In May 1969, the AGARD Guidance and Control Panel held a meeting on "Aircraft Landing Systems," where many nations made presentations on their activities in this field. At that time, the United States presented the work of RTCA SC-117.

AGARD will be invited to have representation at the annual technical symposia and will be requested to report on related projects, studies, etc., being conducted under its auspices. The U.S. delegates to AGARD will keep the group appraised of the MLS activity conducted in accordance with this plan and suggest that AGARD provide a technical forum for the discussion of specific issues which may arise.

3.3.2.4 Committee for European Airspace Coordination (CEAC)

The basic purposes of CEAC include coordination of civil/military matters in the area of airspace and systems related to airspace use. Historically, CEAC has proven to be a very useful and effective forum in Europe. Accordingly, the subject of U.S. developments in RTCA SC-117 was introduced in the June 1970 CEAC Plenary.

The U.S. has agreed to provide more documentation for the next meeting of the group.

3.3.2.5 Summary

The U.S. military services will continue their efforts to guide NATO programs so that they will be compatible with this plan. This effort began in 1970 and will continue during the ensuing years.

3.3.3 International Development Activities

It would be highly desirable if full scale development activities could take place overseas in harmony with the signal format recommendations of SC-117. These recommendations are being accepted by the U.S. government as a guide to the development program outlined in this report. As mentioned earlier, foreign industry participated in the work of the RTCA, and at least two countries in Europe are totally familiar with the technical deliberations of the committee and the strengths and shortcomings of its recommendations.

The problem arises on how best to assure that coordinated development work is undertaken in Europe as an adjunct to the total program effort to achieve a system suitable for international standardization. There are a number of alternative approaches to this problem:

(1) Urge European industries on their own initiative to engage in development activities using SC-117 as a guide, with the hope that eventual standardization might occur and that they will then be in a position to obtain commercial advantages in future procurements by their governments.

(2) Urge U.S. industries to reach agreements with foreign industries so that support provided by the U.S. government can result in complementary development efforts overseas.

(3) Establish government-to-government agreements that will result in foreign government support of its industry in meeting the goal of international standardization in a compatible manner. Such agreements could include mutual exchange evaluation programs and provide a means for resolving any system difficulties as they arise.

(4) Permit the expansion of the development plan to include U.S. government direct support of foreign industry for development of equipment. (This extension of the planned effort is not included in section 2 of this document.)

Clearly, the first alternative listed would be most preferable if properly coordinated with U.S. effort so that no incompatibilities arise. However, it is believed unlikely that the economic advantage is evident enough at this time to encourage such use of risk capital without European industries receiving direct financial support from their governments. There are indications that this will take place in some countries and that programs similar to the one described in this plan will be undertaken. However, this does not preclude the use of the second alternative in furtherance of this plan. The request for proposal (RFP) to U.S. contractors for development of prototypes will encourage teaming agreements with European industry competent in the field of landing system development.

The problems of international standardization are sufficiently important to warrant further specific coordination endeavors. These endeavors are warranted if there are incompatible developments overseas, even though such programs are addressed to meeting agreed-to general statements of operational requirements. This probably will require the establishment of bi-lateral research and development agreements with those nations undertaking active development programs aimed at meeting the ICAO-approved operational requirements. Plans for initiating such agreements will be undertaken concurrently with the work outlined in this plan.

Over and above the encouragement of development effort by foreign industry, full foreign participation in technical symposia and demonstrations will be encouraged. Where necessary, participation will be arranged at the highest appropriate level of government representation.

4.0 TRANSITION TO THE NEW LANDING SYSTEM

This section includes the following topics:

- General discussion of transition from an existing system to a new system.
- Summary of current FAA landing system plans
- Current Department of Defense plans
- International military plans
- Problems anticipated during transition to a new landing system
- Discussion of an interim standard, and
- Initial MLS implementation considerations.

4.1 General

Transition is perhaps the most difficult problem associated with introducing a new system element. In the case of approach and landing systems, the need to fulfill urgent civil and military requirements has made it impossible to wait for the complete solution outlined in this plan. Not only is it impractical to maintain the status quo while awaiting implementation of the new microwave landing system, but it will be necessary particularly for military users and for civil V/STOL operations to rely increasingly on interim systems to meet immediate operational needs. This is unfortunate from a transition viewpoint but must be accepted as one of the difficult areas requiring careful consideration. It should be possible, however, to manage the transition process in a manner which will have minimum impact on achievement of the goal. Guidelines are recommended in this section on how to accomplish this objective.

The problem is compounded by the fact that in addition to the widespread and continued expansion of the system in general use (VHF/UHF ILS), a number of new developments exist, some of which are in operational use. The planned expansion of the current ILS over the next five to ten years is in recognition of the need to increase the level of safety and the operational capability of the civil fleet and of military transport aircraft, while the expedited development and introduction of the new common system takes place. Of major concern and an area most amenable to proper program direction, is that relating to new interim solutions which have been developed and are in limited use, or are at this time being proposed.

4.2 Current FAA Program Plans

The FAA program for the expanded implementation of the standard VHF/UHF ILS is fully

documented in the National Aviation System Ten Year Plan 1972-1981*, dated March 1971 (Ref. 5). The plan provides for installing conventional Category I, II and IIIA ILS through FY 1976, and the procurement of microwave landing systems (MLS) beginning in FY 1977. Conventional systems will be maintained and operated for at least ten years after the introduction of microwave systems. Unless other considerations intervene, by 1978, 635 runways will be equipped with ILS equipment and approach lighting (according to the FAA 10-Year Plan); of these, 76 will have been upgraded to Category II, and 12 to Category IIIA.

Of more significance with regard to the transition problem is the FAA program to provide a precision IFR approach capability for STOL vehicles. There is full appreciation of the need, since it is clear that these vehicles must have such a capability in order to fulfill their short haul transportation role, if economically and operationally useful vehicles are developed. Physical and electromagnetic factors prohibit the existing VHF/UHF ILS from meeting the needs associated with STOL airports. There is a current research and development program underway directed toward this requirement. Test models of a new development (MODILS) designed to meet FAA accepted operational requirements have been delivered. An agreement exists between FAA and NASA for this equipment to be made available to NASA for use during the STOL avionics development program. Other developments (such as TALAR) which could be used to fulfill the STOL needs are also under evaluation.

The FAA considers these STOL systems to be interim devices, and intends to limit their deployment so that early implementation of the new MLS standard, evolving from this plan, will not be prejudiced.

4.3 Current Department of Defense Plans

The growth and advantages of mobile warfare concepts and the recognized advantage of helicopters for medical evacuation have dictated the need for a landing guidance system which will permit the operation of helicopters in all types of weather.

To realize the full military potential of the helicopter and the vertical envelopment concept, the Army, Air Force, and Marine Corps have actively pursued programs aimed at providing landing systems capable of meeting the requirements of their respective services.

The USAF, as an outgrowth of the interim remote area terminal equipment (IRATE) program, procured a portable Ku band system known as TALAR IV. Delivery of hardware has been completed. Installation will be in tactical support cargo aircraft. When completed, 423 aircraft will be equipped and 40 portable terminal equipments will be available.

A research and development program is currently under way sponsored by the U.S. Army to provide a landing system for helicopters. The A-SCAN system evaluated to date utilizes a Ku band

*Note: all dates given in section 4 are calendar years, unless otherwise indicated.

scanning beam with extremely broad coverage and provides for simultaneous multiple-approach paths. The system also includes a DME function. Plans include the development of additional models reflecting the results of a thorough flight research program into the course-width aspects of helicopter instrument approaches. Production quantities for use by operational forces are expected to be introduced by 1976. However, the pressures of current operational needs may force introduction at an earlier date.

Similar operational pressures are being encountered by the Marine Corps in accomplishing their mission. An interim system has been operationally evaluated in Southeast Asia. A decision has been made by the Marine Corps to procure a transportable system compatible with the airborne hardware currently being installed in high performance fixed wing Navy aircraft.

The U.S. Navy has already made substantial progress on a $50 million dollar program to provide an in-flight monitor for the Automatic Carrier Landing System (AN/SPN-42) which also will serve as a backup for Category II landing operations. Twenty-five ground stations and 1,325 airborne units have been procured. These units are to be installed starting in 1971. Plans exist for the procurement of additional shipboard and airborne units. The in-flight monitor system, known as the AN/SPN-41, is a microwave scanning beam device stemming from early development work on these techniques. Although it does not have DME, it is essentially compatible with the Army A-SCAN system. These characteristics, although adequate for the specific operational requirements of the Navy and Marine Corps, do not approach, in either scope or format, the requirements of the MLS defined system, such as channelization and coverage.

4.4 International Military Plans

European NATO countries are also developing new military approach and landing systems which are summarized below.

The French have done a considerable amount of work on a fixed beam, C band ILS system known as SYDAC/ILS. The X band scanning beam systems developed by Thomson/CSF formed the basis for the French input to the RTCA-117.

In England, considerable effort has been devoted to a modification of the conventional ILS known as CPILS, and the UK military is supporting an interferometer system (MADGE) for possible NATO use.

The West German government has actively pursued a landing system program which makes use of onboard TACAN equipment. The system is called Sector TACAN (SETAC).

Sweden is considering production of a landing system (using equipment derived from the C-SCAN/A-SCAN systems) developed by a U.S. firm and currently installed in the VIGGEN aircraft.

4.5 Transition Problems

The large number of existing interim systems and the projected expansion of their operational

deployment make it clear that a major transition problem exists. At best, the transition from the conventional to a new-type ILS will be a difficult process for both the implementing agency and system users. Nevertheless, it is clear that the longer the changeover is postponed, the harder and more costly it will be.

The anticipated time frame and schedule for the transition are listed below.

Table 4-1. Transition Schedule

CALENDAR YEARS		
1971 – 1976	1976 – 1980	1980 – 1986
Procure & Install Conventional ILS	Maintain & Operate Conventional ILS	Maintain & Operate Conventional ILS
Limited Procurement of Interim Systems	Cease Implementation of Interim Systems	Phase Out Interim Systems
Design and Develop Common MLS	Introduce MLS	MLS in Full Operation at Major Terminals by 1980

Control of the transition is highly dependent on the confidence which can be placed in the time scales stated in this plan. 1976 is projected as the availability date for the new system; however, this can have various meanings, depending on one's particular area of concern. From a development and production viewpoint, there is a firm conviction that the availability dates described in this plan can be achieved. Achieving an operational capability can be quite another matter, and projection to the 1980's by those responsible for assuring a continuous capability is entirely understandable. Past history leads many to a "safe viewpoint" by planning for the extended use of what we are calling "interim systems."

The most powerful force available to alleviate the problems of transition will be the expeditious acceptance of this plan, and providing the support necessary to carry out a vigorous development program. These actions can result in limiting the proliferation of interim systems. With progress and an emerging product, it will be proper to request that transition plans be exercised and the phasing process began.

Regardless of plans to achieve the early use of the new system, one can face realistically the pressures which will arise for extended use of interim systems. The first task is to be certain that any such interim system does not create direct interference with the accepted common goal. Electromagnetic interference is already known to be one such factor, because a number of the systems designed for limited service (to satisfy a particular operational need) occupy the same portion of the frequency spectrum chosen by the RTCA SC-117 for the future common system.

Recognizing that the existence of these various partial solutions compounds a difficult transition problem, the following guidelines are offered:

(1) Prohibit the use of any interim system which creates a frequency interference problem with the signal format likely to be accepted for the future common system.

(2) Limit the use of any interim system to that required to meet urgent civil and military needs which cannot be met adequately by existing aids.

(3) Restrict the introduction of new types of interim systems over those which now exist, and

(4) Strive to reduce the number of interim systems now existing to a minimum.

4.6 Interim Standard

There are good arguments against the designation of an "interim standard." It is clear that once one is established, the incentive for achieving the total solution is reduced. The pressure is off, since "interim" decisions have been made, and there will be a tendency to coast and postpone the very difficult task still ahead. This can have serious consequences and is a strong argument against the establishment of such a standard.

On the other hand, the absence of a firm policy encourages proliferation and provides no mechanism for preventing harmful interference. A clearly defined interim standard can indicate the permissible use of the frequency spectrum. Furthermore, it would then be possible to specify the performance required in unambiguous terms so that no confusion will exist between the limited capabilities of an interim system and the full capabilities of the new system designed to meet all user requirements through the next several decades. It appears advantageous, therefore, to designate from among the many existing interim systems, one (or perhaps two) which will be most useful during the interim period and which will cause the least difficulty in achieving the transition to the MLS.

4.6.1 Interim Requirements

A first step in making a selection is to reach agreement on a common set of requirements covering the limited range of operational capabilities required by the various agencies who have sponsored the use of interim systems. These are the FAA for STOL operation, and the three services of the DOD for military use. Commonality must exist to some extent, or the goal cannot be achieved. Fortunately, a good deal of similarity is evident since these are all limited sets of requirements which do not look toward the long-term, full-capability solution, and are addressed essentially to the same problems.

A common set of interim requirements would include typically the following:

Operating Weather Minimum ..... { Cat. I Required / Cat. II Desired

Minimum Range ..... 7 miles

Coverage	
Azimuth	±10°
Elevation	0-10°
Channels	10
DME	Distance measuring must be available in some form
Glide Path	Air selectable.

Of the interim system concepts currently being pursued, one type, the Ku band scanning beam, is being implemented by at least two of the military services. The concept has also been evaluated by FAA as "AILS" and "Site Scan" and was considered to be a potential concept to meet the civil V/STOL requirement.

Each of the several candidate systems now in existence has undergone evaluation to some extent, and it is expected that selection of a preferred interim system will require only limited modification and testing.

If a system in the Ku band is chosen, definite frequency assignments within that band can be made so that no interference will occur with the recommended RTCA signal format. However, the process of making a selection must include economic as well as technical considerations and, therefore, further analysis will be required. This need not be a lengthy process, since data on the candidates are available.

In summary, during the first stages of this plan, a common set of limited requirements will be formulated, designed to meet current military tactical and urgent civil V/STOL needs. Following agreement, a selection will be made for limited evaluation. The designation of a preferred interim system(s) will permit decisions to be made on the role of competing interim candidates and establishment of a policy which discourages the introduction of new partial solutions adversely affecting the transition to the MLS.

4.7 Initial MLS Implementation Considerations

In the air traffic control-navigation environment, past experiences in accomplishing system changes have demonstrated the difficulty of the process. With regard to cooperative systems, there have been very few changes since World War II, and all of these have been laborious undertakings, sometimes traumatic. We have learned the difficulties, but on the positive side, some procedures have evolved which should help in the future.

4.7.1 Civil Environment

In the civil environment, it is essential that the ground facilities be provided in sufficient quantity to encourage airborne implementation. It may be necessary to put in many facilities before a significant number of aircraft are equipped (as was the case with DME before 1960). This availability serves to encourage the voluntary procurement of airborne equipment by the user, and furthermore provides a basis for regulatory action, if needed, to expedite the process. Considering this approach, it can be seen that any attempt to determine the economic value of ground implementation at any given time, based on the number of equipped users, would be fatal and only serve to stall the entire process.

Another guideline gleaned from the past is that the first priority for a new system should be for the fulfillment of a service that cannot possibly be provided by the older system. This means that the MLS should first be installed for STOL operations; then perhaps Category III, as a redundant facility; followed by new runway installations, with reduced parallel spacing; and lastly as a replacement for facilities providing a usable service. This will permit a continuous, although slow, increase in the number of equipped aircraft. In some cases, having the microwave avionics will be the "price of admission" to selected terminal areas. Clearly, new aircraft, after a designated date, should all be equipped with the new system. This will only take place if the government can point to the existence of an extensive ground environment, as mentioned above.

4.7.2 Military Transition

Military transition programs will be costly and pose many scheduling problems. This is particularly true with many military tactical aircraft. Transition is complicated by limited space within the aircraft which precludes carrying redundant systems, and the unrealistic option of having multiple ground systems available in forward tactical areas.

Improved technology will result in hardware for the MLS which is no larger than the current hardware being considered for interim systems for the same class of service. Therefore, barring any major growth in demands for service, space and weight provisions for the new hardware should not be a major obstacle. It may be that the transition to the new avionics must await the normal obsolescence cycle of equipment existing in particularly aircraft types. Fortunately, in military usage, this is approximately an eight year period, and may be acceptable on an entire fleet transition basis. There should be relatively little difficulty in making the transition to the new system in the military ground environment.

Aircraft carriers present a unique problem and these will probably await the normal equipment replacement schedule.

5.0 CONCLUSIONS AND ACTIONS REQUIRED

5.1 Conclusions

(1) It is feasible to meet the objective stated by the Under Secretary of Transportation for development, within five years, of the new microwave landing system, provided that the plan presented in this document is implemented and the required fiscal, manpower, and facilities resources are made available;

(2) Centralized, careful coordination among the various concerned civil, military, industrial, and user organizations will be required because of the complexity of the plan;

(3) Full reliance on industry development of the new system over the five year period, with support from government laboratories, is the proper course of action; and

(4) Funding required to complete the development of the new microwave landing system within five years is estimated to be $41 million for system development contracts, and $50 million for supporting government activities.

5.2 Actions Required

The following actions will be taken by the participating agencies:

DOT

- Establish a priority for the implementation of the plan with respect to national aviation needs.
- Approve and support the DOT (FAA/TSC) funding levels described herein unless the program described herein is officially revised.
- Identify the office of responsibility within DOT for coordinating the executive reviews shown on Figure 2-4 and for other joint meetings as may be required.

DOD/NASA

- Establish a priority within the DOD/NASA structure comparable to the DOT priority
- Approve and support the funding requirements as shown herein, maintaining that funding support, unless this program is officially revised
- Identify the office of responsibility within the DOD and NASA that is to represent the DOD and NASA in joint program reviews.

FAA

- Establish a program management office to include no less than 21 people at the peak of activity. Take immediate action to assign to that office the qualified people necessary to support the program. Services of appropriate consultants may be necessary to initially meet this objective.
- Review internal management procedures and take actions required to provide the program office with prompt and adequate support.
- Program and budget funds in accordance with the fiscal year funding plan shown on Figure 2-4.
- Implement the plan as described herein and refer to DOT any problems that cannot be resolved by FAA that may jeopardize the timely completion of the plan.
- Take action to resolve interim system requirements.

NASA, Navy/Marine Corps, Army, and Air Force

- Establish internal programs to execute the responsibilities identified herein.
- Program and budget funds in accordance with the funding plan on Figure 2-4.
- Make designated aircraft available for airborne equipment installation and the flight test and evaluation program.
- Provide personnel for full time active participation in the FAA Program Management Office.*
- Identify, by name, the primary and secondary representatives to the interdepartmental advisory group that will, from time to time, assist the program management office of the FAA in source selections.
- Make allowances in personnel and TDY funding plans for participation in regular and special meetings of the interdepartmental advisory group.

*This does not apply to NASA.

6.0 REFERENCES

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2. Letter from Department of Transportation, Under Secretary of Transportation, to the Honorable Philip N. Wittaker, 19 June 1970.

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4. A New Guidance System for Approach and Landing, Volume One; Document No. DO-148; December 18, 1970; Prepared by SC-117; Radio Technical Commission for Aeronautics, 1717 H Street, Northwest, Washington, D.C. 20006.

5. The National Aviation System Plan: Ten Year Plan 1972-1981, Department of Transportation, Federal Aviation Administration, March 1971.

7.0 INTERDEPARTMENTAL PLANNING GROUP PARTICIPANTS

Group Membership

A. B. Winick, DOT/FAA, Chairman

J. W. Klotz, DOD

Charles Gould, NASA

Robert Wedan, DOT/TSC

Participants

DOT/FAA:	J. W. Edwards, Secretary to the Group
	R. D. Munnikhuysen
DOT:	W. S. Devereaux
	L. P. Greene
DOT/TSC:	R. Pawlak
FAA/NAFEC:	L. G. Craymer
NASA:	L. Goolsby
	J. Painter
	L. H. Person
DOD:	COL M. E. Kay
U.S. Army:	LTC H. C. Finger
	1LT H. M. Frietchen
	J. T. Saganowich
	LTC T. D. Sargent
U.S. Navy:	CDR R. E. Doucet
	L. V. Gumina
	G. Jensen
	G. F. Miller
	H. Nordenberg
	C. H. Taylor
U.S. Marine Corps:	MAJ R. A. Govoni

U.S. Air Force:	T. J. Emerson
	MAJ J. M. Gurski
	MAJ G. W. Gute
	G. B. Johnson
	G. L. Yingling

APPENDIX A. CONTENTS OF RFP FOR INDUSTRY DEVELOPMENT PROGRAM

The material which follows describes, in general terms, the scope and type of work effort contained in an FAA Request for Proposals (RFP) to be available to all of industry. Industry will be asked to respond to this RFP with their plans for a complete five-year microwave landing system development program covering:

1. Concept formulation and verification activity;
2. Development of feasibility models and engineering prototypes;
3. Support of government system validation tests;
4. Preparation of production specifications; and
5. Time and cost estimates for limited production quantities.

The technical/management proposals must be specific, detailed and complete, clearly stating the proposed system concept and its applicability to the total spectrum of civil and military operational requirements so as to fully demonstrate to the government that the prospective bidder has the technical capability, background experience, resources, and management organization required to undertake the entire program.

Proper program management is a significant factor in the successful completion of this program and will be weighed heavily in the selection of contractors. The contractors' proposals are to address the management structure proposed for management of the program with specific attention to the following:

1. Management structure within the organization with the names of key personnel;
2. Management techniques to be employed to monitor and control the progress of the program;
3. Authority of the program manager within the organization;
4. Contractor teaming arrangements with other U.S. companies;
5. Working relationship or data interchange arrangements with foreign industrial organizations;
6. Government liaison techniques proposed;
7. Proposed methods to assure the acceptability of the system to national groups and international users.

This program covers a three phase development process consisting of a technique analysis and contract definition phase, a feasibility demonstration phase, and a system prototype hardware development/flight test and system evaluation phase. The technique analysis and contract definition phase of activity will require approximately eight months to complete. As many as six (6) contractors will be

supported on a fixed-price basis. At the conclusion of this phase, all contractors' progress will be evaluated and as many as four (4) will be released to proceed into the second phase, which will consist of feasibility model demonstrations. At the completion of feasibility model demonstrations, the technique/signal format to be prototyped will be selected and as many as two of the contractors will proceed with prototype system hardware development flight test and system evaluation. The second and third phases will require approximately three to four years to complete and will employ cost-reimbursable contract procedures.

In response to the RFP, the contractor's proposal will highlight discussion of how he will:

1. Select and refine a signal format based on the recommendations of RTCA SC-117 and define the proposed system technique and design;

2. Review and refine as necessary the operational and functional requirements for the system;

3. Relate the compatibility of the selected signal format and system design to the various requirements including:

   (a) Aircraft types, missions and control dynamics;

   (b) Airport/aircraft carrier characteristics and environments, including military applications;

   (c) Air traffic control and navigation system interfaces;

4. Identify technical areas critical to a successful system design and evaluate and relate the technical data base and risks appropriate to these areas;

5. Specifically define this first phase program of verification studies, experiments, simulations, or tests necessary to evaluate the feasibility and adequacy of the basic system concept;

6. Define the methodology by which the results of the concept verification program activities will be used to modify the signal format parameters and/or the system design.

7. Identify any component developments deemed necessary for the proposed system to function in a cost effective manner including costs, scheduling, and risks associated with each development;

8. Define the total five-year program including tasks, schedules, costs, methodology for program performance evaluation and key decision points, risk areas and trade-off factors through feasibility model demonstrations and prototype hardware fabrication and delivery, general plan for total system validation testing, cost and schedules for production specification preparation, and a general plan for implementing limited production;

9. Define the requirements and scheduling for government equipment and facilities to conduct the concept verification and flight test/evaluation programs as well as requirements (including design and costs) for any special purpose equipment.

During the first phase, technique analysis and contract definition, the contractor will:

1. Review, refine, and amplify those requirements, selections, plans, costs, and schedules noted in the proposal;

2. Perform the concept verification program and report on results;

3. Identify feasibility demonstration and prototype hardware configurations, both ground and airborne;

4. Establish criteria for all hardware configurations;

5. Prepare a reliability and maintainability plan for the proposed system design for each prototype hardware configuration;

6. Define a feasibility model demonstration program covering feasibility hardware design and the test program, including numbers of models necessary to validate the proposed design and a detailed description of the issues to be resolved and the associated test details and evaluation criteria;

7. Define in detail a system validation program designed to evaluate the performance of the prototype system hardware including evaluation criteria, factory and flight tests, contractor and government roles, costs, schedules, facilities, logistics support, major support equipment, aircraft, and engineering/installation support.

During the second and third phases, the contractor will:

1. Develop feasibility models suitable for validating (including flight test) that the proposed technique has the potential to satisfy the wide range of user operational requirements; conduct the feasibility demonstration test program and provide test and engineering support as necessary;

2. Develop and provide to designated government agencies a number of prototype ground and airborne equipments of various configurations suitable for government system flight tests and evaluation during the prototype development/flight test and system evaluation program (Phase 3).

The numbers and configurations of equipments to be fabricated during the prototype development program; the allocation of those equipments to the various government agencies; and the aircraft to be used in the flight test program are shown in Table A-1. With respect to the ground equipments, one contractor is to supply one each of the configurations G, I and K and one special (modified split site) configuration E. The other contractor is to supply one each of configurations D, E, I (shipboard) and K, and one special (modified co-located) configuration E (see Table A-1). It is believed that this selection of ground configurations will enable the government to evaluate the potential of each contractor's design with respect to all configurations and will also allow direct comparison tests of each design.

3. Develop and provide all special test equipment required for the calibration and maintenance of both ground and airborne units during the government flight test and evaluation programs;

4. Provide installation, engineering, logistics and test support of the prototype hardware at designated facilities and in designated aircraft;

5. Refine the system validation program defined in the first phase including specific test plans and procedures;

Table A-1. MLS Prototype Equipment To Be Delivered
(Including Aircraft Installations)

AGENCY	GROUND EQUIPMENT		AIRBORNE EQUIPMENT		
	SC-117 Configuration	Quantity	Number of of Sets	Configuration	Aircraft Type
FAA	K	1	4	K	Airline (CV-880)
	D	1	4	D	General Aviation (Aero Commander)
NASA	K	1	3	K	STOL (C-8A)
USAF	E	1	4	E	T-39
	I	1	8	I	C-135B, F-106B
USN/USMC	I (Shipboard)	1	8	I	F-4J, A-7E
	G	1	4	G	CH-46, AV-8
USA	E (Modified) (Split Site)	1	4	E	Fixed Wing
	E (Modified) (Co-Located)	1	4	E	Helicopter
TOTALS	9 Ground Sets		43 Airborne Sets		12 Aircraft Installations

6. Refine the plans for preparing production specifications and for implementing limited production;

7. During the feasibility demonstration phase, refine the reliability and maintainability plan prepared in the first phase; perform a reliability and maintainability analysis during the prototype development/flight test and system evaluation phase;

8. Conduct an analysis of and prepare performance and interface specifications for specified user aircraft control and display equipment;

9. Refine prototype hardware designs based upon validation test results and produce a family of production specifications for various ground and airborne configurations; produce a draft of a national standard for the microwave landing system;

10. Develop time and cost estimates and quote on an option to procure the production quantities of ground and airborne equipment shown in Table A-2; refine these time and cost estimates and quote on production options during Phase 3;

11. Provide a logistics support proposal and manufacturing data/drawings to permit reprocurement for the equipment shown in Table A-2.

Table A-2. Production Items To Be Included In Production Option
(Funded By Each Agency At Its Option)

AGENCY	GROUND EQUIPMENT		AIRBORNE EQUIPMENT	
	Configuration	Quantity	Configuration	Quantity
FAA	K	5	K	10
	D	5	D	10
NASA	K	1	K	10
ARMY	E (Man Pack)	1	E	5
	G (Man Pack)	1	G	5
NAVY/MARINE CORPS	I (Shipboard)	1	K	10
	G (Man-Transportable)	1		
AIR FORCE	I	2	K	10
	E	2	E	10
TOTALS	19 Ground Sets		70 Airborne Sets	

APPENDIX B. SUPPORTING GOVERNMENT PROGRAMS

1.0 Introduction

The three areas of effort, (1) techniques investigations, (2) application to user needs, and (3) flight tests and evaluation, which make up the supporting government programs, were summarized in section 2. This appendix further identifies and describes activities including specific tasks and funding requirements, along with the sponsoring government agency (DOT, DOD, NASA) responsible for their accomplishment. Table B-1 summarizes tasks, funding requirements, and schedules.

It should be noted that the work described under section 3.1, "Aircraft Control/Display", of this appendix, is a major portion of the concurrent government programs in the user application area. It represents the work required to initially validate the capability of the guidance system to meet the full range of approach and landing requirements, and also treats important technical and operational problems which extend beyond the five year microwave landing system development program. Although some portions of the effort contribute directly to the industry development program, other portions provide information related to the operational deployment of the system in ensuing years. The total funding requirements should be viewed with this dual objective in mind.

1.1 Participating Agencies

Task assignment has been based on two factors: (1) the unique capabilities (including facilities) of a particular agency, and (2) the unique requirements which provide the motivation for the thorough exploration of some specific task by a particular group.

2.0 Techniques Investigations

The specific tasks included in this area of effort are grouped into three categories: experiments using existing systems, advanced technology investigations, and signal format investigations.

2.1 Experiments Using Existing Systems

This area of activity includes a series of tasks to be undertaken with existing R&D microwave scanning beam systems in expectation of early test results which will provide data on the selection and evaluation of techniques and signal formats. Immediate utilization of the various available resources will make a substantial contribution to the early identification and resolution of many critical problem areas. The following is a tabulation of these tasks.

Table B-1. Supporting Investigations And Flight Tests

Program/Gov't Agency	Funding By Fiscal Year ($000)						
	1971	1972	1973	1974	1975	1976	Totals
TECHNIQUES INVESTIGATIONS							
1. Experimentation Using Existing Systems							
(1) FAA							
A. Evaluation of Signals In Space	0	300	300	0	0	0	600
(2) TSC							
A. Develop Test Program	100	200	0	0	0	0	300
(3) U.S. Army							
A. Propagation	0	250	225	150	150	50	825
(4) U.S. Navy							
A. Data Rate With Tracking Radar	0	150	50	0	0	0	200
B. Data Rate With Scanning Radar	0	50	100	0	0	0	150
C. Ku Band Azimuth Antenna	0	40	0	0	0	0	40
D. Range In Rain At Ku Band	0	20	15	5	0	0	40
E. Aircraft Response Characteristics	0	75	75	50	0	0	200
F. Antenna Polarization Evaluation	0	40	10	0	0	0	50
G. MARCORPS V/STOL Performance Requirement	0	50	50	0	0	0	100
(5) U.S. Air Force							
A. Signal Format Investigation	150	1250	500	200	0	0	2100
B. Low Angle Ground Effects	0	250	200	100	0	0	550
C. Geometry Effects	0	150	100	0	0	0	250
D. Flight Test Aircraft Modification/ Support	550	1500	1500	0	0	0	3550
2. Advanced Technology Investigations							
(1) FAA							
A. Component Development	0	100	100	500	500	500	1700
(2) TSC							
A. Phased Array Feasibility Study	305	500	500	0	0	0	1305
3. Signal Format Investigations							
(1) FAA							
A. Analytical & Experimental Program	600	300	300	0	0	0	1200
(2) U.S. Army							
A. Basic Format Studies	0	110	115	110	110	0	445
B. Encoding/Decoding Techniques	0	75	75	75	50	0	275
C. Two Frequency Band Investigations	0	75	65	70	50	0	260
(3) U.S. Navy							
A. FM/CW Modulation Techniques	0	100	0	0	0	0	100
B. Lightweight, Low Inertia Scanning Antenna Techniques	0	70	80	50	0	0	200
(4) U.S. Air Force							
A. Data Rate	0	250	200	0	0	0	450
Sub-Totals	1705	5905	4560	1310	860	550	14890
APPLICATION TO USER NEEDS							
1. Aircraft Control/Display							
(1) FAA							
A. Signal Processor	0	500	750	1000	750	0	3000
B. Command & Situation Display	0	700	600	600	600	400	2900
C. All Weather Flight Simulator	0	500	100	100	100	0	800
(2) U.S. Army							
A. Coupled Helicopter Approaches	0	100	875	225	225	0	1425
B. Helicopter Steep Approach Display	0	300	325	300	275	100	1300
(3) U.S. Navy							
A. Aircraft Display Studies	0	50	50	100	0	0	200
B. Coupled Curved Approaches	0	200	200	100	0	0	500

Table B-1. Supporting Investigations And Flight Tests (Cont'd)

Program/Gov't Agency	Funding By Fiscal Year ($000)						
	1971	1972	1973	1974	1975	1976	Totals
(4) U.S. Air Force							
A. Processor Developments	0	450	200	100	100	0	850
B. Command & Display Experiments	50	700	500	500	500	0	2250
C. Flight Test Aircraft Modification/Support	0	100	0	650	750	0	1500
2. U.S. Army Operations							
A. Low Power C Band DME	0	100	75	75	75	75	400
B. Simulation	0	300	500	450	400	250	1900
3. U.S. Navy Operations							
A. Integration Into Navy ATC Environment	0	70	115	0	0	0	185
B. Doppler from Moving Platform	0	60	100	0	0	0	160
C. C Band Antenna for Aircraft Carriers	0	0	100	100	0	0	200
D. FM/CW Adaption for ARA-63	0	100	100	0	0	0	200
4. U.S. Air Force Operations							
A. Simulator Modifications and Programming	50	400	110	110	110	0	780
5. ATC/NAS Interface							
(1) TSC							
A. System Requirements Analysis	0	300	300	300	300	300	1500
Sub-Totals	100	4930	5000	4710	4185	1125	20,050
RELATED PROGRAMS*							
1. NASA							
A. Development of STOL Avionics	(1800)	(4000)	(3500)	(1600)	(700)	(0)	(11,600)
2. USAF							
A. STOL Flight Control and IFR Landing	(1150)	(1150)	(1150)	(1150)	(0)	(0)	(4600)
FLIGHT TEST & EVALUATION							
1. Provide Test Facilities							
(1) FAA							
A. Develop NAFEC Test Facility	0	300	500	200	0	0	1000
(2) TSC							
A. MLS Testing Requirements	0	100	100	0	0	0	200
(3) U.S. Army							
A. Mobile Tracking Facility	0	350	1170	270	245	200	2235
(4) U.S. Air Force							
A. Field Test Facilities	0	900	500	300	300	0	2000
2. Flight Test							
(1) FAA							
A. System Evaluation	0	0	100	400	1500	1000	3000
(2) NASA							
A. STOL System Evaluation	0	0	0	200	700	800	1700
(3) U.S. Army							
A. System Evaluation	0	0	100	550	700	0	1350
(4) U.S. Navy							
A. System Evaluation	0	0	100	200	800	700	1800
(5) U.S. Air Force							
A. System Evaluation	0	0	200	500	500	500	1700
Sub-Totals	0	1650	2770	2620	4745	3200	14,985

*Related program funding is not included in the sub-totals and totals.

Table B-1. Supporting Investigations And Flight Tests (Cont'd.)

Program/Gov't Agency	Funding By Fiscal Year ($000)						
	1971	1972	1973	1974	1975	1976	Totals
SUMMARY BY AGENCY							
FAA	600	2700	2750	2800	3450	1900	14200
TSC	405	1100	900	300	300	300	3305
NASA	0	0	0	200	700	800	1700
U.S. Army	0	1660**	3525	2275	2280	675	10415
U.S. Navy	0	1075	1145	605	800	700	4325
U.S. Air Force	800	5950**	4010	2460	2260	500	15980
TOTALS	1805	12485	12330	8640	9790	4875	49925
SUMMARY BY PROGRAM							
TECHNIQUES INVESTIGATIONS	1705	5905	4560	1310	860	550	14890
APPLICATION TO USER NEEDS	100	4930	5000	4710	4185	1125	20050
FLIGHT TEST & EVALUATION	0	1650	2770	2620	4745	3200	14985
RELATED PROGRAMS							
NASA	(1800)	(4000)	(3500)	(1600)	(700)	(0)	(11600)
USAF	(1150)	(1150)	(1150)	(1150)	(0)	(0)	(4600)

** The U.S. Army and the U.S. Air Force will require program adjustments in FY 1972 in order to meet these funding requirements.

2.1.1 FAA Tasks

A. Evaluation of Signals in Space: Test and evaluation of the existing microwave scanning beam systems at NAFEC will be continued regarding (1) multipath effects on signal quality, (2) noise content of signals and acceptable signal-to-noise ratios, (3) suitability of signals for use in deriving velocity terms for airborne equipment, (4) beam shape and beam width requirements. A test program for this task will be developed by TSC. (See task 2.1.2 below.)

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	300	300	0	0	0	600

2.1.2 TSC Task

A. Develop Test Program: A series of experiments will be designed which most effectively utilize the existing ground and airborne elements of the scanning beam systems at NAFEC in conjunction with other existing avionics in the FAA's CV-880 test aircraft for the FAA "Evaluation of Signals in Space" task (2.1.1).

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	100	200	0	0	0	0	300

2.1.3 U.S. Army Task

A. Propagation: This task will employ available Ku band scanning beam hardware to examine the influences of ground and other reflections (e.g., other aircraft using the system simultaneously) on

beam shape, accuracy, and guidance quality. This work is an extension of limited testing of this type planned under the ongoing USAECOM program. Two antenna configurations (i.e., beam sizes) are available for testing. The wider beam configuration is believed to be the minimum practical antenna aperture size useful for generating scanning beam landing guidance. Use of the minimum size antenna will likely be limited to the steeper approach angles (5° to 6° minimum) of helicopters and STOL aircraft. It is important that this lower boundary of scanning beam technique performance be established. The need for including means for adjusting spatial radiation coverage on a site-to-site basis will be determined. Also, performance of the Ku band system in rain will be checked when the opportunity presents itself during the normal course of testing.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	250	225	150	150	50	825

2.1.4 U.S. Navy Tasks

A. Data Rate with Tracking Radar: Determine the minimum data rate necessary to control and land an aircraft by actual tests. The AN/SPN-42 All Weather Carrier Landing System has the inherent flexibility of varying the command rate to the aircraft by simple software changes. It is proposed to vary this data rate over a wide range, i.e., 1 to 10 messages per second for several types of aircraft and measure the change in aircraft response. Additionally, the rate of radar update will be varied and an externally controlled level of noise will be introduced. It is also anticipated that initial experiments with curved approaches and flares can be conducted by minor software changes.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	150	50	0	0	0	200

B. Data Rate with Scanning Radar: The quality of signal and, therefore, aircraft control is related to the number of radar hits on the target and the accuracy with which this beam position of radar is controlled and known. The AN/TPN-22 X band phased array radar will be used in conjunction with the AN/DPN-42 control system to investigate the aircraft control feasible with a radar system which is time-shared (scanned).

Note: The Navy's experience with automatic landing systems has been with tracking radars that provide continuous data on the position of the aircraft under control. The radar systems proposed for future use will update available aircraft positions at a rate dependent upon the specific design accepted. This update rate will introduce errors (noise) due to position extrapolation that could be additive to the noise contained in the message system itself.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	50	100	0	0	0	150

C. Ku Band Azimuth Antenna: Conduct evaluations of position accuracy attainable with a one degree Ku band azimuth antenna on long (greater than 10,000 feet) runways. Data will be provided at a rate of 5 per second over a sector of 40°. Although the proposed system format does not provide for a Ku band azimuth unit, the available device will permit early determination of accuracy and indicate whether a 1° beamwidth is sufficient for the intended mission.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	40	0	0	0	0	40

D. Range-in Rain Measurements at Ku Band: Establish a range-in-rain measurement site at NATC, Patuxent (Pax) River, employing installed equipment and a remotely controlled receiver and recorder. During periods of rainfall, the remote receiver/recorder would be activated and the receiver output recorded. The rainfall would be measured at several points along the transmission path. The amount of measured data on rain attenuation at Ku band is limited. The above system could be easily implemented and operated and would be a source of valuable data for future decision-making regarding frequency.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	20	15	5	0	0	40

E. Aircraft Response Characteristics: Evaluation can be accomplished at NATC, Pax River, employing the AN/SPN-41, ASW-25, and available data reduction facilities. The program assumes that the aircraft under evaluation include autopilots with both vertical and lateral control and that a versatile coupler can be built which can be adapted to various autopilots.

The data rate required of the new landing system is directly related to the response characteristics of the aircraft to be controlled. The data rate requirements of several types of naval aircraft will be determined.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	75	75	50	0	0	200

F. Antenna Polarization Evaluation: The purpose is to conduct tests to establish the most acceptable polarization for antenna systems employed with forward area types of equipment.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	40	10	0	0	0	50

G. MARCORPS V/STOL Performance Requirement: The purpose is to conduct a flight test program for the A-V8A aircraft to investigate the performance envelopes required of the MLS in a forward area V/STOL environment. (Note: The availability of the A-V8A aircraft or a suitable V/STOL substitute in FY 1972 has not been determined at this time.)

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	50	50	0	0	0	100

2.1.5 U.S. Air Force Tasks

A. Signal Format Investigations: Using the Flarescan unit, the Varian narrow-band FM transmitter-receiver, and commercially available laboratory equipment, tests will be conducted to quantify the effects of the dwell time of a single received beam passage on the accuracy of an angular measurement; using the recommended SC-117 signal format, the amount of co-channel cross-talk will be determined between the angle data tones and the function identification and auxiliary data tones as a function of modulation indexes, tone frequencies, etc.; and the effect of strong out-of-band interference will be determined as a function of the interference level, signal level, and frequency separation.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	150	1250	500	200	0	0	2100

B. Low Angle Ground Effects: At low angles required for flare, substantial energy is radiated into the ground; this may result in angular measurement errors. The Flarescan transmitter and receiver in their present form and, in a second phase, the Flarescan antenna, excited with the Varian FM transmitter, will be used to measure the effect of ground reflections for receiver elevation angles ranging from 0 to 3 degrees in 0.2 degree steps. This will be done for the ground reflection area of the first sidelobe occurring on a runway, grass, and bare ground. The distance of the ground reflection area from the Flarescan antenna will range from 250 feet (well into the near zone) to 3000 feet in four or five steps. The influence of terrain on low elevation angle accuracy for various proposed coding techniques will be determined.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	250	200	100	0	0	550

C. Geometry Effects: Investigations will be conducted to verify that the planar beam geometry behaves as predicted and to determine the actual magnitude of the effect on glide path angle relative to the runway intercept point as elevation scanner siting is varied. This will establish the parameters for the calculation required in airborne signal processing equipment to satisfy the range in operational requirements.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	150	100	0	0	0	250

D. Flight Test Aircraft Modification/Support: The Air Force Flight Dynamics Laboratory has a test fleet of flying laboratories including T-38, T-39, C-131, C-135B, C-141, OV-2, YOH-6 and CH-3E aircraft, and in addition, a very uniquely configured and equipped variable stability aircraft known as TIFS (Total Inflight Simulation). The TIFS aircraft can simulate, in flight, a large variety of aircraft stability and control characteristics. These aircraft will be used, as required, for flight verification tasks in conjunction with technique investigations which will include tests of various signal formats, low angle ground effects and geometry effects using existing experimental systems. Funds are required to modify the aircraft and to provide contractor support for conducting tests, maintaining equipment, accumulating and reducing data, and assisting in report preparation.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	550	1500	1500	0	0	0	3550

2.2 Advanced Technology Investigations

Early engineering prototype models will, by necessity, utilize components which will be available in the FY 1972-74 time period. It is known, even today, that much can be done to improve the quality and decrease the costliness of components that will be required. Exploratory developments will be undertaken with industry and within government that have the potential for increasing the performance, reducing the cost, or otherwise benefiting the guidance system. Experimental hardware and test data will be available for incorporation in the final system design, or as the basis for writing detailed production specifications.

2.2.1 FAA Task

A. Component Development: New design concepts and techniques with the potential for improving performance and/or reducing costs in either the ground or airborne elements of the total system will be investigated. Work will be confined to areas not covered by the basic industry effort. It is expected that this type of effort will be principally directed toward components having a high risk factor but successful effort will also result in high payoff. Airborne antenna configurations for the MLS two frequency band operation and the application of solid state technology (for instance for replacement of the magnetron) to improve system integrity are typical of the areas which will be investigated.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	100	100	500	500	500	1700

2.2.2 TSC Task

A. Phased Array Feasibility Study: Phased array technical advantages, capabilities, limitations, complexity, and cost will be considered with regard to the operational requirements of the microwave landing system for both azimuth and vertical guidance.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	305	500	500	0	0	0	1305

2.3 Signal Format Characteristics

Tasks in this area consist of analytical and experimental studies designed to quantify the effects of various signal format parameters on the achievable accuracy and completeness of the guidance technique. Potentially serious problems may be created by interference of various types for Doppler, CW, and pulse-modulation formats as proposed by the RTCA. Examination of the possible interference produced by the sub-carrier present on a CW guidance signal, for example, reveals some potentially serious problems with function identification. The effects of strong "out-of-band" interference on the guidance signal may also be quite serious. Items requiring investigations and validation in this area include:

- Modulation techniques
- Encoding and decoding techniques
- Coverage/accuracy/resolution requirements
- Scan rate/data rate/beam dwell time
- Channelization/adjacent channel interference, and
- Dual frequency band problems – including simultaneous reception of both bands.

Investigation in several areas is being held in abeyance until specific information is available on the techniques proposed by industry. At that time the extent of the investigation efforts into the following areas can be planned so as to complement and support the program sponsored with industry:

- Continuous vs. step scan techniques
- Sum vs. null beam shapes, and
- Planar vs. conical beam shapes.

2.3.1 FAA Task

A. Analytical and Experimental Program: An analytical and experimental program will be conducted to resolve certain critical issues, to build a data base for the evaluations of industry proposals, and to highlight problem areas to be addressed by industry in the major industry development effort of the plan. In addition to the investigation of basic signal formats and modulation techniques the effort will include: (1) adjacent channel interference, (2) analysis of the three-dimensional geometry to resolve the planar versus conical beam shape problem, (3) laboratory simulation regarding susceptibility of candidate techniques to multipath effects, (4) examination of the effects of runway gradients on the Ku band elevation scanner for flare and touchdown, and (5) analysis of the suitability of a C-band-only MLS to meet system requirements.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	600	300	300	0	0	0	1200

2.3.2 U.S. Army Tasks

A. Basic Format Studies: The ability of techniques proposed by industry to yield high quality fine resolution data over broad regions of coverage will be of primary concern. Auxiliary data capacity and format will be evaluated to determine utility in performing special message functions of interest and importance to the Army tactical instrument landing problem. These messages include, for example, azimuth reference course assignments, obstacle clearance information for each azimuth course, station identification, and ground equipment siting constants when appropriate. The basis for these evaluations will be existing Army requirements and criteria established through the on-going exploratory and advanced development landing programs and flight research (not covered herein) at the Avionics Laboratory, USAECOM.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	110	115	110	110	0	445

B. Encoding/Decoding Techniques: Analysis and laboratory experiments will be conducted to determine that industry-proposed guidance techniques and hardware will be both technically and economically suitable for Army use. Effort will be directed toward conceiving simple, low cost encoding/decoding schemes which are at the same time compatible with any class of service or system configuration.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	75	75	75	50	0	275

C. Two Frequency Band Investigations: The Army's tactical landing guidance needs are best served by a total Ku band system. The MLS as proposed by the RTCA, however, will employ both C and Ku bands—with C band being preferred for the civil environment. This task will concentrate on resolving questions concerning the impact if the Army is required to carry both C and Ku band equipment to achieve compatibility with the civil environment. Investigations will include dual frequency band airborne antennas, dual frequency band receiver RF sections, and channelization schemes.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	75	65	70	50	0	260

2.3.3 U.S. Navy Tasks

A. FM/CW Modulation Techniques: An in-house study of accuracy and acceptability of employing FM/CW modulation for shipboard landing guidance data will be conducted. The effects of ship motion (moving source) on the performance of an FM/CW system will be determined.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	100	0	0	0	0	100

B. Lightweight, Low Inertia Scanning Antenna Techniques. The purpose is to investigate low inertia scanning antenna systems suitable for use with man-transportable systems and rugged enough to withstand the rigors of a combat environment. The antenna systems must be sufficiently accurate to meet the operational requirements of a forward area operation.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	70	80	50	0	0	200

2.3.4 U.S. Air Force Task

A. Data Rate: The minimum acceptable as well as the optimum data rates as a function of information quality at the receiver output for various aircraft and control system configurations, will be determined. In-house hybrid (digital and analog) simulation facilities will be used for dynamic analysis. Flight verification in several aircraft types will be performed using existing scanning beam systems.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	250	200	0	0	0	450

3.0 Application to User Needs

The tasks encompassed by this area of effort are intended to identify and resolve problems related to the use of the guidance system. The primary efforts will be related to aircraft control and display problems and those problems created by unique environments.

3.1 Aircraft Control/Display

Aircraft control/display concept validation encompasses those activities required to ensure effective utilization of the airborne receiver's output. The received signal must be processed and then interfaced with the pilot, through flight director and situation displays, and with the aircraft control system.

The validation activities are designed to provide the technological data base required for the development and evaluation of flight control and display techniques. Evaluation of exploratory development work will be accomplished by both analytical studies and flight-test programs.

Today's aircraft are provided with couplers which serve as signal processors when using VHF/UHF ILS or ground-originated data link signals. Modifications to these couplers and processors will be required. Analytical studies will be undertaken to specify the signal processor functional requirements or autopilot coupler modifications, as the case may be, and to determine cost effective and reliability

implementation guidelines. Available general purpose digital and hybrid airborne computers will be used, in conjunction with modified scanning beam receivers, to gain early flight experience and understanding of this problem.

Flight test results using an R&D scanning beam system have revealed that the most modern flight director and autopilot couplers are inadequate. The requirement to fly curved paths is an extension of current flight director technology. Consequently, concept validation requires both analytical and experimental studies to determine adequate data processing concepts and implementation.

Flight tests of various situation displays will be carried out to determine combinations and configurations required for optimum utilization of available guidance information in accordance with specific aircraft and operational requirements.

3.1.1 FAA Tasks

A. Signal Processor: Analytical studies to determine the performance requirements for signal processors will be undertaken, followed by computer verification and feasibility model development. Simulation and flight testing will be conducted to evaluate the product when used with various aircraft/flight control systems. Of particular concern in this effort is the feasibility of programming for a variety of approach paths, operational suitability of such procedures, and investigation of methods for accepting changes to the path using both automatic and manual flight control.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	500	750	1000	750	0	3000

B. Command and Situation Display: Simulator and flight evaluations of special displays, display generating systems, and display controls will be undertaken using the all-weather flight simulator and test aircraft at NAFEC. To take advantage of the volumetric coverage provided by the MLS, modifications of cockpit displays, display-generating equipment, and associated pilot controls of the displays are required. These modifications are necessary to provide the pilot with adequate information to monitor an automatic approach or to conduct such an approach manually while maintaining a precise flight path and arriving at predetermined way points at the predicted or commanded time. The flight paths to be investigated include curved paths in both elevation and azimuth and appropriate combinations of each. Simulator and flight display equipment hardware will be procured and installed, and experiments will be designed to determine the pilot performance. It is anticipated that electronic displays will be used to the greatest extent possible due to their flexibility for display changes.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	700	600	600	600	400	2900

C. All Weather Flight Simulator: The characteristics of flight simulator requirements associated with the need for increased capacity will be identified and trade-off studies accomplished to determine those to be incorporated in the NAFEC research facility. The NAFEC all weather landing simulator will be configured and programmed for flight instrument evaluation.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	500	100	100	100	0	800

3.1.2 U.S. Army Tasks

A. Coupled Helicopter Approaches: The purpose of this task is to determine the guidance needs (e.g., accuracy, resolution, data rate) for steep, coupled approaches in a helicopter. One Army helicopter will be outfitted with autopilot/coupler equipment. Initial evaluation of requirements for guidance data resolution, data rate, and smoothing for anything between straight line and constant speed approaches to curved (both azimuth and elevation) decelerating approaches can be undertaken with available Ku band scanning beam guidance equipment. Results of this work will permit evaluation of the MLS prototype systems for use in coupled, steep helicopter approaches.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	100	875	225	225	0	1425

B. Helicopter Steep Approach Display: Ongoing flight research at the Avionics Laboratory, USAECOM, is defining landing guidance requirements for steep helicopter approaches. The performance and data base being established are derived from manual approaches with the pilot being given only pure position error information (course deviation indicator). Preparations must be made to evaluate the versatile guidance information of the MLS prototype systems with representative advanced display hardware.

This task will build on prior work directed toward defining solutions of the steep angle approach and landing problem through analysis and simulation. Initially, efforts will be directed toward verification of results derived from a current program wherein display/control functions and signal characteristics have been thoroughly examined with respect to approach angles up to 15°. Other results from these programs have provided additional data concerning formats and configurations of displays, such as head-up displays, which appear to be the most desirable in terms of transition to visual conditions. Once satisfactory operation has been established through live flight testing, representative hardware will be modified to the extent necessary and evaluated further in a steep approach flight program. The task would include an examination of problems associated with deceleration of rotary-wing and V/STOL aircraft. This aspect of the display/control program has a major impact upon ceiling and visibility minimums achievable in helicopter instrument approaches.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	300	325	300	275	100	1300

3.1.3 U.S. Navy Tasks

A. Aircraft Display Studies: Studies will be conducted to determine the most effective means of presenting the guidance information available to the pilot on various forms of instrumentation and displays. Display techniques which provide the greatest amount of usable data and utilize the available guidance capability must be developed. This work will not include development of the signals which drive the instruments and displays.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	50	50	100	0	0	200

B. Coupled Curved Approaches: Existing airborne hardware and existing ground facilities will be employed to determine the level of control and accuracy needed to complete a curved approach with Category II minimums. Coupled curved approaches are principal functions possible with the new MLS. This task will provide early consideration of the hardware and data quality required to accomplish same. While existing equipment will be used, certain modifications, relocation, and reprogramming will be required to achieve a coupled curved approach capability.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	200	200	100	0	0	500

3.1.4 U.S. Air Force Tasks

A. Processor Developments: Analytical studies, and laboratory and flight experiments will be performed to specify signal processor functional requirements or current autopilot coupler modifications, as the case may be, and to interface the receiver output with display instruments and the flight control system. Developments will be initiated for experimental equipments to assure usability of the new system. These will range from simple innovations for light aircraft limited to low approach to sophisticated tactical and cargo aircraft requiring zero/zero capability.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	450	200	100	100	0	850

B. Command and Display Experiments: The adequacy (in terms of both accuracy and usability) of the scanned guidance information presented to the pilot is critically dependent upon the availability of suitable command and situation displays. Studies will first be performed in laboratory flight simulators with experimental and synthesized displays obtained from exploratory development programs funded separately from this program. Information requirements and functional

relationships will be determined for curved and segmented approach landing, rollout, and go-around. Flight verification will be performed, using the experimental instruments and configurations resulting from the simulation work, for multicrew cargo, single-seater fighter/interceptor and lightweight forward air controller (FAC)-type aircraft.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	50	700	500	500	500	0	2250

C. Flight Test Aircraft Modification/Support: The Air Force Flight Dynamics Laboratory has a test fleet of flying laboratories including T-38, T-39, C-131, C-135B, C-141, OV-2, YOH-6 and CH-3E aircraft, and in addition a very uniquely configured and equipped variable stability aircraft known as TIFS (Total Inflight Simulation). The TIFS aircraft can simulate, in flight, a large variety of aircraft stability and control characteristics. These aircraft will be used, as required, for flight verification tasks in conjunction with aircraft control/display validation activities which will include signal processor experiments and command and display experiments. Funds are required to modify test aircraft and to provide contractor support for conducting tasks, maintaining equipment, accumulating and reducing data, and assisting in report preparation.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	100	0	650	750	0	1500

3.2. U.S. Army Operations Tasks

A. Low Power C Band DME: In recent Army landing system developments, the DME subsystem is an optionally employed module in both ground and airborne equipments. The penalty of preserving this desirable characteristic in an MLS design which employs Ku band angle guidance components and C band DME components needs to be established and minimized. Since inclusion of a DME sub-system approximately doubles the cost of the airborne portion of the landing system, it is relevant for the Army to undertake a small but intensive effort to assure that MLS C band DME sub-system design(s) being evolved by industry can be realized with cost effective components and designs. Since Army requirements demand relatively short range DME performance, use of low power transmitter components will be emphasized.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	100	75	75	75	75	400

B. Simulation: Under this task, the USAECOM Avionics Laboratory's Tactical Avionics System Simulator (TASS) will be employed to investigate several operational facets of the MLS. This effort will include a study of the breakout or instrument-to-visual transition part of the approach and landing operation. Manual and automatic approaches in perhaps four different types of aircraft of interest

to the Army will be examined (i.e., conventional helicopter, compound helicopter, stopped-stowed rotor, and tilt-prop aircraft). Since the projected useful life of the new system extends well beyond 1990, it is likely that the system will be operationally used in similar aircraft. It is important, therefor, to examine the ability of the new system to serve these aircraft.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	300	500	450	400	250	1900

3.3 U.S. Navy Operations Tasks

A. Integration into Navy ATC Environment: Studies will be made to determine the most effective means of employing the microwave landing system within the Navy's air traffic control and landing environments. The interface between the terminal ATC and the MLS will be evaluated and the impact on existing command and control software and operational procedures will be assessed.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	70	115	0	0	0	185

B. Doppler from Moving Platform: Studies will be conducted to determine the accuracy and technical implications of employing a Doppler form of landing system from a moving platform such as an aircraft carrier. Since a Doppler system is one candidate for the future common landing system, its acceptability for shipboard use (where there is deck motion) must be evaluated.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	60	100	0	0	0	160

C. C Band Antenna for Aircraft Carriers: Studies and tests will be conducted to determine the antenna techniques most suitable for providing C band ILS for shipboard application. The antenna will be required: (a) to provide an accurate operating capability, (b) to be stabilized, and (c) to be small enough to meet the space constraints imposed by a shipboard environment. To be fully compatible with the planned system, it may be necessary to convert all shipboard systems to C band. C band antenna size currently represents a major obstacle.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	0	100	100	0	0	200

D. FM/CW Adaptation for ARA-63: A study will be conducted and hardware will be developed to determine and demonstrate the technical brass board feasibility and economic acceptability of converting the existing Ku band pulse receiver to a CW receiver.

The current Navy system operates with pulse modulation. The object is to accomplish the transition from the current Navy system to the proposed modulation system with minimum impact and cost.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	100	100	0	0	0	200

3.4 U.S. Air Force Operations Task

A. Simulator Modification and Programming: While in-house simulator facilities are capable of performing broad aircraft control system and flight instrument research and evaluation, modifications to these in-house simulator facilities will be made to adapt them to scanning beam investigations and to interface them with new control and display elements for pilot-in-the-loop studies.

A number of computer programs are available which simulate the aerodynamic characteristics of several military aircraft. Nevertheless, additional programs are required to permit system dynamic analysis of scanning beam systems used with expected future Air Force aircraft designs. Computer programs will be developed under contract, and contractor support will be used to assist in conducting investigations and reducing data.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	50	400	110	110	110	0	780

3.5 ATC/NAS Interface, TSC Task

A. System Requirements Analysis: System requirements will be investigated with initial emphasis on the interface problem. The signal quality required for effective control of the aircraft during approach and landing will be determined. This includes both ground and airborne sub-system considerations for curved approaches and the flare and touchdown phases of operation. The investigations will involve the spectrum of user aircraft and various system configurations.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	300	300	300	300	300	1500

4.0 Related Programs, NASA And Air Force Tasks

A. NASA Development of STOL Avionics: This task involves the preparation of an all-digital guidance and control system in a STOL research aircraft in FY 1974; this will provide an effective tool for validation of the new MLS for STOL application. The first phase of this task will involve implementation of state-of-the-art hardware in an augmenter wing, jet STOL aircraft (a modified C-8A Buffalo), and software implementation of advanced terminal area navigation, guidance, control functions, and concepts. Guidance and control algorithms will be developed and tested by simulation with experimental flight tests starting in the second half of FY 1972. The ground environment will be provided by a scanning beam microwave ILS (MODILS). This will permit flight tests of precision, time constrained, steep gradient, curvilinear approach paths; and of automatic, semi-automatic, flight-director-aided, and manual flight modes. Cockpit displays of navigation, guidance, and other

types of information will receive particular emphasis. The design for the more advanced system will incorporate the results of the FY 1972 flight experiments.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	(1800)	(4000)	(3500)	(1600)	(700)	(0)	(11600)

B. Air Force STOL Flight Control and Instrument Landing Program: The Air Force has an elaborately equipped CH-3E "flying laboratory" which is currently flying as a STOL flight profile simulator to define high angle STOL guidance, control, and display criteria. The first phase of flying is underway using modified STATE, C band equipment which provides coarse/fine localizer, glide slope, and very accurate omni-range and range rate information. Later phases will involve installations in STOL-type aircraft and flights against a synthesized SC-117 system using the Flarescan/Varian FM/CW narrow band transmitter and receiver and STATE equipment.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	(1150)	(1150)	(1150)	(1150)	0	0	(4600)

Note: These tasks are not considered a direct charge in the development of the MLS.

5.0 Flight Test and Evaluation

Two groups of tasks are included in this area of activity: those required to provide the test capability to support test and evaluation of the MLS, and those directly involved in flight tests.

5.1 Provide Test Facilities

The national MLS development program is based upon the principle that all participating agencies of government will be required to decide favorably upon the adequacy of the new system before it will be considered for adoption as a standard. A favorable decision requires that satisfactory prototype system test results be achieved in the flight test and evaluation phase of the program. To accomplish the critical flight test and evaluation, several government agencies require that existing facilities be improved or that new test facilities be provided. This section describes the effort needed to provide these facilities.

5.1.1 FAA Task

A. Develop NAFEC Test Facility: The testing capacity and capability at NAFEC will be determined and recommendations will be made to develop the test environment so as to meet the requirements of the MLS validation program. This will involve range instrumentation, data reduction, aircraft, manpower, etc.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	300	500	200	0	0	1000

5.1.2 TSC Task

A. MLS Testing Requirements: This task will assist in the investigation of the overall testing requirements for the MLS validation program. An overall test plan will be formulated delineating the test and test facility requirements. Data reduction procedures and new test techniques will be investigated.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	100	100	0	0	0	200

5.1.3 U.S. Army Task

A. Mobile Tracking Facility: The aircraft position measurement facilities being provided in USAECOM's ongoing exploratory development program are portable; (this allows quantitative measurements of landing system performance at almost any typical site). However, the current Army facilities possess two disadvantages: there is an appreciable delay (days) before reduced data are available, and the facilities are not usable for the entire landing approach during instrument flight rules (IFR) weather. What is needed to supplement the camera facilities is a mobile, real time tracking facility – a high precision radar tracker. The radar could provide real time aircraft position data and at the same time could serve as a back-up landing guidance system during actual IFR testing. This facility would be useful for evaluating landing system performance not only at typical Army sites, but also for application of the MLS at civil airports as well – particularly those relatively small general aviation airports which now have no landing guidance facilities of any kind but which will become candidates to receive the simpler configurations of the new system. The proposed Army facility will also provide the necessary ground and airborne recording equipment and a reference time system to synchronize ground and airborne data collection equipments.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	350	1170	270	245	200	2235

5.1.4 U.S. Air Force

A. Field Test Facilities:

1. The electronic countermeasures tower facility at Wright-Patterson Air Force Base (WPAFB) will be modified to permit antenna pattern measurements and static microwave propagation tests, particularly at low grazing angles represented in flaring, high performance aircraft. The tower projects 350 feet above the runway and is located on a hill. This limits its ultimate capability but it will be useful in initial testing.

2. Facilities at Clinton County Air Force Base, 30 miles from WPAFB, will be upgraded to permit field and flight testing under simulated tactical conditions. A 150-foot microwave test tower will be included.

3. To accommodate multi-site experimentation and operational suitability testing, a mobile (large trailer) laboratory will be constructed to provide for data acquisition, calibration, and aircraft tracking facilities. Work bench type space will also be available in the trailer.

4. Modify the antenna test range at Rome Air Development Center and provide modern test equipment for "free air" antenna pattern measurements.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	900	500	300	300	0	2000

5.2. Flight Test

Each participating agency must conduct flight tests to determine that the MLS is completely suitable and adaptable to its needs. The tasks below describe each agency's effort in the overall flight test evaluation of the total microwave landing system.

5.2.1 FAA Task

A. System Evaluation: The FAA has the responsibility for system validation in accordance with the spectrum of operational requirements established for civil aviation. Not only will the technical characteristics and operational capabilities of the prototype systems be evaluated in the NAFEC airport environment, but tests will be conducted at active airports which are representative of a full range of actual operations (i.e., from small, low density, general aviation airports – to large, high density commercial airports).

Two different system configurations, the simplest and the most complex, will be evaluated using the various types of aircraft necessary to validate that the new system will satisfy the spectrum of user requirements. The total system validation effort will include both ground and airborne elements of the microwave landing system in the total air traffic control operational environment.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	0	100	400	1500	1000	3000

5.2.2 NASA Task

A. STOL System Evaluation: Under this task, the best available STOL aircraft with an advanced avionics system will be used in flight experiments to test and evaluate the effectiveness of the microwave landing system for STOL applications. This program will include flight test of time-constrained, curvilinear approach paths in automatic, semi-automatic, flight-director-aided, and manual approaches and determination of approach and touchdown accuracy during various wind conditions and different control modes. Existing simulation capabilities at NASA research centers will be used to increase the productive time of the flight test aircraft and provide data supplementing and extending the flight test results.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	0	0	200	700	800	1700

Note: This task, because it evaluates the applicability of the MLS to STOL operations, is considered a direct charge to the development of the MLS.

5.2.3 U.S. Army Task

A. System Evaluation: The Army will conduct acceptance and validation testing of the prototype MLS hardware resulting from the industry contractual effort. These evaluations will be conducted for the purpose of establishing: (1) whether or not the prototype hardware satisfies specific technical performance requirements, and (2) whether or not the guidance technique embodied within the prototype hardware can be modified so as to be satisfactory for the purposes and requirements of the Army user under tactical conditions. The test plan which will be prepared for system validation will also include tests covering all areas of concern identified as a result of the Army's concurrent supporting program.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	0	100	550	700	0	1350

5.2.4 U.S. Navy Task

A. System Evaluation: The Navy will evaluate prototype systems aboard an aircraft carrier to demonstrate operational feasibility on a moving platform. Additional tests will be conducted to demonstrate operational feasibility for the Marine Corps requirements for both the expeditionary air base at a short airfield for tactical support (SATS field), and the remote area sites for helicopters and fixed-wing VTOL aircraft such as the Harrier.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	0	100	200	800	700	1800

5.2.5 U.S. Air Force

A. System Evaluation: The military command's functional and operational requirements will be determined with respect to tactics and operation within military air traffic control and near navigation environments and the interfaces with the landing guidance system. Evaluation criteria for various flight conditions to verify system adequacy and adaptability to operational needs will be established. Following this, multicrew cargo (C-135B, C-141, or C-5), high performance fighter/interceptor (F-5, F-106B, or F-4), and representative FAC-type aircraft will be used to determine suitability of the system for Air Force operations. Typical operational type sites will be set up at Eglin Air Force Base and Clinton County Air Force Base. The funding reflects cost of flight testing and government support.

Fiscal Year	1971	1972	1973	1974	1975	1976	Total
Funding ($000)	0	0	200	500	500	500	1700

APPENDIX C. ABBREVIATIONS

AEEC	Airline Electronic Engineering Committee
AFB	Air Force Base
AILS	Advanced Integrated Landing System
ALPA	Airline Pilots Association
AM	Amplitude Modulation
ANC	Air Navigation Commission
AOC	Airport Operators Council
AOPA	Aircraft Owners and Pilots Association
ARINC	Aeronautical Radio Incorporated
ATA	Air Transport Association of America
ATC	Air Traffic Control
ATCAC	Air Traffic Control Advisory Committee
ATCLS	Air Traffic Control and Landing System
AWOP	All Weather Operations Panel
CAA	Civil Aeronautics Authority
CEAC	Committee for European Aerospace Coordination
CNAD	Conference of National Armaments Directors
CPILS	Correlation Protected Instrument Landing System
CTOL	Conventional Take-off and Landing
CW	Continuous Wave
CY	Calendar Year
DME	Distance Measuring Equipment
DOD	Department of Defense
DOT	Department of Transportation
FAA	Federal Aviation Administration
FM	Frequency Modulation

FSF	Flight Safety Foundation
FY	Fiscal Year
GCA	Ground Controlled Approach
GFE	Government Furnished Equipment
HUD	Head-Up Display
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IRATE	Interim Remote Area Terminal Equipment
LGS	Landing Guidance System
MADGE	Microwave Aircraft Digital Guidance Equipment
MARCORPS	Marine Corps
MLS	Microwave Landing System
MODILS	Modular Instrument Landing System
MRAALS	Marine Remote Area Approach and Landing System
NAFAG	NATO Air Force Armaments Group
NAFEC	National Aviation Facilities Experimental Center
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATC	Naval Air Test Center
NATO	North Atlantic Treaty Organization
NBAA	National Business Aircraft Association
NIAG	NATO Industrial Advisory Group
OSEM	Office of Systems Engineering Management
PCM	Pulse Code Modulation
PRF	Pulse Repetition Frequency

RAPCON	Radar Approach Control
R & D	Research and Development
RFP	Request for Proposal
RTCA	Radio Technical Commission for Aeronautics
SC-117	Special Committee No. 117 of the RTCA
SETAC	Sector TACAN
SFDT	Signal Format Development Team
SRDS	System Research and Development Service
STATE	Simplified Tactical Approach Terminal Equipment
STOL	Short Take-Off and Landing
TACAN	Tactical Air Navigation
TALAR	TALAR was originally an acronym for tactical approach and landing radar; this is no longer correct but the word "TALAR" is used to designate an existing microwave approach guidance system.
TASS	Tactical Avionics Systems Simulator
TDY	Temporary Duty
TSC	Transportation Systems Center
UHF	Ultra High Frequency
UK	United Kingdom
USA	U.S. Army
USAECOM	U.S. Army Electronics Command
USAF	U.S. Air Force
USMC	U.S. Marine Corps
USN	U.S. Navy
VHF	Very High Frequency
VORTAC	VHF Omni-Directional Range/Tactical Air Navigation

V/STOL	Vertical and Short Take-Off and Landing
VTOL	Vertical Take-Off and Landing
WPAFB	Wright-Patterson Air Force Base

☆U.S. GOVERNMENT PRINTING OFFICE: 1971-720-234/319