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Report to the Congress; by Elmer B. Staats, Comptroller General.

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Congressional Relevance: House Committee on Armed Services; Senate Committee on Armed Services; Congress.

The Federal Aviation Administration's (FAA's) microwave landing system (MLS), which is designed to replace existing instrument and other landing systems, is to be an all-weather precision guidance system making instrument landings possible at more locations and providing flexibility in approach paths. It is expected to be easier to install and maintain and less expensive than the current system. Findings/Conclusions: A high level of uncertainty exists in the Department of Transporation and the aviation community concerning the overall expected benefits of the MLS. It is generally believed that instrument landing systems are reliable, safe, and provide efficient service within technical and operational capabilities. However, the current system is limited to 40 channel frequencies; it does not meet military tactical requirements; and it is adversely affected by heavy snow, irregularities in the terrain, and structures built close to the runway. The MLS is expected to overcome these limitations. The total research and development effort for the MLS program will be between $90 million to $100 million more than originally estimated. No urgent need exists for the military MLS systems; therefore, to plan for production deliveries of both civil and military systems in 1985 and an initial operating capability in 1986 appears unnecessary. Recommendations: The Secretary of Transportation should: continue the use of existing instrument landing systems at U.S. domestic airports in accordance with a mutually agreeable microwave landing system implementation plan; require FAA to consider the opinions of users in developing cost-benefit data and an implementation plan; and require FAA to clearly validate the technical, operational, and economic benefits of the MLS by conducting a comprehensive demonstration program with clearly defined evaluation criteria. (RRS)

BY THE COMPTROLLER GENERAL 8038

Report To The Congress

OF THE UNITED STATES

Status Of The Federal Aviation Administration's Microwave Landing System

The Federal Aviation Administration's new common civil/military microwave landing system is about 5 years behind schedule and research and development will cost between $182 and $192 million--approximately $90 to $100 million more than originally estimated.

Large amounts of money are still being invested for ground equipment for the existing system. Recognizing these continued investments, along with the probable extension to 1995 of instrument landing systems at international airports, existing instrument landing systems at U.S. domestic airports should be continued in accordance with a mutually agreeable microwave landing system implementation plan.

The Congress may wish to consider the necessity of funding the rapid development of a joint tactical system at this time since the military's needs are not immediate. However, an orderly military development program may be justified to assure the desired compatibility and interoperability and to properly research and develop systems which will meet military requirements.

PSAD-78-149

OCTOBER 19, 1978

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-164497(1)

To the President of the Senate and the
Speaker of the House of Representatives

This is our report on the status of the Federal Aviation Administration's Microwave Landing System which is expected to eventually replace the current instrument landing system and other landing systems.

We made our review pursuant to the Budget and Accounting Act, 1921 (31 U.S.C. 53), and the Accounting and Auditing Act of 1950 (31 U.S.C. 67).

We are sending copies of this report to the Director, Office of Management and Budget; the Secretaries of Transportation and Defense; the Secretaries of the Army, Navy, and Air Force; and the Administrators of the Federal Aviation Administration and the National Aeronautics and Space Administration.

Comptroller General
of the United States

COMPTROLLER GENERAL'S REPORT TO THE CONGRESS

STATUS OF THE FEDERAL AVIATION ADMINISTRATION'S MICROWAVE LANDING SYSTEM

D I G E S T

The microwave landing system, which is to replace the existing instrument and other landing systems, is to be an all-weather precision guidance system making instrument landings possible at more locations and providing flexibility in approach paths. It is also expected to be easier to install and maintain and therefore less expensive than the current system. (See p. 2.)

The current system is reliable and offers safe and efficient services within its technical and operational capabilities, but it

--is limited to 40 channel frequencies (20 of which are currently in use),

--does not meet military tactical requirements, and

--is adversely affected by heavy snow, irregularities in the terrain, and structures in close proximity to the runway.

The microwave landing system is expected to overcome these limitations.

The transition to a microwave landing system will require substantial investments by the Federal Aviation Administration (FAA) and users, including the Department of Defense (DOD). FAA envisions that approximately 1,250 systems will be justified by the year 2000 at a cost of about $510 million to the users and $280 million to FAA (in 1977 constant dollars). (See p. 7.)

Although FAA believes its technical assumptions in the cost/benefit analysis were extremely conservative, there appears to be a significant level of uncertainty in the Department of Transportation and the aviation community regarding the overall benefits to be expected from the new system. To date FAA has not developed a cost/benefit analysis acceptable to the Department of Transportation or a transition plan. (See pp. 8 and 9.)

Civil and military users believe the existing landing guidance systems adequately meet all but the most demanding needs and will continue to do so through the 1990s. (See pp. 9 and 26.)

GAO believes that although the microwave landing system has improved capabilities over the current landing system, a positive determination of cost/benefits, need at specific locations, and safety should be demonstrated before full scale implementation is initiated. (See p. 13.)

The Secretary of Transportation should:

--Continue the use of existing instrument landing ground systems at U.S. domestic airports in accordance with a mutually agreeable microwave landing system implementation plan. This should coincide as closely as possible with the recommendation of the International Civil Aviation Organization to protect the existing instrument landing system until 1995 at international airports.

--Require FAA to consider the opinions of users in developing cost/benefit data and an implementation plan.

--Require FAA to clearly validate the technical, operational, and economic benefits of the microwave landing system by conducting a comprehensive demonstration program with clearly defined evaluation criteria.

The microwave landing system is an integral part of FAA's proposed upgraded air traffic control system which will permit aircraft to operate safely closer together. The microwave landing system is expected to provide better regulation of air traffic and increase airport landing capacities. GAO previously questioned whether FAA should go forward with the air traffic control system in view of the prospect of lower air traffic than originally expected, the availability of satellite airports, and the inability of surface transportation to provide access to airports. (See pp. 12 and 13.)

FAA should be required to inform the Congress of the status of the subsystems comprising the upgraded air traffic control system and show how the microwave landing system can accomplish its stated advantages if other elements of the system are not developed for concurrent use with the microwave landing system.

Originally, FAA had estimated the microwave landing system research and development effort would cost $90.9 million--$58.5 million for its program and $30.7 million and $1.7 million, respectively, for the DOD and National Aeronautics and Space Administration (NASA) programs. FAA now estimates the program will cost approximately $112.6 million and the DOD and NASA programs are estimated to cost $65 million to $75 million and $4.6 million, respectively, increasing the total program cost to between $182 and $192 million--approximately $90 to $100 million more than originally estimated. In addition, based on changes in the program, GAO believes it is unlikely that FAA can complete its research and design efforts for $112.6 million and that these estimates are outdated and should be revalidated. (See p. 15.)

FAA estimates that the civil development program will extend through 1981, a delay of approximately 5 years. Part of this delay was deliberate. Estimated completion of the military derivations is yet to be determined.

A fully integrated basic wide expanded microwave landing system configuration has neither been procured nor fully demonstrated. Demonstrated performance supports a limited procurement to show how the total system performs in more demanding civil airport and tactical military environments. GAO believes the lack of an acceptable transition plan and the uncertainty of expected benefits preclude a large-scale implementation decision at this time. (See p. 23.)

FAA was to have overall management responsibility for all microwave landing system prototype development. Rising development costs have forced FAA to reconsider its military prototype development effort, and it plans to transfer contracting and management responsibility to Defense if the Congress will concur. GAO believes future funding for military microwave systems should consider that the military's needs are not immediate and that interoperability with civil systems is essential. (See p. 26.)

The Congress should obtain answers to the following questions before providing additional funds for military microwave landing system research, development, and production.

--Why is it necessary to rapidly develop a joint tactical system for the military at this time? Current landing systems are considered adequate until the 1990s and in some cases until the year 2000.

--If Defense takes over the development of the military systems, does FAA intend to reduce its expenditures by $14.5 million--that portion of its cost estimate designated for development of the military systems?

--Will there be a loss of technical expertise and continuity if Defense assumes responsibility for the military systems?

--Are there any critical military requirements (such as shipboard signal format) which would have an impact on compatibility and interoperability with civil systems that FAA should consider during development?

The Departments of Defense and Transportation and the National Aeronautics and Space Administration agreed with GAO's conclusions and recommendations when commenting on a draft of this report. (See apps. V and VI for written agency comments; DOD's comments were obtained orally.)

Contents

ABBREVIATIONS

DOD	Department of Defense
FAA	Federal Aviation Administration
GAO	General Accounting Office
ICAO	International Civil Aviation Organization
ILS	Instrument landing system
MLS	Microwave landing system
NASA	National Aeronautics and Space Administration
R&D	Research and development

CHAPTER 1

INTRODUCTION

The microwave landing system (MLS) is a common civil/ military all-weather precision approach and landing guidance system. It generates and transmits signals that permit aircraft in the coverage area, with compatible equipment, to determine their azimuth and elevation angles and range. The ground station also transmits the necessary auxiliary information required for the aircraft to effect safe approaches and landings. (See fig. 1.)

The MLS program is a Government effort to identify, design, and develop a new landing system to replace the existing instrument landing system (ILS) and other landing

MICROWAVE LANDING SYSTEM (MLS)

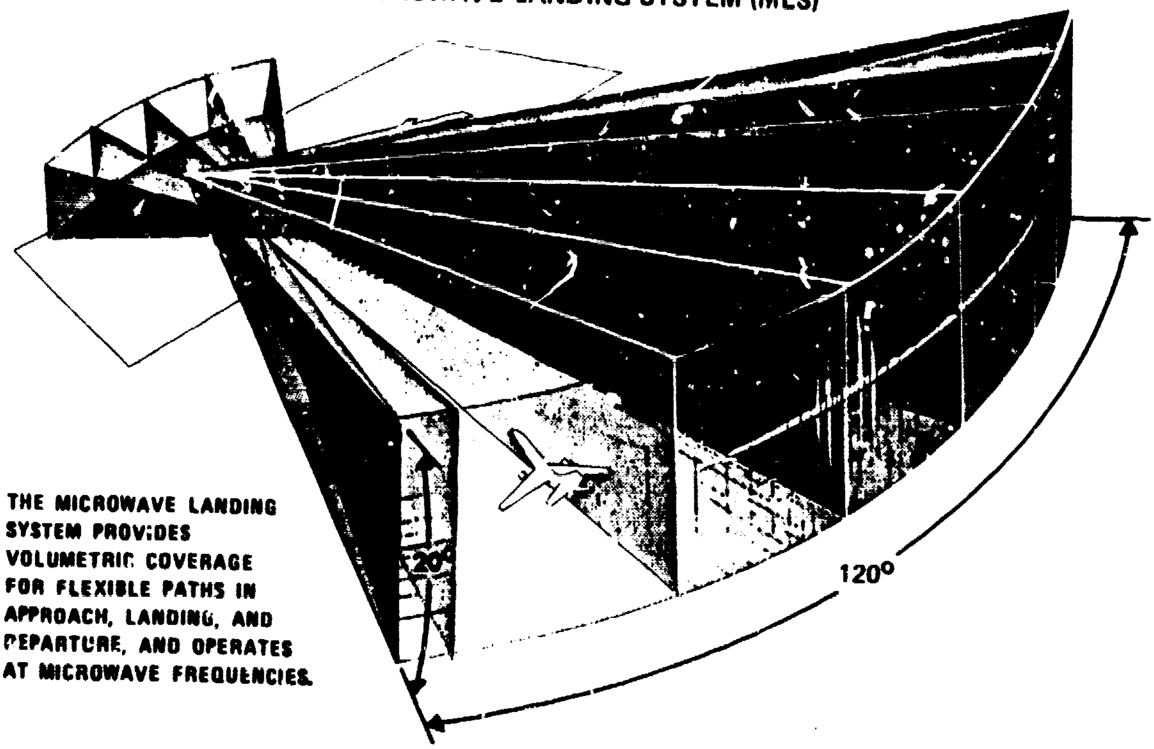

FIGURE 1

systems. The program includes joint efforts by the Department of Transportation's Federal Aviation Administration (FAA), the Department of Defense (DOD), and the National Aeronautics and Space Administration (NASA).

The MLS program consists of three phases. Phases I and II deal with conceptual designs and equipment evaluations. Phase III of the program includes the design, fabrication, and evaluations of prototype operational systems.

INSTRUMENT LANDING SYSTEM--THE CURRENT STANDARD AND ITS LIMITATIONS

ILS (see fig. 2, p. 3) was first demonstrated commercially in 1939, nearly 40 years ago. It was adopted for national service in 1941 and as an international standard by the International Civil Aviation Organization (ICAO), an affiliate of the United Nations, in 1949. ILS, which has since been improved, is still providing satisfactory precision landing guidance at airports where it is in use and, in April 1978, an ICAO All Weather Operations divisional meeting recommended extension of the ILS protection date for international airports from 1985 to January 1, 1995. It was noted at this meeting that regardless of the system's limitations, it represents a worldwide implemented, well-established, and reliable system, offering safe and efficient services within its technical and operational capabilities. It also noted that the implementation of MLS should be gradual and correspond to the advantages demonstrated and the experience gained, allowing for a smooth and cost-effective transition from the current to the new system.

ILS has a number of limiting factors (see fig. 3, p. 3) which would leave some operational requirements completely or partially unfulfilled--particularly in a future aviation environment which envisions more demanding all-weather operations with larger numbers of sophisticated high-performance aircraft. The system is limited to 40 channel frequencies (20 channels are currently in use); does not meet military tactical requirements; and is adversely affected by heavy snow, irregularities in the terrain, and structures in close proximity to the runway.

Advantages of MLS

MLS is expected to overcome the limitations inherent in ILS and provide many operational advantages. MLS will make instrument landings possible in many more locations as well as provide flexibility in approach paths to enable more efficient use of airspace. MLS is also expected to be easier to install and maintain and therefore less expensive.

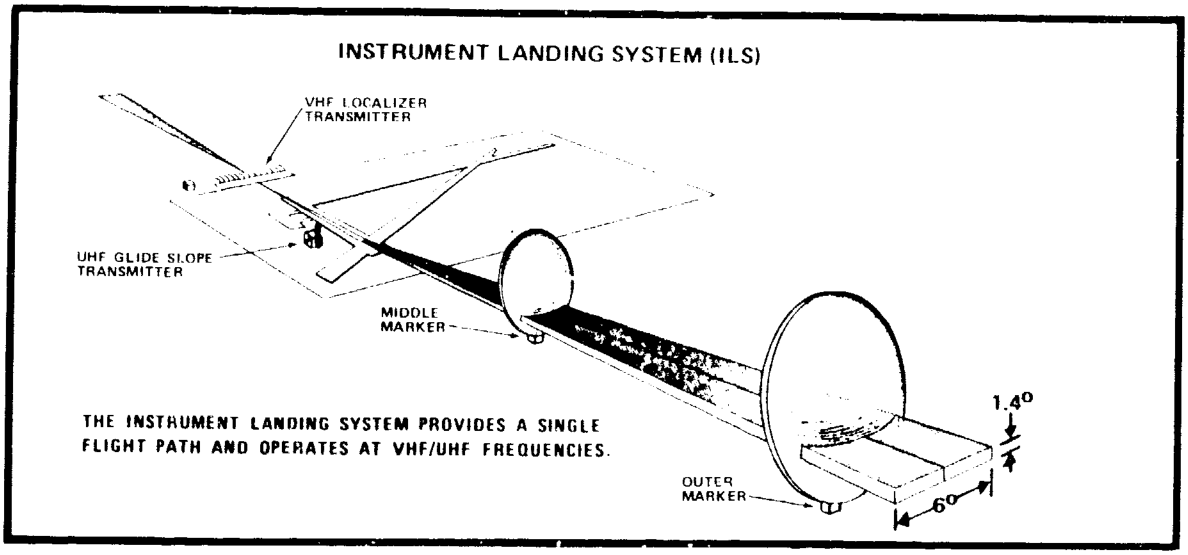

FIGURE 2

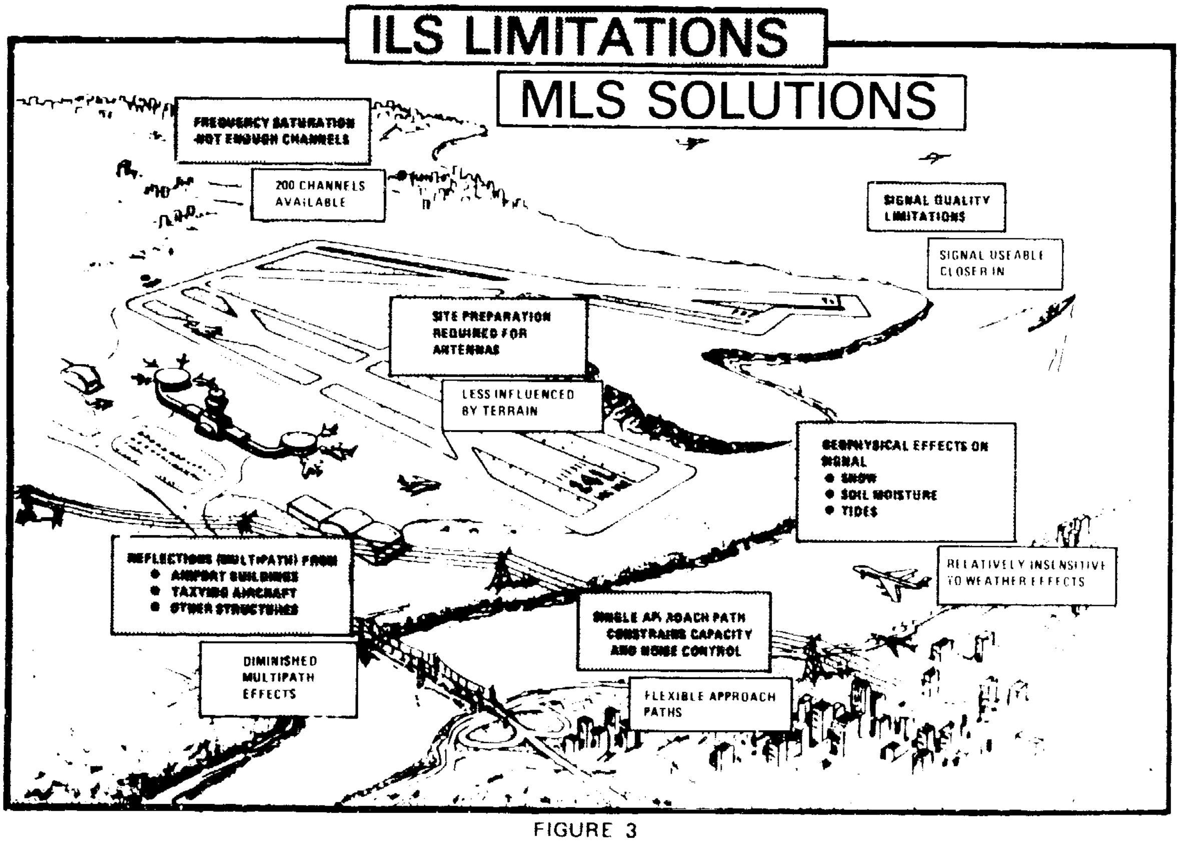

FIGURE 3

System operation in the microwave frequency band provides relative freedom from site effects, a large increase in channel availability, and a higher degree of signal integrity in providing more accurate information to pilots in all weather conditions. (See app. I.)

NEED FOR SUCCESSOR ESTABLISHED

In a December 1969 report, the Department of Transportation's Air Traffic Control Advisory Committee indicated that the projected demand for air traffic control services would outstrip the capabilities of the present system and concluded that MLS was required as part of the future national aviation system. The committee report added impetus and importance to the work of the Radio Technical Commission for Aeronautics which, after 3 years, produced a comprehensive recommendation for a new guidance system for approach and landing. The commission, consisting of several hundred aviation experts, developed a concept and signal format to satisfy the operational needs of the various classes of aircraft users.

The national MLS development plan, dated July 1971, was jointly prepared by DOD, NASA, and Transportation/FAA--all of whom are MLS program participants. The plan was conceived as the mechanism for developing and implementing a new system intended to meet both civil and military requirements through at least the year 2000. The national plan envisioned a three phase development program that would result in production specifications for an MLS with an initial operational capability by 1978.

Initially, nine different system development proposals were evaluated, with six selected to continue into phase I for technique analysis and contract definition. During phase II, four complete systems, two scanning beam and two Doppler scan (see app. II and III), were built and tested. In the assessment at the end of phase II, the scanning beam technique with time reference coding was selected as the system to be further developed and submitted by the United States to ICAO as its candidate for international standardization. The MLS program is currently in phase III with two ground system prototypes, the small community (multiple glide paths with minimum guidance altitude to 150 feet with precision information within 10 degrees either side of the runway center line) and the basic narrow (multiple glide paths with minimum guidance altitude to 50 feet with precision information extending to 40 degrees either side of the runway center line), being tested and evaluated. Phase III calls for the building of a small community system, two basic versions, an expanded system, a joint tactical system, an air transportable system, and a shipboard system. (See app. IV.)

International program for a successor

In April 1972, ICAO developed operational requirements for a precision approach and landing system for international civil aviation. The requirements specified a high integrity precision guidance system to permit an approach, landing, and missed approach capability

--at most airports and on most runways,

--at a maximum acceptable rate,

--with no cloud base or visibility restrictions,

--with the flexibility of visual approach operations in all weather conditions,

--with no limitations or constraints imposed by the guidance system (except where limitations are deliberately accepted for economy and simplicity),

--with simplified versions of air and ground equipment for limited operations but with a system design to permit compatibility between all versions of the air and ground equipment, and

--in order to aid noise abatement.

A number of ICAO member states--including the United States, the United Kingdom, Australia, France, and Germany--pursued development programs designed to meet the ICAO operational requirements. The various candidate systems were evaluated by ICAO, and in April 1978 the All Weather Operational divisional meeting recommended that the U.S./Australian candidate MLS be adopted for international use. This recommendation was noted by the Air Navigation Commission and approved by the ICAO council.

SCOPE OF REVIEW

Our primary objective was to evaluate the status of the FAA MLS program. We reviewed cost, schedule, and performance data on the U.S. system as well as cost/benefit data, implementation plans, and the status of the DOD and NASA phases of the program.

We interviewed Department of Transportation, FAA, DOD, and NASA personnel at both the headquarters and field level. We also reviewed available documentation at these locations. The locations visited during this review included:

--The Department of Transportation, FAA, DOD, and NASA headquarters, Washington, D.C.;

--National Aviation Facilities Experimental Center, Atlantic City, New Jersey;

--Ames Research Center, Naval Auxiliary Landing Field, Crow's Landing, California; and

--Lincoln Laboratory, Lexington, Massachusetts.

CHAPTER 2

PROBLEMS WITH MLS IMPLEMENTATION

A high level of uncertainty exists in the Department of Transportation and the aviation community concerning the overall expected level of MLS benefits. ICAO believes that ILS is reliable, safe, and provides efficient service within its technical and operational capabilities. Since the conversion to an MLS standard could cause significant costs to be incurred by FAA and the aviation community--including DOD--with potential compensating benefits accruing slowly over time, a need exists for a well defined, carefully planned program to demonstrate its operational and economic viability both to the civil and military communities. Successful completion and evaluation of the results of the demonstrations should be the basis for any decision regarding replacement of ILS with MLS.

The transition to MLS will have an impact on its users, DOD, and FAA requiring substantial investment in avionics and ground equipment. Major consideration should be given to accomplishing the transition in a smooth and orderly manner and minimizing the adverse impact on all parties.

The introduction of MLS into the national aviation system will be a complex process requiring careful planning. As of May 1978, approximately 650 operational ILS ground systems were in service at 498 civil U.S. airports and approximately 50,000 (47,000 general aviation and 3,000 air carrie /commuters) aircraft were equipped with ILS avionics equipment. In addition, a large number of military aircraft have ILS avionics equipment. FAA expects about 600 additional airports to qualify for MLS by the year 2000.

Based on a January 1978 study, FAA envisions that the transition from ILS to MLS will require about 20 years (1980 - 2000) with approximately 1,250 MLS systems being justified by the year 2000. MLS ground system costs are expected to exceed $280 million (in 1977 constant dollars) and avionics equipment costs to civil users are estimated at about $510 million (in 1977 constant dollars).

FACTORS INFLUENCING MLS IMPLEMENTATION

Primary factors influencing implementation of MLS are (1) the users' need for the system, (2) the cost of obtaining and installing the required avionics, and (3) the derived benefits. The cost of avionics will be a major factor in determining the rate at which users will equip their aircraft and in turn utilize and accrue the benefits of MLS. The required installation of MLS avionics may not be attractive to some airlines and general aviation users who foresee little benefit accruing to them from the new landing system.

The cost of a ground system is an important factor in determining the pattern of implementation and the total number of systems. There is a direct relationship between cost and the number and type of systems to be installed. The number of ground systems and the aircraft owner's perception of the benefits derived from these systems in turn influence decisions to equip aircraft with MLS avionics.

Cost and benefits derived from ground systems are used to develop criteria for determining if airports are eligible for instrument landing systems. If the current landing system criteria is used for MLS, a favorable benefit/cost ratio will be required for individual sites to be eligible to receive MLS. Annual funding levels and the types of systems to be installed dictate how many of the eligible locations will be equipped with MLS.

UNCERTAINTY IN ACHIEVING MLS BENEFITS

In March 1974, the Under Secretary of Transportation requested a comprehensive review of major FAA engineering and development programs. This review recommended a comprehensive cost/benefit analysis to justify the investment required for implementing the new system and cautioned that FAA needed to more carefully assess the effect of avionics costs upon the users.

In keeping with this recommendation, in December 1976 FAA completed a cost/benefit study of MLS, which it believed included extremely conservative technical assumptions. The study analyzed the requirements for MLS by comparing the relative merits of implementing MLS nationally to continuing with the present landing system. The study concluded that the development of MLS can be economically justified with an incremental benefit to cost ratio for aviation users of 3.9 to 1 if 1,250 total ground systems were installed by the year 2000. Air carriers and commuter airlines are estimated to benefit substantially while general aviation users are expected to experience marginal or negative benefits. Finally, the study indicated that a $40 million reduction in FAA investment, operating, and maintenance costs was possible with installation of 1,250 civil MLS systems. The study did not quantify military benefits but did indicate that substantial operating and maintenance cost savings were possible with the MLS alternative.

Although reviewed by the Office of the Secretary of Transportation, the study was never approved. Transportation officials have expressed reservations about the underlying assumptions and data employed in the study, including a (1) 10-year transition period, (2) the practicality of making curved approaches, (3) an over optimistic forecast for air carriers fleet size, (4) use of as yet unapproved approach procedure maneuvers, (5) advisibility of closer spacing of aircraft on approach, and (6) airport landing capacities. Transportation stated that the study by itself did not support implementation of MLS and indicated that the cost/benefit study must be viewed in conjunction with the results of another study of alternate MLS implementation strategies (transition plan). In August 1977 Transportaion urged FAA to complete its transition plan and make it available, along with the cost/benefit study on MLS, to the aviation community for review. Although the studies have not been released publicly, the cost/benefit study and a preliminary draft of the MLS transition plan were made available to us.

Using a 20-year transition period, the transition plan shows MLS to have only a very marginal (1.3 to 1) incremental benefit to cost ratio over ILS as opposed to the 3.9 to 1 ratio indicated in the initial cost/benefit study. Additionally, the transition plan assumes that ILS decommissioning would begin in 1986. Recent agency analysis indicates that if all ILS decommissioning would not begin until 1996, FAA's costs would increase by $27 million, thus reducing potential MLS saving from the estimated $40 million to $13 million. If FAA were to gradually decommission ILS systems at domestic airports beginning in 1986, FAA costs would increase $6 million to $11 million depending on the decommissioning strategy used. FAA estimates that potential savings by gradual ILS decommissioning could range from $29 million to $34 million.

USER CONCERNS

The aviation community, as represented by various aviation associations and prospective users of the new system, has expressed concerns and reservations regarding how, when, and under what circumstances transition to MLS should be carried out. A special committee of the Radio Technical Commission for Aeronautics was established in June 1974 for the purpose of providing user recommendations for a national MLS implementation policy. The committee, which consisted of Government representatives and a wide spectrum of prospective users and manufacturers of MLS, was to provide user recommendations for the planning and execution of an MLS implementation plan to best meet the needs of the aviation community.

In its July 1977 report on MLS implementation, the committee recommended a strategy which maximized user benefits, was expected to stimulate implementation of MLS avionics needed to realize the benefits, and eventually expand MLS service on a nationwide basis. Among its many recommendations which bear on the planning and execution of a national policy for MLS, the committee recommended that FAA:

--Plan for a 20-year transition period.

--Develop an implementation program that does not force users to equip with MLS avionics, but which is based on incentives produced by providing benefits as perceived by each user.

--Conduct further work to validate and quantify benefits to resolve uncertainty regarding their availability.

--Commit itself to those actions necessary to ensure that the potential benefits of MLS will actually be realized by those users who are so equipped.

Although recommending a general strategy for implementing MLS, the committee was unable to reach agreement on an optimum strategy. The committee also recommended that FAA establish and keep current a data base suitable for use in planning, evaluating, and revising MLS implementation plans. The committee further recommended that MLS be installed at locations which sustain 400 or more annual instrument approaches. FAA analysis, however, indicates that MLS ground systems at locations with fewer than approximately 1,600 general aviation or 1,000 air carrier instrument approaches annually would not be cost beneficial because the installation and operating costs would exceed the benefits to be derived by the system users.

Air carriers strongly oppose restraints on the continuation of ILS and other means to force transition to MLS until the benefits are clear and a transition timetable is agreed to by FAA and the users. The airlines believe that rather than FAA establishing hard and fast timetables for nationwide system implementation at this time, MLS must first show clear advantages in terms of cost and benefits both in aircraft and on the ground. They believe transition to any new system must be based on clearly demonstrable major superiority of the new system from the standpoint of technical performance, flexibility, and economics. In addition, the carriers believe that, during the transition, the new system and ILS must be capable of simultaneous operations without interference to either system or adverse effects to runway capacity.

The Air Transport Association of America stated in its policy manual that transition planning must provide for use of simple airborne systems during the early period, to allow use of MLS and ILS service with minimum change of airborne installations and instrumentation.

The Aircraft Owners and Pilots Association supports the development of MLS as the eventual replacement for the present ILS system when it is found that ILS can no longer fulfill the demand for precision approach service. It also supports retention of existing ILS installations throughout the normal useful life of the ground based equipment.

The National Business Aircraft Association conducted surveys which indicate that business aircraft operators would be generally satisfied with navigational aids being provided at as many airports as possible, enabling landings at ceiling minimums of 200 feet and one-half mile visibility. The association believes that under the present FAA airways planning standards, thousands of airports used by business aircraft will continue to be ineligible for an instrument landing system.

The association endorses efforts by Government and industry to provide accurate, reliable, cost-effective, and safe approach aids at the maximum number of airports throughout the world. Within the context of this broad policy, it believes that the present ILS cannot provide the widespread coverage required, either now or in the future. Therefore, it supports development of MLS and feels that its availability to operators should not be unduly delayed.

NEED FOR A DEMONSTRATION PROGRAM TO QUANTIFY BENEFITS

The Radio Technical Commission for Aeronautics special committee also recommended that FAA and other Government agencies establish service test and demonstration programs to better quantify potential MLS benefits. The committee believes the program is needed to resolve uncertainty and provide substantiation for some of the benefit areas, such as reductions in flight and landing delays, landing capacity increase, flight operation usage, safety, and other technical benefits.

The FAA service test and evaluation program (which is exclusive of unique military requirements) is expected to ease the transition from the research and development phase to the implementation phase by demonstrating that MLS will satisfy all areas of civil user requirements and serve to develop and validate operational and maintenance procedures. Other expected accomplishments are

--educating civil users on system formance and capabilities,

--stimulating interest in avionics equipment,

--refining procurement specifications,

--providing initial training for FAA and users, and

--helping create an early international market for U.S. industry.

ACHIEVING MLS ADVANTAGES DEPENDS ON OTHER PROPOSED SYSTEMS

MLS is also expected to provide better regulation of air traffic and increase airport landing capacities by sequencing arrival times of various aircraft and letting aircraft safely operate closer together. This advantage, however, cannot be realized by MLS alone since the closer spacing of aircraft will require the avoidance of aircraft wake vortexes 1/ and the ability to rapidly clear aircraft off the runways. These limitations are to be addressed by the development of individual elements of FAA's proposed upgraded air traffic control system planned for the 1980s and 1990s. Our previous report ("Issues and Management Problems in Developing an Improved Air Traffic Control System," PSAD-77-13, Dec. 15, 1976), however, questioned

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1/Air turbulence caused by large aircraft during low speed final approach which adversely affects the ability of following aircraft to be controlled by the pilot.

whether FAA should go forward with the planned pace and content of the air traffic control system--of which MLS is an integral part--in view of (1) the prospect that the rate of increase of air traffic will be lower than originally expected, (2) the availability of underused satellite airports at major hubs, and (3) the increasing inability of surface transportation to provide access to airports.

CONCLUSIONS

In our opinion the selection of an international signal format standard for MLS is not a sufficient basis for implementing MLS without first demonstrating its need at specific locations, considering both safety and economic benefits. To date FAA has not developed an acceptable cost/benefit analysis or MLS transition plan. We believe FAA should develop and disseminate an implementation plan to facilitate user planning. FAA should also continue to maintain liaison with the aviation community in order to remain aware of user needs, obtain user input, and disseminate planning information. We also believe there should be no restraints on ILS improvements and use where needed until MLS benefits are accepted as achievable by the users, and a final transition timetable is established and agreed to by FAA and the users.

ICAO recognized that large investments have been made in ground and airborne equipment in the past and will continue to be made for some time to come. Although ICAO felt sufficient time was required to permit amortization of these investments and has recommended extension of the protection date for ILS at international airports to January 1, 1995, the protection date in the United States is currently January 1, 1985. Inasmuch as the development of MLS continues and it has not been demonstrated as cost beneficial or actually needed at all locations, failure to extend the protection date of ILS at all locations within the United States currently utilizing ILS could impose economic hardships on current owners of ILS avionics equipment.

In view of the recommended extension of the ILS protection date to 1995, we believe an implementation plan based on a comprehensive demonstration program and structured to maximize user benefits, would be prudent. We believe this would provide FAA and the users with more reliable data on the benefits to be derived from MLS, provide more time to take advantage of technological advancements which may occur over the next few years, and provide more time for users to amortize current ILS avionics.

We believe the need for MLS at this time is limited to a relatively small number of airports in the United States. According to most civil and military users, the current landing guidance system adequately meets all but the most demanding needs and will continue to do so through the 1990s.

RECOMMENDATIONS

We recommend that the Secretary of Transportation:

--Continue the use of existing ILS ground systems at U.S. domestic airports in accordance with a mutually agreeable MLS implementation plan to coincide as closely as possible with ICAO's recommendation to protect ILS until 1995 at international airports.

--Require FAA to take into consideration the opinions of users in developing cost/benefit data and an implementation plan.

--Require FAA to clearly validate the technical, operational, and economic benefits of MLS by conducting a comprehensive demonstration program with clearly defined evaluation criteria.

MATTERS FOR CONSIDERATION BY THE CONGRESS

We believe FAA should be required to inform the Congress of the status of the systems which comprise the upgraded air traffic control system and show how MLS can accomplish its stated advantages (better regulation of air traffic, increased airport landing capacity, and closer spacing between landing aircraft) if the other elements of the overall upgraded air traffic control system are not developed for concurrent use with MLS.

AGENCY COMMENTS

The Department of Transportation generally agreed with our conclusions and recommendations when commenting on a draft of this report.

CHAPTER 3

STATUS OF MLS COST, SCHEDULE, AND PERFORMANCE

COST

The total research and development (R&D) effort for the MLS program will be between $182 million and $192 million--approximately $90 million to $100 million more than originally estimated. Since the national plan was implemented in 1971, there have been many events which have affected the program's R&D costs. The 1971 national plan estimated the R&D effort would cost $90.9 million--$58.5 million for the FAA program and $30.7 million and $1.7 million, respectively, for the DOD and NASA programs. Program changes since 1971 and increased ICAO participation have increased the estimated FAA program costs to an estimated $112.6 million. In addition to FAA's program, DOD and NASA estimate they will spend approximately $65 million to $75 million and $4.6 million, respectively. FAA officials told us that the 1971 national plan did not include the costs of engineering development for military systems now included in the estimated program costs.

FAA R&D PROGRAM COSTS

Current estimate may be understated

Even though ICAO has adopted the time reference scanning beam as the international standard, it is unlikely that $112.6 million will be sufficient to complete the fiscal year 1976 development program. Specifically, the funding available for the remainder of phase III is inadequate for developing both the military systems and the expanded civil system without reducing the scope of the program.

Military systems

In March 1976, FAA estimated that approximately $15 million would be needed for the development of the joint tactical MLS and the shipboard MLS during phase III through prototype or advanced development. Subsequently, Bendix Corporation and Texas Instruments, Inc., performed design definition studies, at a total cost of $500,000, which resulted in a statement of work for the joint tactical MLS through the end of engineering development. As part of this approach, DOD was to provide $1.2 million for the added design effort to meet military specifications.

The technical proposals were much higher than had been anticipated, and available FAA funding was considered inadequate for a complete engineering development program.

As a result, FAA and DOD agreed to revert back to an advanced development program. Present estimate for this effort is still $15 million.

Expanded system

Approximately $3.4 million is currently programed for developing an expanded system. This system is intended to satisfy the needs of NASA and all other users of a full capability system. While most of the modules will be technically equivalent to those used in the basic system, fundamental differences exist which dictate the need for separate prototype testing. Since the development of the expanded version embodies the solution of the most difficult civil system problems, FAA believes that this system must be developed along with the versions required to meet less demanding problems in order to ensure overall system integrity. FAA plans to procure a basic wide system (multiple glide paths with minimum guidance altitude to touchdown on the runway and precision information extending to 60 degrees either side of the runway centerline) which will eventually, if funds are available, be upgraded to an expanded system. To assist FAA, NASA has provided $600,000 toward the procurement of a basic wide system. Even with the assistance, however, it appears that FAA will not have enough funds to upgrade the basic wide system to an expanded system with its full complement of capabilities.

NASA participation in the program has been primarily in a support role and in conducting flight tests. NASA's funding contribution ($4.6 million) has been used primarily for these purposes. There are no plans for NASA to contribute additional funds to aid FAA in providing an expanded system. NASA, however, does plan--in a cooperative effort with FAA--additional investigations to simplify and bring to a more advanced state of readiness the airborne systems technology and flight control procedures which exploit the utilization of MLS capabilities.

Cost growth

The MLS program has changed significantly from the program outlined in the national plan and, as a result, a cost comparison between FAA's current program and the one presented in the original national plan would be misleading. FAA's R&D program estimate for fiscal year 1976 more closely resembles the current program. At that time, the program was well established and program objectives have not markedly changed. The following table contrasts this estimate with the national plan and FAA's latest estimate.

FAA R&D Program Cost Estimates

Program element	Program estimates: National plan	Fiscal year 1976	Current (as of 3/1/78)
	--------(000 omitted)--------		
Industry program	$41,000	$61,908	$ 62,888
Supporting programs			
Supporting investigations	17,505	3,597	15,586
Test & evaluation	-	9,385	9,046
Program management	-	4,385	6,519
ICAO support	-	10,734	18,544
Subtotal	$58,505	$90,009	$112,583
Program adjustments	1,100	-	-
Total FAA R&D program	$59,605	$90,009	$112,583

Differences between the national plan and the 1976 plan

The two major differences between the national plan and the 1976 plan involve DOD participation and the prototypes to be developed. The national plan envisioned DOD as being actively involved in the early development efforts and contributing approximately $30 million to the project. DOD's responsibilities included initial signal format verification, flight evaluations, and developing specific military ground hardware and avionics for specific aircraft. In 1973, the Congress directed that FAA assume full funding responsibility for the development of the civil and military systems. This reduced the military's involvement by approximately $15 million and the funding responsibility was transferred to FAA to conduct related military support studies.

The national plan identified eight separate configurations as being needed for prototype testing by the principal user groups. These configurations were intended to be specific designs for category I, II, and III performance levels. (See app. IV.) A modular concept used in the phase II technique selection process resulted in only five configurations being required, which resulted in cost savings of approximately $13.9 million.

After adjusting for the redirected military participation and the reduced number of configurations, a comparison of the 1976 cost estimates with that of the national plan indicates a cost growth of $30.4 million. FAA attributes $21.9 million to contractor cost growth, $4.4 million to program management, and the remaining $5.1 million to ICAO support costs. Neither of the last two items was costed as a separate item in the national plan.

Differences between the 1976 plan and FAA's current program

As previously noted, program objectives have not changed substantially since fiscal year 1976. The cost growth since 1976, however, has amounted to approximately $22.6 million, primarily due to contractor overruns, inflation, and the extended ICAO process.

The following table compares the hardware FAA planned to procure in 1976 with FAA's latest planned procurement.

Quantities of Prototype Equipment To Be Delivered

Configuration	1976 estimate Ground	1976 estimate Airborne	Current (as of 8/1/78) Ground	Current (as of 8/1/78) Airborne
FAA:				
Basic narrow	2	8	2	4
Small community	2	8	4	4
Basic wide:				
Development program	1	4	a/1	-
Service test and evaluation program	5 or 10	20 or 40	-	-
Experimental test bed	1	4	-	-
Expanded	1	8	a/-	-
DOD:				
Joint tactical	3	12	3	12
Shipboard	1	8	1	8
DOD airborne receivers	-	-	-	10
NASA:				
Expanded	1	4	-	-
Total	17/22	76/96	11	38

a/ Under the current program the basic wide system will be upgraded to an expanded system.

FAA officials cited contractor cost increases as the primary reason for the reduction in the quantities of prototypes to be developed. NASA will not receive its own expanded system but rather will use FAA's basic wide system. (See p. 16.) Two other line items have also been deleted--the experimental test bed and the basic wide systems for the service test and evaluation program. The experimental test bed was to provide an economical means of evaluating several system tradeoffs. The service test and evaluation program, originally estimated to cost $2.4 million, may be funded separately as part of the facilities and equipment program and is now estimated to cost about $8 million to $14 million.

In addition, FAA also planned to develop a 360-degree azimuth antenna capability at an estimated cost of $1 million. ICAO had indicated this capability would be a desirable feature and the U.S. system originally possessed this growth capability which has potential civil and military applications. At ICAO's suggestion this requirement will be studied in cooperation with the Federal Republic of Germany and subsequent action will depend on the results of this study.

Additional research and development efforts

The national plan envisioned a joint partnership between the Department of Transportation, DOD, and NASA in developing MLS. While Transportation, through FAA, was charged with overall program responsibility, DOD and NASA were to conduct supporting tests and investigations.

DOD estimates development of tactical derivatives of MLS will cost $65 million to $75 million. Of this, approximately $27.1 million is in support of the FAA effort and the remainder is for R&D work peculiar to the military, including a shipboard system, a lightweight transportable system that can be used at unimproved landing sites under worldwide climatic conditions, and required military avionics.

Discussions are currently underway among DOD, FAA, and representatives of the Congress to transfer the management and the funding for the military MLS derivatives to DOD. DOD officials stated that agreement in principle has been reached at high levels within DOD and FAA but the Congress has not fully accepted the proposal. DOD is concerned that FAA would not be able to develop both the joint tactical and the shipboard systems because of budgetary constraints. If the Congress accepts the proposal, DOD would have control over future military development efforts; therefore, the services will be responsible for ensuring that the system satisfies its individual requirements while maintaining interoperability with the other military and civilian MLS systems.

Under the proposed approach, the joint tactical MLS engineering development is estimated to be completed in 1983 with deliveries beginning in 1985.

In February 1978, DOD outlined the major milestones for the joint tactical MLS development effort as shown below.

Major milestones	Estimated dates	
	Start	Complete
Advanced development	6-78	7-80
Engineering development	10-80	7-83
Initial production	10-83	8-85
Production delivery	2-85	-
Initial operating capability	4-86	-

UNIT COST ESTIMATES

Unit cost estimates are a particularly sensitive and important issue as far as the MLS program is concerned. Users want to minimize airborne avionics costs and FAA wishes to minimize its ground system costs.

FAA first developed unit costs for various MLS configurations during the phase II technique assessment process. At that time, the emphasis was on total cost differences between the time reference scanning beam and Doppler techniques. Scanning beam system costs were based on the national plan's system configurations--the reduced capability (category I) system and the full capability (category III) system. The ground equipment for these systems were estimated at $67,000 and $511,000, respectively, excluding installation costs because such costs are about the same for either system.

FAA later updated the estimates to correspond to the new configurations. The analysis shown below was completed in November 1975 and became the basis for the ground system estimated costs used in a report on potential MLS implementation strategies issued by a special committee of the Radio Technical Commission for Aeronautics.

Ground system	Capability	Estimated acquisition costs as of Nov. 1975	
		Installed	Hardware only
		(000 omitted)	
Small community	Straight in	$ 214	$ 69
Category I	Curved path	310	131
Category III	Curved path full capability	1,060	520

The estimates, which are over 2 years old, have not been updated.

An informal working group established by the special committee examined expected airborne costs. This group, comprised of experts who conducted intensive investigation into this area, provided estimates which varied depending on the aircraft involved and the capability desired. Following are the group's 1975 airborne cost estimates for three distinct user groups. FAA considers these estimates unrealistically high.

User	Capability: Straight in	Capability: Curved path
Air carrier	$25,850	$33,800
General aviation (multiengine)	3,700	11,500
General aviation (single engine)	1,950	6,250

As with the ground system cost estimates, FAA has not updated these costs.

DESIGN IMPROVEMENTS

Since November 1975, FAA has continually refined its design, and these refinements have generally resulted in lower projected costs. For example, the ground system costs presented above do not include an antenna design refinement developed by Hazeltine Company. The redesigned antenna, referred to as the cost minimized phased array circuit technique, is estimated to save approximately $5,000 and $18,700 in the category I and category III systems, respectively. Other antenna design refinements to the category I system are estimated to save about $6,000 per unit, and the MLS transmitter has also been refined with an estimated savings of approximately $8,000 for the category I system and $52,200 for the full capability system. Other design refinements in categories I and III amounted to estimated savings of $4,000 and $10,900, respectively. The anticipated cost savings associated with the design improvements are shown below.

Improvement	Cost savings as of 3/1/78: Category III	Cost savings as of 3/1/78: Category I
Cost minimized phased array circuit technique	$18,700	$ 5,000
Other antenna modifications		6,000
Transmitter	52,200	8,000
Other design improvements	10,900	4,000
Total savings	$81,800	$23,000

While FAA has not limited its refinements to the ground systems, the design changes to the airborne avionics have not resulted in FAA projecting any anticipated cost reduction. Consequently, the airborne cost estimates remain substantially unchanged.

SCHEDULE

The 1971 national plan for development of MLS established a 5-year period to complete the three-phased program, with limited production to be started in June 1976. Current estimates indicate limited production will not begin before 1981, a delay of about 5 years. Part of this delay was deliberate, awaiting ICAO's selection of a signal format before completing the development program.

The MLS procurement plan is a three-phase program: technique analysis and contract definition (phase I), feasibility demonstration (phase II), and prototype hardware development/flight test and system evaluation (phase III). Phase I involved six contractors furnishing technique analysis and contract definition proposals with two competing techniques (scanning beam and Doppler scan) having the potential to meet operational requirements. Phase I was completed with a 2-month delay.

Phase II efforts consisted of feasibility demonstrations, development of prototypes, and test and evaluation of feasibility system hardware. Four of the six phase I contractors were selected to conduct phase II development efforts, with two of the contractors pursuing the Doppler technique and two the scanning beam technique. Completion of phase II was delayed by about 10 months because evaluation and selection of the scanning beam over the Doppler technique took longer than was anticipated. Following a 4-month assessment effort by a team of experts--including representatives from the U.S. Government, foreign governments, and industry--and after review by an executive committee comprised of Transportation, DOD, FAA, and NASA personnel, the scanning beam technique was selected for further development.

The prototype phase of the development effort (phase III) was initiated in 1975 when contracts for two scanning beam systems from each of two contractors (Bendix and Texas Instruments) were awarded. Each contract provided for delivery of one basic and one small community ground system and counterpart avionics. Phase III has experienced significant delays. None of the major phase III required tasks have been fully completed because of intervening delays in the ICAO selection process and a decision by the Deputy Secretary of Transportation in April 1976 to withhold authorization to proceed with all remaining phase III activities pending ICAO's selection of an international MLS standard.

Phase III activities were originally scheduled for completion by June 1976. In June 1978, FAA updated the national plan and estimated that the program will extend through July 1981, excluding DOD-managed portions of the program. Estimated completion of the military MLS derivations are yet to be determined.

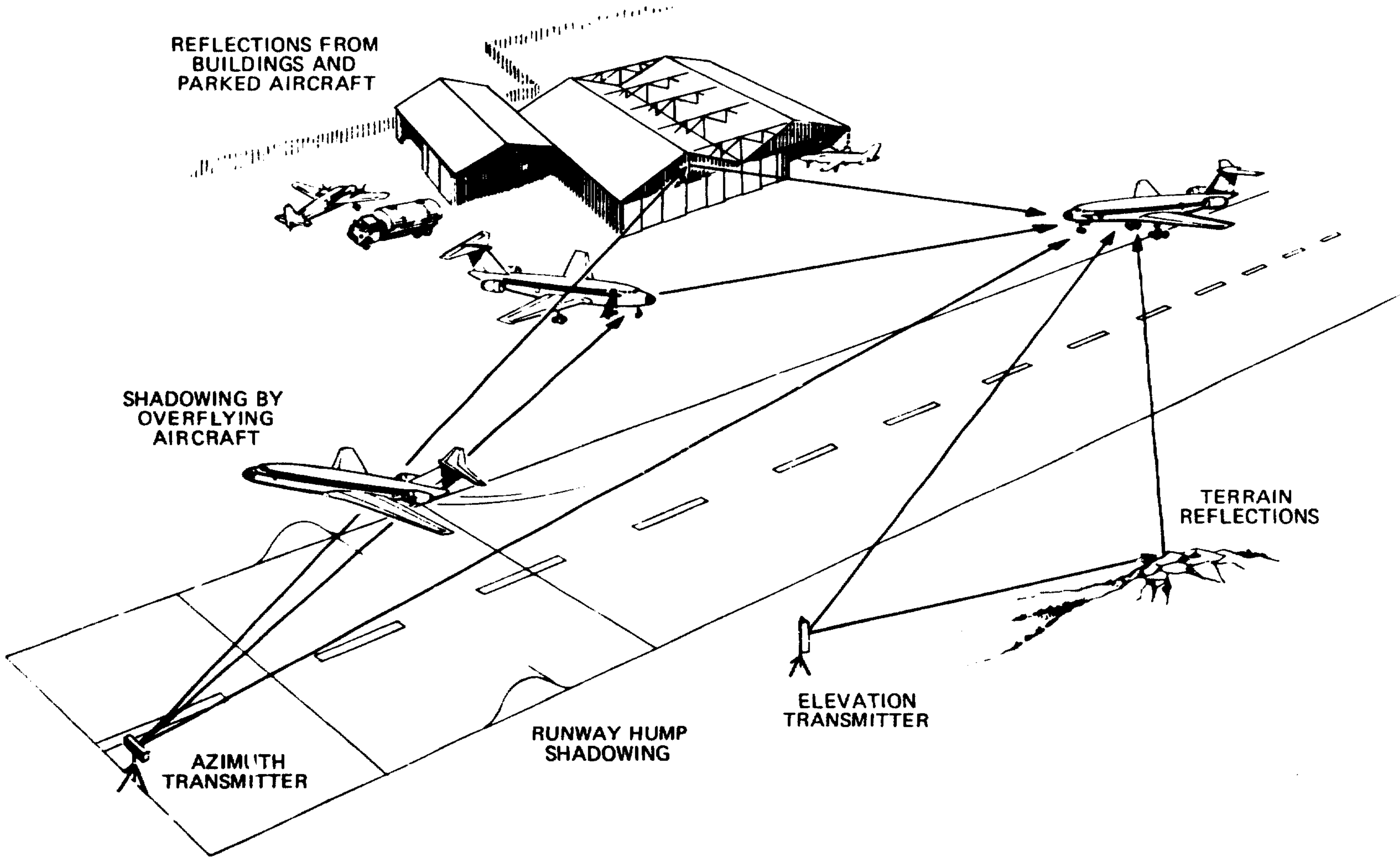
PERFORMANCE

The 1971 national plan called for a system which would be internationally acceptable as a replacement for the ICAO standard ILS. In April 1978, the ICAO All Weather Operations divisional meeting adopted the scanning beam system signal format as the international standard for MLS.

ICAO decided that computer simulations would be the best method for comparative assessment of the competing systems. Selection of the scanning beam signal format was based on evaluations of the various candidate system proposals, supported by static and flight tests; simulations of candidate systems by Lincoln Laboratory, Massachusetts Institute of Technology; and demonstration flights by the United Kingdom and the United States at selected airports throughout the world. FAA considered several of these demonstration sites to be stressful tests of MLS. Lincoln Laboratory's involvement in these simulations was limited to the effects of multipath phenomena (signal reflection) on each of the systems. (See fig. 4, P. 24.)

Although the U.S./Australian scanning beam signal format was selected for the international standard, a fully integrated MLS basic wide expanded (category III) configuration which includes both ground and airborne systems for touchdown and back course guidance has neither been procured nor fully demonstrated. The demonstrated performance to date of the small community and basic narrow time reference scanning beam configuration supports a limited procurement of integrated prototype systems to demonstrate total system performance in more demanding civil airport and tactical military environments, including an indication of the benefits to be expected from system implementation. We believe the lack of an approved transition plan and uncertainties regarding the benefits to be obtained preclude a large-scale FAA implementation decision at this time.

At the time FAA was preparing for the April 1978 ICAO meeting, Lincoln Laboratory was preparing a paper on computer model validation, comparing simulation tests with



MLS MULTIPATH PHENOMENA

FIGURE 4

field tests and identifying locations where all competing systems would be subject to stressful conditions.

CONCLUSION

The total R&D civil and military effort for the MLS program is much more costly than had been expected. In the civil portion, this has resulted in fewer prototypes and, in one case (the expanded system), a less capable prototype being procured. It is unlikely that FAA will be able to complete its R&D effort for $112.6 million, as stipulated in the fiscal year 1976 program. In addition, in light of design changes made since unit cost estimates were developed, we believe the unit cost estimates are outdated. To demonstrate that MLS can effectively and economically replace ILS, we also believe further testing of MLS at stressful locations would be advisable.

RECOMMENDATION

We recommend that the Secretary of Transportation advise the Administrator of FAA to revalidate the program and unit cost estimates for MLS. In addition, during the service test and evaluation program, we recommend that FAA and the military services further test the system at stressful locations to validate whether MLS can effectively and economically replace ILS and meet all precision landing guidance requirements.

AGENCY COMMENTS

The Departments of Defense and Transportation and the National Aeronautics and Space Administration agreed with our conclusions and recommendations when commenting on a draft of this report. (See apps. V and VI for written agency comments; DOD's comments were obtained orally.)

CHAPTER 4

DEFENSE MLS PROGRAM STATUS

As initially envisioned, FAA was to have overall management responsibility for all MLS prototype development. Rising development costs along with budgetary constraints have since forced FAA to reconsider its military prototype development effort. FAA plans to transfer contracting and management responsibility for future military development to DOD if the Congress will give its endorsement. Future funding for the military MLS should take into consideration that the military's need for MLS is not immediate and that interoperability with civil systems is essential.

MILITARY NEED IS NOT IMMEDIATE

The national plan established requirements for a common civil/military system and compatible tactical systems. The plan cited the need for frequency compatibility, the expected use of airports by both civil and military aircraft, and the desirability of standardization for requiring a common civil/military system. In the past, incompatibility between military and civil systems has resulted in costly and time-consuming conflicts between the two sectors. For example, the military's tactical air navigation system and the civil distance measuring equipment were developed independently and, although they used the same frequency band, other system characteristics were incompatible. The plan also acknowledged that joint civil/military use of airports is becoming increasingly necessary. The high cost of new airports and environmental issues such as noise and pollution have increased the pressure to utilize existing facilities more effectively, particularly in urban areas where the need for additional aircraft capacity is the greatest. Initial development efforts for future military landing systems considered only individual service needs, but it has become increasingly clear that a common civil and military design would be desirable to eliminate concurrent development efforts and assure equipment compatibility.

Except for unique hardware to meet military specifications, FAA was responsible for prototype development of civil and military MLS configurations. FAA prototype development is roughly equivalent to DOD's advanced development phase and is designed to produce hardware for military feasibility testing. FAA performed a study to define critical R&D efforts needed to complete engineering development of the military systems, taking into consideration each service's MLS operational requirements. The study stressed the desire to have a common military system which would be compatible with both the national and ICAO standards.

Individually the services cited the need to operate aircraft from unimproved tactical landing areas in worldwide climatic and weather conditions. The common tactical system must provide positive guidance in operational environments which could include sites with uneven surfaces, structural obstructions (trees or buildings), snow, dust, or blowing debris. The Navy requires a shipboard system that meets or exceeds the capabilities of its current all-weather carrier landing system (AN/SPN-42). The shipboard MLS system must be capable of automatically controlling aircraft to touchdown and compensating for deck motion and siting offsets.

At the present time each service has landing guidance systems for all of its operational or soon to be operational aircraft. None of the military representatives cited an immediate need for the military version of the MLS. The Air Force is currently updating its vacuum tube ILS ground systems to solid state circuitry. This, along with the ground controlled approach system for its combat roles, should serve the Air Force's needs through the year 2000. The Marine Corps' remote area approach and landing system is expected to satisfy its needs through the early 1990s. The Marine Corps believes, however, that development should be initiated for multimode avionics to achieve long term standardization and interoperability. In May 1976, the Army acknowledged a serious void in its air traffic management system because its current precision approach and landing systems, precision approach radar and ILS, were facing obsolescence. Since that time, the Army stated that although a need for improved tactical precision approach capability exists, it prefers to wait for a system with civil/military interoperability rather than field a system lacking this feature. The Navy is currently upgrading its SPN-42 system to satisfy its needs through the 1990s.

STANDARDIZATION OFFERS THE GREATEST POTENTIAL FOR THE SERVICES

According to the Radio Technical Commission for Aeronautics, the principal advantage of MLS for the military is its potential for standardization among all users, both civil and military. Specifically the military would receive the following benefits

--complete interoperability (military/military and civil/military);

--tactical systems fully compatible with fixed based systems;

--significant reductions in annual operating, maintenance, and support costs; and

--increased mission effectiveness, such as deployability, maintainability, availability and increased operational capability during low visibility.

In order to realize these benefits:

--The majority of each category of aircraft would have to be equipped with MLS.

--A sufficient number of bases and joint use airfields must be equipped with MLS.

--The transition from ILS/precision approach radar to MLS must be of a reasonable duration permitting an orderly but expeditious transition program as well as accommodating acceptable budgeting and training schedules.

--The MLS life expectancy must be at least 20 years.

--Except where unique military operations dictate, MLS hardware would be acquired using off-the-shelf hardware.

SUBSTANTIAL DEVELOPMENT EFFORT STILL REQUIRED

Based on the design definition study for the military's tactical and shipboard MLS, available FAA development funds are inadequate to complete the entire (advanced development plus engineering development) military development effort. In December 1977, DOD formally changed the joint tactical MLS program to an advanced development effort while continuing negotiations with FAA and the Congress to transfer its management and contracting responsibility to DOD.

DOD estimates of the entire MLS development effort include funds spent in support of the FAA development effort and the funding required to complete its own engineering development effort. DOD officials said an austere effort could probably be conducted for approximately $65 million while a more desirable program would cost approximately $75 million.

CONCLUSION

No urgent need exists for the military MLS systems; therefore, to plan for both production deliveries in 1985 and an initial operating capability in 1986 appears to be unnecessary. An orderly military development program may be justified to (1) assure that the desired compatibility and interoperability is achieved and (2) properly research and develop systems which will meet military requirements. Placing MLS in operation in 1986 would result in either underutilization of MLS until the services can afford to purchase the required avionics or retiring existing systems before their full useful life has been reached. Either action appears unwarranted.

MATTERS FOR CONSIDERATION BY THE CONGRESS

The Congress should obtain answers to the following questions before providing additional funds for Defense MLS research, development, and production:

--Why is it necessary to rapidly develop a joint tactical system for the military at this time? We have been told that current landing systems are adequate until the 1990s and in some cases until the year 2000.

--If DOD takes over the development of the military systems, does FAA intend to reduce its expenditures by $14.5 million--that portion of FAA's cost estimate designated for development of the military systems?

--Will there be a loss of technical expertise and continuity if DOD assumes responsibility for the military systems?

--Are there any critical military requirements (such as shipboard signal format) which would have an impact on compatibility and interoperability with civil systems that FAA should consider during development?

MICROWAVE LANDING SYSTEM DESCRIPTION

The MLS system consists of azimuth, elevation, and ranging (distance from airport) elements which provide continuous three dimensional position information within a wide coverage area nominally 40 degrees (either side of runway center line) in azimuth and 0 to 20 degrees in elevation. Operation is in the microwave band at approximately 5 gigahertz 1/ with 200 channels available for discrete frequency assignment. The system utilizes narrow scanning beams which sweep through the coverage sector in a "to-fro" mode, and angle measurements are translated from the time interval between the "to" and "fro" scans. This enables an airborne receiver/processor to derive precise azimuth and elevation angle information. A separate distance-measuring system provides continuous distance-to-touchdown information. The information is suitable for display to the pilot and for use by an automatic flight control system. MLS is expected to be an improvement over ILS because of the following attributes:

--Signal quality. The narrow beam widths, typically 1 degree, are expected to provide accuracy levels and stability substantially better than ILS.

--Siting insensitivity. In MLS the signal in space is essentially formed in the antenna aperture and is independent of nearby terrain. In addition, the narrow beam width will make the signal essentially independent of buildings and obstructions close to the signal path. Thus, MLS is expected to have fewer siting problems than ILS and will provide good quality signals at difficult airport sites.

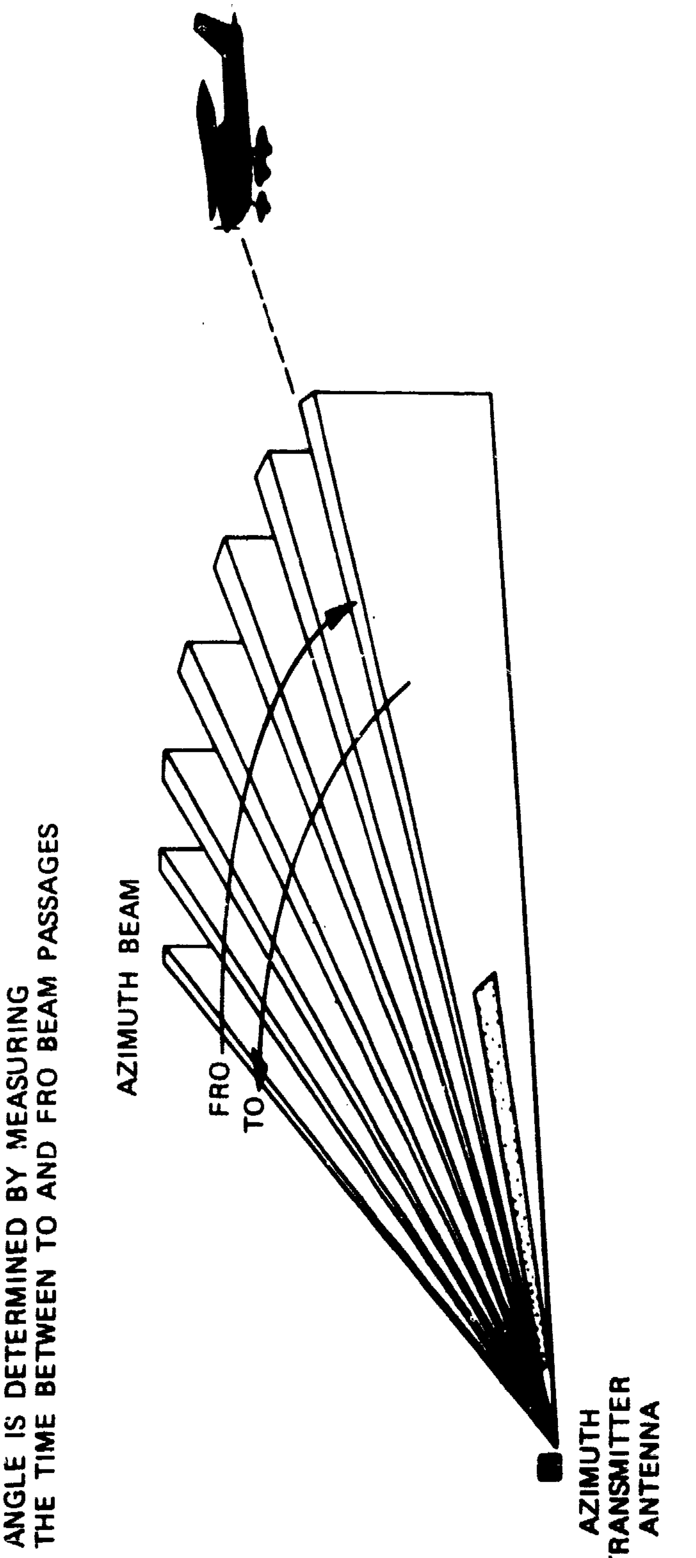
--Channelization. Use of C-band frequencies for MLS provides 200 channels compared with the present 20 (and the potential 40) available with ILS. The 200 channels available for MLS were deemed adequate to meet all foreseeable needs without compromise and will completely remove a constraint that now imposes limits in some sections of the country, such as New York, Los Angeles, and Chicago.

1/ Unit of frequency equal to 1 billion cycles per second.

--Coverage. The use of microwave signals combined with modern antenna designs make possible a wide area of coverage. Typically, MLS guidance is expected to cover 40 degrees either side of the runway center line and 1 to 15 degrees in elevation, versus ILS guidance of about 3 degrees either side of runway center line and approximately a 3-degree glide path angle.

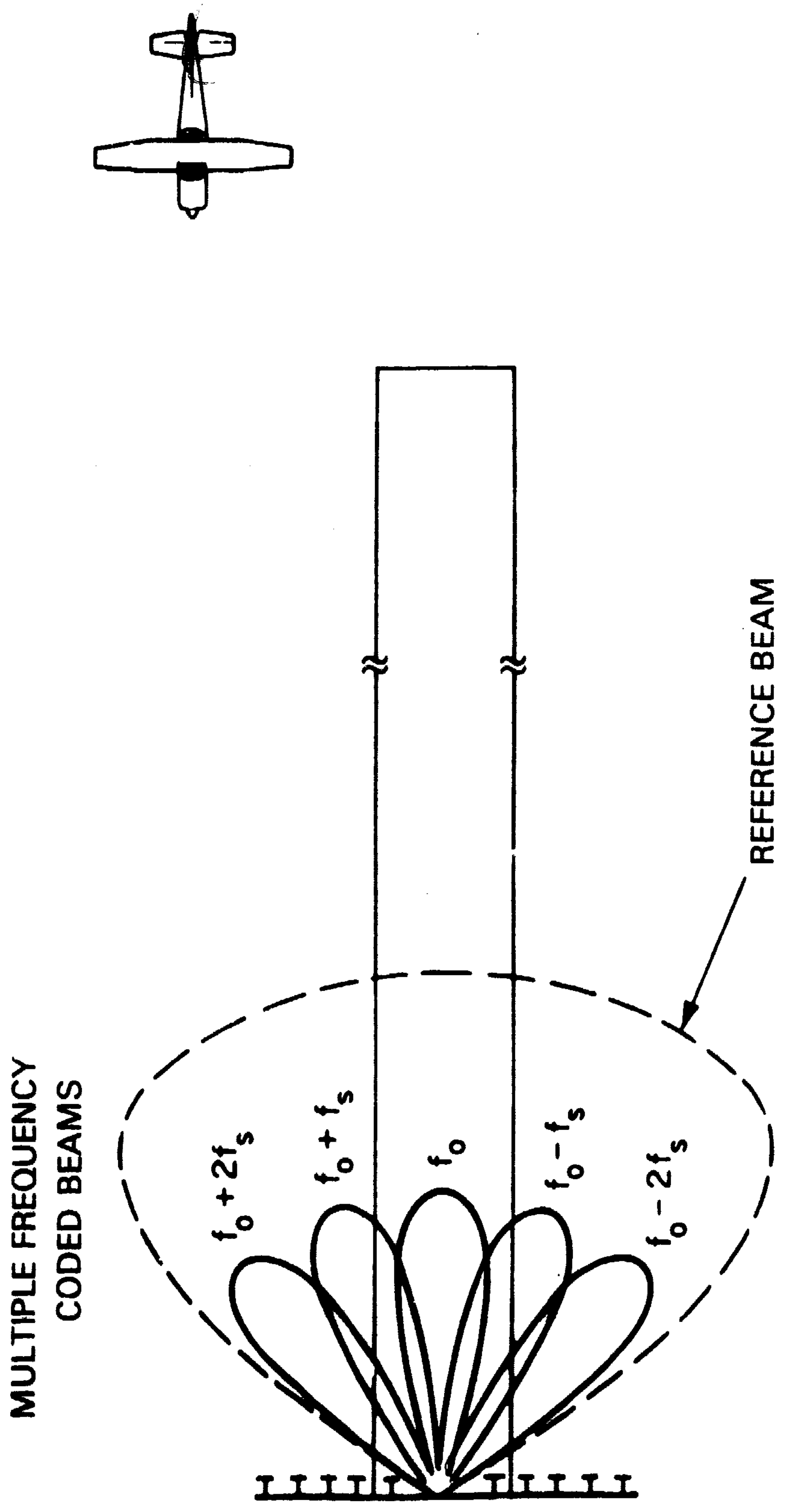
--Flexibility in final approach paths. This allows interception of the final approach path anywhere along the runway center line and furnishes a range of approach angles from 1 to 20 degrees.

--Military requirements. The smaller antennas and shorter wave lengths are expected to enable MLS to meet military requirements for a portable precision approach tactical system.



SCANNING BEAM CONCEPT

APPENDIX III



ANGLE IS DETERMINED BY MEASURING NARROW BEAM SIGNAL FREQUENCY RELATIVE TO REFERENCE SIGNAL FREQUENCY

DOPPLER SCAN CONCEPT

MICROWAVE LANDING SYSTEM CONFIGURATIONS

Small community:

--An austere system for the lowest cost avionics and ground system applications. The system provides for multiple glide paths within a range of 2 to 9 degrees elevation usable to 150 feet elevation with precision information within 10 degrees either side of the runway center line.

Basic:

--The predominant MLS system for civil use. Two versions of the basic system are available: (1) narrow aperture and (2) wide aperture. The basic narrow performs to category II (see chart below) accuracies and the basic wide will enable auto-land under visual flight rules conditions using a radar altimeter.

Expanded:

--Requires a higher level of system monitoring and redundancy for category III operation (see chart below) and incorporates a flare glide path transmitter, back azimuth, and primary glide path angles up to 15 degrees.

Joint tactical:

--A system fulfilling the requirements of the Army, Marine Corps, and Air Force. It is a transportable system which provides performance comparable to the basic narrow system.

Shipboard system:

--A configuration designed to compensate for ship motion and other special needs of aircraft carrier operations.

Air transportable:

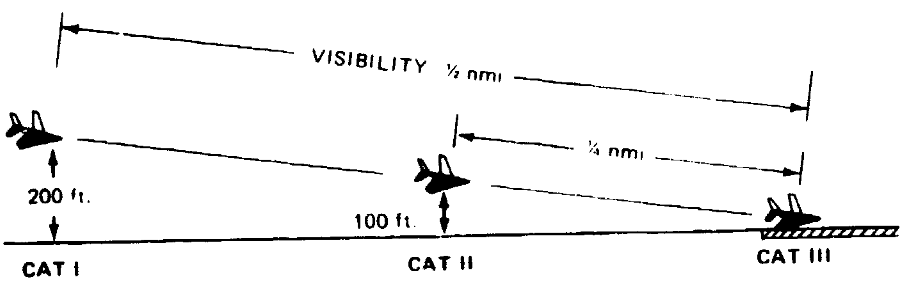
--A system to support U.S. Air Force forward operating bases and Marine Corps expeditionary airfields.

INTERNATIONAL VISIBILITY LANDING CATEGORIES*

CATEGORY	RUNWAY VISUAL RANGE, FEET	DECISION HEIGHT, FEET	MGA
I	2400	200	150
II	1200	100	50
IIIa	700	–	Touchdown
IIIb	150	–	Touchdown
IIIc	0	–	Touchdown

* The decision height is a height (above runway elevation) below which a pilot must not descendif adequate visual references have not been obtained. He must be assured he has adequate references to land by visual means or execute a missed approach procedure at this height. The minimum guidance altitude (MGA) is that height for which the landing system accuracy is specified.

ICAO Performance Categories (Runway Visual Range & Ceiling)



NASA

National Aeronautics and
Space Administration

Washington D C
20546

Sep 1 1978

L-1

Mr. Jerome H. Stolarow
Director
Procurement and Systems Acquisition
Division
U.S. General Accounting Office
Washington, DC 20548

Dear Mr. Stolarow:

Thank you for the opportunity to review GAO's proposed report to Congress entitled "Status Of The Federal Aviation Administration's Microwave Landing System", that was transmitted with your letter dated July 24, 1978.

The enclosed NASA comments and suggested revisions to the draft report are submitted to clarify and/or amplify NASA's programmatic activities in the MLS Program. We have not commented on those segments of the proposed report that are primarily the concern of the Federal Aviation Administration.

Sincerely,

Arnold W. Frutkin
Acting Associate Administrator
for External Relations

Enclosure

[See GAO note 1, p. 38.]

Comments and Suggested Revisions to GAO Draft Report to Congress entitled "Status of the Federal Aviation Administration's Microwave Landing System"

Prepared by Aeronautical Operating Systems Division, NASA Office of Aeronautics and Space Technology

Page IV, paragraph 2: There is now a published update of the "National Plan for Development of the Microwave Landing System," dated June 1978.

Page 22, line 19: Delete "for NASA use." As stated in the subsequent sentence, the expanded system will be a national asset which will be located at the NASA Wallops Flight Center and available for use by DOT, DOD, NASA, and other users of a full capability system.

Page 23, line 5: Delete "for NASA's use" for the reason stated above.

Page 23, line 7: Replace line 7 in its entirety with the following:

> "To assist FAA, NASA has provided $600,000 toward procurement of a Basic Wide system. This was done in response to an FAA request wherein it was pointed out that a Basic Wide system for use at the Wallops Flight Center in conjunction with the TCV program could materially benefit NASA's research programs while complementing the national MLS program by accelerating the availability of this prototype. The expanded system would provide the ultimate test bed to help meet the goals of the TCV program as well as providing the FAA with a needed facility for developing a full Category III autoland capability. Even with the assistance, it appears that..."

Page 23, second paragraph: Substitute the following paragraph for the existing paragraph:

> "NASA's participation in the program has been primarily in a support role which has included support of Phase II testing at Wallops Flight Center; analyses and conduct of comprehensive static and dynamic tests to validate prototype MLS for STOL applications; demonstrations at a number of sites with a typical jet transport aircraft to validate the technical maturity and suitability of the TRSB MLS for broad operational deployment; and development

of a feasibility model of a high technology yet low cost airborne MLS receiver. There are no plans for NASA to contribute additional funds to aid FAA in providing an expanded system. However, NASA does plan, in a cooperative effort with FAA, additional investigations to simplify and to bring to a more advanced state of readiness the airborne systems technology and flight control procedures which exploit the utilization of MLS capabilities for CTOL, STOL, and rotorcraft applications."

Page 26, table showing Quantities of Prototype Equipment To Be Delivered: NASA has custody of the Texas Instruments Basic (Narrow) system, installed at Crows Landing, CA, in early 1977, not an expanded system as shown.

[See GAO note 2, below.]

GAO notes: 1. Several comments refer to material not included in our final report. Other comments were incorporated where appropriate. Page references refer to our draft report and may not correspond to the pages of this final report.

2. Paragraph deleted. NASA told us that the statement was not relevant and should be ignored.

OFFICE OF THE SECRETARY OF TRANSPORTATION
WASHINGTON, D.C. 20590

OCT 6 1978

Mr. Henry Eschwege
Director
Community and Economic
Development Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Eschwege:

We have enclosed two copies of the Department of Transportation reply to the General Accounting Office draft report "Status of the Federal Aviation Administration's Microwave Landing System."

In general, we consider the report to be a thorough and comprehensive coverage of a complex program. We have few disagreements with the data included in the body of the report, but we feel that some of the views and recommendations in the cover summary and the report digest are not supported by this data. These are addressed in the enclosed statements.

Please let us know if we can assist you further.

Sincerely,

Brock Adams

Enclosure

[See GAO note, p. 44.]

DEPARTMENT OF TRANSPORTATION REPLY

TO

GAO DRAFT REPORT OF JULY 1978

ON

THE STATUS OF THE FEDERAL AVIATION ADMINISTRATION'S MICROWAVE LANDING SYSTEM

SUMMARY OF GAO FINDINGS AND RECOMMENDATIONS

The General Accounting Office (GAO) states that research and development (R&D) for the Microwave Landing System (MLS) will cost between $182 and $192 million, which is approximately double the amount originally estimated. Further, the program is about four years behind schedule.

The GAO believes that a significant level of uncertainty exists both within the Federal Aviation Administration (FAA) and among the aviation community concerning the achievability of MLS benefits. In this regard, the GAO states that the conversion to an MLS standard presents the prospect of significant costs being incurred by FAA and the aviation community with potential compensating benefits accruing slowly. They therefore conclude that a need exists for a well defined, carefully planned program to demonstrate MLS's operational and economic viability. Also, that successful completion and evaluation of the results of the demonstrations should be the basis for any decisions regarding replacement of the existing Instrument Landing System (ILS) with MLS. The GAO further states that significant amounts are still being invested in equipment for the ILS. They believe that continued use of ILS at U.S. airports should be permitted at least until 1995 in recognition of the continued investment in the current system and to coincide with the planned transition for international airports.

The GAO recommends that the Secretary of Transportation: (1) permit the continued use of ILS ground systems at U.S. airports for at least an additional 10 years to January 1, 1995, to coincide with the International Civil Aviation Organization's (ICAO) plans for international airports; (2) require the FAA to take into consideration the opinions of users in developing cost/benefit data and to explain how 600 additional airports which currently do not qualify for ILS will qualify for an MLS by the year 2000; and (3) require the FAA to clearly validate the technical, operational and economic benefits of MLS by conducting a comprehensive demonstration program with clearly defined evaluation criteria. The GAO further believes that FAA should advise the Congress of the status of the subsystems comprising the upgraded Air Traffic Control System of which MLS is an integral part. In addition, the GAO states that the Congress may wish to consider the necessity for funding and developing a joint tactical system at this time considering the military's needs are not immediate. According to the GAO, delaying the system's deployment pending the completion of future FAA development would provide technical expertise and continuity and would assure that improved technological advancements are taken into consideration.

DEPARTMENT OF TRANSPORTATION POSITION ON GAO RECOMMENDATIONS

In general, we consider the report to be a very thorough and comprehensive coverage of a very complex program. We have very few disagreements with the data included in the body of the report, but we feel that some of the views and recommendations contained in the Cover Summary and Digest are not supported by this data.

In the Cover Summary, we believe it is important to state that the MLS development program being managed by the FAA is a joint Department of Defense (DOD), Department of Transportation(DOT), and National Aeronautics and Space Administration (NASA) effort to define a common civil/military system capable of meeting the diverse needs of all users. In this context it would not only eventually replace the existing ILS but would satisfy the needs of general aviation for a simple, low-cost system and the needs of the military for man-transportable, air-transportable and shipboard versions as well. In this broad role MLS has no single competitor.

As is noted in the draft report, MLS is accepted by the user community as being needed--the question is when. We believe that it is absolutely necessary to take the views of all users into account regarding the date and method to be adopted for implementing MLS. However, we also believe that it should be a matter of national policy that implementation of this internationally accepted system be encouraged in a responsible manner and every opportunity be taken to bring about the acknowledged difficult transition to the new system in a mutually acceptable and cost-effective way. In this regard, we believe that the Congress should be advised to encourage the continued, orderly development of the Joint Tactical MLS (JTMLS) at this time. In accordance with the schedule set forth for this effort on page 40 of the draft, a production phase could begin in FY 1984 that could be important in stemming the further proliferation of interim systems. Such proliferation only postpones the achievement of the benefits offered by a single, universal approach and landing system. They should be permitted to move forward rather than be required to wait for some form of "spin-off" from civil development or experience from a demonstration program.

In the Digest on pages ii and iii three specific recommendations are made to the Secretary of Transportation. The following comments address these recommendations:

1. The April 1978 All Weather Operations Divisional Meeting recommended the extension of the ILS protection date until January 1, 1995. Until this recommendation is agreed to by at least half the contracting States, it will not be an official ICAO position. However, the U.S. delegation, headed by FAA's Mr. Quentin Taylor, the Deputy Administrator, supported this recommendation and we would expect, upon confirmation by a sufficient number of other States, to maintain ILS at U.S. international airports in accordance with this date. However, flexibility should exist at other U.S. airports with regard to the eventual replacement of old ILS's with MLS's prior to 1995 should this become part of a mutually acceptable implementation plan for domestic airports.

2. As noted above, we agree that FAA should take the views of the user community into consideration in developing cost/benefit data and transition plans and this will be done. The 600 potential additional precision landing systems discussed are based on data generated in the early 1970's. As part of the normal implementation process, we will be studying cost factors and economic criteria in addition to updating forecasts of aviation growth that may change this initial estimate.

3. We also agree that the FAA should demonstrate the technical, operational, and economic benefits of MLS. This will be accomplished through a comprehensive Service Test and Evaluation Program (STEP) currently being planned in FAA. To the best of our knowledge the Congress has been kept fully apprised of the status of all elements of our research, development and engineering programs, and in particular those concerned with major upgrading of the system. This information is transmitted in semiannual hearings with the House Authorization Subcommittee, annual hearings with both the House and Senate Appropriations Committees, and through special briefings to the various Congressmen and their staffs.

On page iv, we recommend that the phrase, "approximately double the amount originally estimated" be deleted. There is no disagreement with estimating \$182 to \$192M as total R&D costs for the system, but this is not the same program estimated to cost \$91M in the 1971 National Plan. The \$182 to \$192M estimate includes <u>\$65 to \$75M for DOD</u>, and as the report states on page 27 in reference to DOD R&D costs, "approximately \$27.1M is in support of FAA effort and the remainder (of the $65 to $75M) is for R&D work peculiar to the military." In other words, FAA is planning to fund for the Advanced Development phase for the military systems as indicated in the National Plan; the $65 to $75 for DOD takes the program through another development phase, Engineering Development, wherein conformance to full military specifications is required and tested.

The second paragraph on page iv discusses program delays. We believe it should be stated that most of this delay was deliberate rather than leave the impression it was slippage. In order to assure that appropriate decisions were made before proceeding to succeeding major phases of the program, the Government evaluations between phases were made much more comprehensive and thorough than originally planned, and most significantly, all further prototype development activity after that initiated in July 1975 was held up until April 1978 pending the outcome of the ICAO decision.

With regard to GAO's comments on the demonstrated performance of the Time Reference Scanning Beam contained in the third paragraph on page iv, we believe that the existing data base is sufficient to support production of systems to meet immediate needs. ICAO predicated its decision on a comparison of system performance, and the accumulated experience to date would indeed support MLS implementation. However, we agree that the procurement of systems to demonstrate the advantages of MLS, to obtain operational experience, and to develop certification criteria and maintenance philosophies is an important task that must be undertaken.

In the last paragraph on page iv, it is stated that "rising development costs" forced FAA to transfer funding and management responsibility for military prototype development to DOD. Rising development costs were not a factor in this decision and FAA is not proposing to transfer "funding" responsibility--only "contracting" responsibility, with FAA providing the funds. The overriding reason for this decision was that it was felt that the military services are much better equipped to carry out the unique coordination and contracting aspects required for military systems development.

On page v of the Digest, the GAO raises certain questions which it believes the Congress should obtain answers to before providing funds for military MLS research, development, and production. The following comments address these questions.

- Our views supporting the DOD plan for JTMLS development are expressed above.

- As indicated in the updated National Plan for Development of the MLS, dated June 1978, the $14.5M of FAA funds designated for military system development is contained in the $112.6M total FAA program figure.

- We do not believe there will be a loss of technical expertise or continuity if DOD assumes responsibility for the JTMLS. Rather, we are convinced that they are uniquely qualified to manage this effort while maintaining system compatibility through interaction with FAA in its overall system architecture role.

With reference to the information and comments contained in Chapter 2, Problems With MLS Implementation, it is our opinion that the economic analysis of the original FAA cost/benefit study provides a comprehensive analysis of the opportunities afforded by an investment in MLS; although it is not, and can never be, the sole basis for making an investment decision. For this reason, we are planning to pursue a STEP to further quantify operational benefits. It must also be recognized that there are many non-quantifiable benefits such as improved noise abatement procedures, civil/military interoperability, guidance service for vertical/short take-off and landing aircraft and helicopters, etc.

GAO note: Several comments refer to material not included in our final report. Other comments were incorporated where appropriate. Page references refer to our draft report and may not correspond to the pages of this final report.

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