1978 FAA R. & D. AUTHORIZATION

HEARINGS

BEFORE THE

SUBCOMMITTEE ON AVIATION AND TRANSPORTATION R. & D.

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

NINETY-FOURTH CONGRESS

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CONTENTS

WITNESSES

1978 FAA R. & D. AUTHORIZATION

TUESDAY, SEPTEMBER 21, 1976

U.S. House of Representatives,
Committee on Science and Technology,
Subcommittee on Aviation and Transportation R. & D.,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10 a.m., in room 2325, Rayburn House Office Building, Hon. Dale Milford, chairman, presiding.

Mr. Milford. The subcommittee will come to order.

This morning the Subcommittee on Aviation and Transportation R. & D. will begin its annual review of FAA research and development programs.

Our first witness this morning will be Mr. Jefferson W. Cochran, the Acting Deputy Administrator of the FAA.

Before proceeding with Mr. Cochran, I would like to make a very important point.

This subcommittee is very concerned with the trend of aeronautical R. & D. spending. There are less and less dollars available for important aeronautical R. & D. programs while at the same time there is increasing demand for R. & D. solutions to aviation problems. Some times these funds are actually insufficient and important programs are eliminated or cut back.

This subcommittee, which is virtually the only congressional body examining all federally supported civil aviation R. & D. programs, is determined that the dollars for these programs be spent in the most effective manner, and that worthy programs are not eliminated or cut back.

Our examinations of these programs over the past few years have revealed that this has not always been the case.

While we support most of the efforts of the FAA and NASA in aeronautical R. & D., we have found some important areas that demand much closer scrutiny.

For this reason, we have advocated an annual authorization for the FAA. This would be in keeping with the jurisdiction the subcommittee currently exercises over NASA and has proven so successful in the past.

It would mean that all federally supported aeronautical R. & D. programs would finally be examined and authorized by one committee of the House. We believe that this would greatly lead to continuity, efficiency and direction in the expenditure of funds for such R. & D.

The House has agreed with the subcommittee on this point. Currently, we are seeking Senate cooperation in order that this annual authorization may become a reality. If such cooperation is not forthcoming in the immediate future, it is my plan to submit an annual resolution to the Appropriations Committee which would contain recommendations on each line item in the FAA's budget submission.

I, myself, will testify before the Appropriation Committee in order to urge the adoption of this subcommittee's resolution recommendation. Therefore, I feel that these hearings are very important in that they, along with the annual NASA authorization, form the basis for the direction of aeronautical R. & D. funding in this country.

The Chair will now recognize Mr. Jefferson W. Cochran, whom we all know as Jeff, Acting Deputy Administrator of the Federal Aviation Administration.

Jeff, we have your statement which will be accepted in full for the record. You may proceed as you so desire.

STATEMENT OF JEFFERSON W. COCHRAN, ACTING DEPUTY ADMINISTRATOR, FEDERAL AVIATION ADMINISTRATION; ACCOMPANIED BY ALBERT P. ALBRECHT, DEPUTY ASSOCIATE ADMINISTRATOR FOR ENGINEERING AND DEVELOPMENT; NEAL A. BLAKE, DEPUTY DIRECTOR, OFFICE OF SYSTEMS ENGINEERING MANAGEMENT; ROBERT W. WEDAN, DEPUTY DIRECTOR, SYSTEMS RESEARCH AND DEVELOPMENT SERVICE; AND DAVID J. SHEFTEL, DIRECTOR, SYSTEMS RESEARCH AND DEVELOPMENT SERVICE

Mr. Cochran. Thank you, Mr. Milford, and we appreciate the opportunity of appearing here before you today.

We join you in believing that coming here and letting this committee look at our engineering research and development projects is an important part of our work, and it helps us in preparing a good aeronautical R. & D. program so that the FAA can carry out its mission in a way that will be acceptable to this country.

Today, I have with me some key members of our engineering and development organization—Mr. Albert Albrecht, the Deputy Associate Administrator for Engineering and Development; Mr. David Sheftel, the Director of our Systems Research and Development Service; Mr. Neal Blake, who is the Deputy Director of the Office of Systems Engineering Management; and Mr. Bob Wedan, who is the Deputy Director of the Systems Research and Development Service.

We are prepared to brief you on what we are doing in our program. We trust that the way we have structured our briefing will answer many of the questions that you have, and then at the end of our briefing we will be prepared to answer questions in detail or follow up questions that you might choose to ask.

I would like to also state that Dr. McLucas wanted me to express to you his regrets in not being able to be personally available here today. I think you and I both understand his great interest in this particular aspect of our work. He had a longstanding, out of the city commitment, and felt he had to fulfill that commitment. As you probably know he has been involved in aeronautical research for much of his career and now, as the FAA Administrator, he has brought a heightened interest to our program and is attempting to assure that these programs meet the aviation requirements of the future.

Since we last appeared before you, we are aware that the air traffic control system has been in a growth process and that air traffic has grown. During the first 6 months of the year the total air operations at the top 13 major airports have increased 4 percent compared to the same 6-month period last year. We have also experienced an increase in the number of delays at these airports.

Of course, as we mentioned to you in our testimony in February, at this rate of growth over the next two decades the traffic will certainly double if not more and with similar delays if we do not vigorously attack the problem through proper research, engineering, and development.

Mindful of these realities we have initiated a responsive research engineering and development program. Its objectives are to insure that adequate capacity is available at a reasonable cost, that needed levels of safety are maintained in both the aircraft and the air traffic control operation, and that we pay proper attention to resource conservation and environmental protection problems. This program will identify the research, engineering, and development efforts we believe necessary to achieve a national air space system that will meet the needs of the American traveling public for the next 25 years.

In looking to these challenges of the future we can see that today's system is becoming saturated. As I testified to you before in our last hearing, 10 major airports have delays that are considered substantial. More importantly, of the 10, 4 have prescribed quotas to enable them to cope with heavy traffic. Yet I think it is pretty obvious that there are not going to be a great number of new airports. Only one that we know that is in the future, is quite a ways in the future. We are pleased of course with Secretary Coleman's decision on the St. Louis airport, but even that airport will not be in operation until 1992. Consequently, our present upgraded third generation R. & D. program is aimed at relieving the majority of the forecasted hub airport congestion during the next two decades by significantly increasing their capacity.

In addition, the public's and the FAA's increased awareness of the total environmental impact of aircraft and airport operations has prompted some changes in our future program.

An integral part of our environmental responsibilities is a concern for conserving natural resources. Obviously, traffic delays account for most of the fuel wasted on the ground and in the air. Implementation of our current automation and navigation research, engineering, and development programs could significantly reduce rising fuel consumption cost by minimizing these delays. With the steady increase in traffic growth and the increases in fuel prices, the issue of fuel conservation will become even more critical by the turn of the century. Our advanced systems development and technology staff is currently exploring ways to optimize fuel usage in the next generation air traffic control system. Such concepts as advanced automation and airborne performance computers to permit more fuel conservative flight profiles are being studied. These and other fuel saving measures in all facets of aviation are being actively pursued now in order to insure a viable future air transportation system. Our R. & D. programs are aimed at eliminating delays and insuring unrestricted access to the system for all users.

We think that we must begin today to plan beyond the Upgraded Third Generation Air Traffic Control System. Studies of the system in the post 1995 period need to be initiated. Despite the increased utilization of automation in the Upgraded Third Generation Air Traffic Control System, the need for a less labor-intensive system is becoming increasingly apparent. Through greatly advanced automation, we foresee the controller being able to manage, rather than control, more aircraft more efficiently in the future air traffic control system. At the same time, airborne automation technology will provide the pilot with more information about his operating environment.

Even with a significant increase in ground and airborne automation, safety in the national airspace system will not be compromised. Safety is and will remain our foremost concern. Indeed, the advent of wide-bodied jets, carrying more passengers at greater speeds, has made it even more essential to further reduce risks. Accordingly, our research and engineering and development efforts are, and will continue to be, focused on attaining the highest degree of safety practicable. Redundancy in the ground and airborne collision avoidance systems is but one example of these research, engineering and development efforts.

I would like to reemphasize, as you have mentioned earlier, the urgency of vigorously pursuing the FAA's R. & D. program. The major features of the Upgraded Third Generation Air Traffic Control System are designed to meet the needs of the 1980–1995 era. Many of these programs, such as the Microwave Landing System, are currently peaking and entering the high cost prototype development phase. In fact, the advanced state of the newly developed Microwave Landing System was recently demonstrated to the International Civil Aviation Organization. Employing only the MLS guidance data, a NASA Boeing 737 aircraft made several full automatic hands-off landings.

Mr. Chairman, I want to express to you personally our appreciation for your going along and witnessing these demonstrations. They represent the results of 15 years of intensive research and development in all facets of microwave guidance technology. The point to be made here is the introduction of new technology into the air traffic control system requires some 15 to 20 years from concept formulation to field implementation. In view of these significant leadtimes we believe that it is imperative to actively begin investigating the concepts that will be the basis for the 1995 air traffic control system.

Mr. Neal Blake will shortly be talking to you about our advanced development and engineering program.

Again, we will say we appreciate having the opportunity to appear here today. Now I am going to introduce Mr. Al Albrecht to you and let him discuss some management structure and some new initiatives that we have taken to improve our internal operation and our coordination with other elements of the Government with respect to R. & D.

So, Al, go ahead.

STATEMENT OF A. P. ALBRECHT, DEPUTY ASSOCIATE ADMINISTRATOR FOR ENGINEERING AND DEVELOPMENT

Mr. ALBRECHT. Mr. Chairman, and members of the committee. It is with great pleasure that I appear before you this morning for the first time as a part of FAA's engineering and development management team. As Jeff Cochran stated, I will take a few minutes to discuss some new initiatives we are pursuing in order to strengthen our internal program management structure. To put this in perspective, please look to the chart stand where we have depicted our program structure. I will briefly describe the elements of this structure and how they relate to each other and to the accomplishment of our objectives.

First, the Agency has recognized that a strengthening of our requirements process, especially as it relates to the engineering and development program, is needed. We are working with other elements of the Agency to more formally design this process, and would expect within the next few months to have a system in being that will assist us in internally focusing our priorities and resources in a more effective manner.

With the requirements process as an umbrella the four major elements of our program are depicted. First, our advanced development and systems engineering programs bring us through the initial feasibility and early conceptual development stages—proceeding on to evaluate system tradeoffs and design options and finally to integrate the selected options through the system engineering process. Neal Blake will brief you today on this advanced development and system engineering program.

Major development such as the upgraded third are carried out to bring significant improvements into the national airspace system. In parallel with these major system developments, the airport and airway technology program feeds advanced technology into today's air traffic control system and provides a basis for future hardware and software development. Five application areas are covered. These are navigation, communication, surveillance, weather and airport/paving development. If a program within any one of these areas develops to the point where it becomes a large systems effort, it will be moved into the organization responsible for major system development under a single point program manager.

Our Agency medical programs under the able leadership of the Federal Air Surgeon, Dr. Reighard, introduces the human being into the research and engineering process. All of these efforts are pointed toward greatly improving airports, airways, air traffic control, and the performance of persons on the ground and in the air who will operate the system of the future. The arrow shown on the bottom depicts the approximately 15–20 years it takes from the time we begin the initial conceptual design and feasibility work to where we have full implementation in the field.

Turning to the first vugraph, you will recall that last February when we appeared before this committee, we discussed major system developments in terms of the upgraded third programs. This vugraph lists those nine programs plus aerosat, and Bob Wedan will bring you up-to-date on a number of these in his briefing. These ugraded third features form the core requirement for our future application of resources and we are continuing to try to move them along on the schedule we showed you last February. I am making every effort to balance our program through our airport and airway technology activities, the air traffic control aviation medicine program, and the advanced development and system engineering program to make sure that we identify the resources necessary to support these as well as the upgraded third. Now let us turn to how we are going about improving management of these programs.

This vugraph depicts our revised organizational structure. I'm not going to bore you by going through all the details inferred by this chart. There are, however, a few important items that need to be highlighted. First we have formed a technical advisory committee, whose objectives are to look at our future programs and advise us on both the scope and direction of these efforts. It consists of 15 highly qualified experts, and we will submit for the record the details regarding the organization of and tasks currently undertaken by this committee.

Mr. MILFORD. It will be accepted in the record when received.

[The document follows:]

Dr. Robert G. Loewy, TAC Chairman, Vice President and Provost, Rensselaer Polytechnic Institute.

Dr. Gerald Dinneen, TAC Vice Chairman, Director, MIT Lincoln Laboratory.

Dr. Betsy Ancker-Johnson, TAC Member, Assistant Secretary for Science & Technology, U.S. Department of Commerce.

Dr. Raymond L. Bisplinghoff, TAC Member, Chancellor, University of Missouri-Rolla.

Mr. Burton P. Brown, TAC Member, Systems Consultant, General Electric Co.

Dr. Harry I. Davis, TAC Member, President, Systems Review Associates, Inc.

Dr. Eugene G. Fubini, TAC Member, President, E. G. Fubini Consultants, Ltd.

Dr. Bryce O. Hartman, TAC Member, Chief Environmental Physiology Branch, USAF School of Aerospace Medicine.

Mr. David R. Israel, TAC Member, Technical Assistant to the Administrator, U.S. Energy Research & Development Administration.

Mr. John W. Klotz, TAC Member, Consultant.

Dr. Vincent V. McRae, TAC Member, Assistant for Business Planning, IBM Corporation.

Dr. F. Robert Naka, TAC Member, Chief Scientist, USAF.

Mr. Courtland D. Perkins, TAC Member, President, National Academy of Engineering.

Mr. Duane Wallace, TAC Member, Senior Consultant, Cessna Aircraft Co.

Mr. H. W. Withington, TAC Member, Vice President, Engineering, Boeing Commercial Airplane Co.

The Administrator of the FAA established this Technical Advisory Committee (TAC) effective March 1, 1976, via FAA Order 1110.78A, dated March 23, 1976.

The TAC Charter is as follows:

OBJECTIVES, SCOPE, AND DUTIES

(*a*) The objectives of the committee are to provide FAA with independent, expert advice on the nature and direction of its technical efforts related to the National Airspace System and other FAA responsibilities.

(*b*) The committee's activities include the total research, engineering, and development program of FAA.

(*c*) In fulfilling its objectives to advise FAA on the adequacy of the current technical program and the direction future development should take, the committee reviews:

(1) FAA plans for research, engineering and development.

(2) The objectives, direction, and balance among the major projects of the engineering and development program.

(3) Potential areas of duplication between the FAA research, engineering and development programs and those conducted by other government agencies especially the Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), and the National Bureau of Standards.

(4) Potential applicability of university and industry research to the FAA research, engineering and development program.

(5) The effectiveness of the engineering and development program in meeting the future requirements of air transportation.

(*d*) The committee responds to special requests and assignments from the Administrator or the Associate Administrator for Engineering and Development.

The topics or tasks currently being addressed by TAC members are FAA's programs in collision avoidance systems; FAA's coordination with DOD and NASA; FAA's general R. & D. program; study the means by which FAA insures that professional and management personnel will be available in the future.

Mr. COCHRAN. Thank you.

Within the engineering and development organization there are three major entities. These are the Office of Systems Engineering Management (OSEM), the Systems Research and Development Service (SRDS), and the National Aviation Facilities Experimental Center (NAFEC). OSEM provides overall program planning, requirements evaluation, conceptual design, systems engineering, and integration. SRDS is the engineering department that transforms these plans and proposed concepts into working prototype hardware and software systems and equipment. NAFEC provides test and evaluation of these systems, as well as other engineering support services requiring such facilities. We are supported by the Department of Transportation Systems Center in Cambridge, Mass., who assist us by supplying expertise in a number of specific technology areas. In addition, we utilize services from the MITRE Corp. and Lincoln Laboratories as appropriate. We coordinate closely with NASA, the Department of Defense, and the National Oceanic Atmospheric Administration (NOAA) on many joint programs of mutual interest.

A word here about the requirements process which interacts with other elements of the FAA. We get suggestions and comments from a lot of people and organizations such as various user groups. These views are seriously considered in our decisions as to where we are to focus our efforts and resources. As you can see by this display, the diverse interests of these groups can cause conflicting requirements even when directed toward meeting the same objectives. Through the consultative planning process and face-to-face meetings with individual groups, we attempt to come to compromise solutions and obtain concurrence in our development direction.

One of the new initiatives we are undertaking in our Office of Systems Engineering Management is to recognize requirements analysis as a formal area of activity. This helps us to focus our advanced development, system planning and integration and resource management in a logical way to meet those needs with the highest priorities. The function of our systems engineering and management office identified by the brighter portion of the vugraph has been strengthened considerably and will also be described by Neal Blake.

The Systems Research and Development Service (SRDS) is responsible for managing our major hardware and software development efforts, bringing them to the point where performance can be demonstrated, specifications can be written, and the system can be acquired for field implementation. A major initiative we have taken in SRDS is to designate single point management for those high visibility, expensive, and sensitive programs in order to focus responsibility. All of the upgraded third elements fall in this category, in that program managers at the division level or division chiefs themselves have been made responsible for carrying out these efforts. In the future, we are requesting additional resources so that we can strengthen the basic technology areas to better support field improvements and future system development.

Our NAFEC acility located just outside Atlantic City is responsible for testing and evaluating the concepts and systems developed under programs in the SRDS and OSEM. At NAFEC, the FAA's proving ground, full-scale operational tests are conducted on prototype equipment under actual operational conditions to demonstrate performance, reliability, and safety before they are introduced into the national airspace system.

This is a picture of NAFEC. The center covers 5,000 acres and has a provisional category III all-weather airport. There are 184 structures that provide a composite of 1 million square feet of administrative, shop, and laboratory floor space.

This next vugraph is an artist's concept of our plan for modernizing the facility and eliminating the majority of World War II structures seen on the previous vugraph. We are presently in the final stages of undergoing approval of this modernized "aviation system proving ground."

Mr. MILFORD. Excuse me. Is that the facility that is to be leased, the one that is currently before the Public Works and Transportation Committee at this time?

Mr. ALBRECHT. Yes, sir.

Mr. MILFORD. OK.

Mr. ALBRECHT. The Civil Aeromedical Institute, which carries out the majority of our aeromedical research, is located at the FAA's aeronautical center in Oklahoma City. Under the research, engineering, and development program, this research and a research contract administered by the Federal Air Surgeon is evaluating performance and stress in air traffic control work, and identifying means for improving air traffic controller retention.

The next chart is a picture of the Civil Aeromedical Institute, which has in it an air traffic control simulation facility and a laboratory that measures the biochemical stress response of air traffic controllers. This building, covering 121,000 square feet of floor space, was designed specifically for aeromedical research in the early 1960's.

The final vugraph depicts some of the areas of common programs that we have with NASA, DOD, and NOAA. We have formalized our relationships through executive level meetings with the three agencies, and actively coordinate with them in almost 40 separate programs. Depicted here are a few of these. We believe that such cooperative efforts are important if we are to make the most effective use of our mutual resources.

At this time, I would like to introduce Mr. Neal Blake, Acting Director, Office of Systems Engineering Management, who will cover our advanced development program.

STATEMENT OF NEAL A. BLAKE, DEPUTY DIRECTOR, OFFICE OF SYSTEMS ENGINEERING MANAGEMENT

Mr. BLAKE. Thank you, Mr. Albrecht.

Mr. Chairman, and members of this committee. The advanced systems development program defines the system improvements beyond those in the upgraded third generation systems program, and are the ones which will be needed in the 1990 time period. We are also defining the R. & D. program needed to produce these improvements over the next 10- to 15-year time period.

The upgraded third generation system improvements will largely be in place by 1986 and will provide the foundation for the next generation of system improvements. During the period 1986 to 2000, total operations will continue to grow at the rate currently forecast of about 4.8 percent per year. Although the upgraded third generation system can accommodate this growth with substantial improvements in all areas, costs in the form of increased staffing, delays, excess fuel consumed, and flight risk will start to rise again during the late 1990 time period.

The advanced system development program is structured to provide the improvements needed to meet the FAA goals shown here of near zero accident risk, continued increases in capacity to meet forecast demand, reduction in controller and maintenance staff growth, improvement of the environment, and conservation of energy.

The plan encompasses all elements of the National Airspace System including air traffic control, airports and airspace change, improvements to aircraft cockpits and aircraft systems, as well as investigations of alternate control concepts and potential applications of advanced technology.

The process of defining advanced programs must consider the performance of the current system, variations in traffic forecasts, policy alternatives, introduction of new types of air vehicles, intermodal interfaces, and interagency program coordination.

The ATC system of the 1990–2000 time period will provide improved direct flight capability, more fuel efficient flight profiles and improved routing around severe weather conditions and increased terminal capacity under adverse weather conditions.

These improved services will be made available at reduced operating and maintenance staff costs which are made possible through higher levels of automation, use of data links for communication, advanced computer systems, and high reliability, solid state equipment with internal fault detection and reporting capability.

The next several vugraphs present three of the concepts being investigated as a part of the advanced ATC automation program.

When the upgraded third automation functions have been implemented, many of the routine decisionmaking functions of the controller will be done automatically, but the controller will still be an integral part of the control loop. While controller productivity will be significantly enhanced by the upgraded third system, future major gains require use of the computer to preplan aircraft profiles, indicate the future control actions to the controller for review, and then issue the new clearances automatically via data link at the appropriate time.

The controller's job now becomes more supervisory in nature and we expect he will be able to handle significantly large numbers of aircraft. A simulation model of this future system is now operational covering a portion of the Washington Center airspace.

Growth in traffic results in implementation of approximately four new control towers each year on the average. Operating and maintenance costs at these new towers average about $250 thousand a year. A program called Automated Terminal Service has been initiated to provide improved service at less than one fourth of this cost. The automated system provides surveillance of aircraft operating in the vicinity of the low density airport and provides, as a part of its initial operating capability, traffic advisories to pilots. Information on the runway in use is set into the system by the airport operator. From that point on, the system operates automatically.

Pilots entering the area log into the system by using a specified transponder code. The computer located at the site utilizes a computer generated synthetic voice to request aircraft type, color, and identity. This data is recorded as the pilot replies over his voice radio channel. Thereafter the computer calls out conflicting traffic using the recorded identity and synthetic voice messages. When IFR traffic is operating into or out of airports equipped with this type of system, the surveillance data can be remoted to an adjacent air traffic control facility to permit the controller monitoring the IFR operations using this facility.

A later stage of the system will utilize the Discreet Address Beacon System surveillance and data link system to provide collision avoidance commands automatically by data link as well as traffic sequencing instructions.

We will have after the main part of the hearing a TV tape on the left which further defines the ATC concept and the progress we have made to date.

Automation provides the tool necessary to achieve fuel efficient flight profiles. Ideally, for a short flight about one-third of the time should be at cruise altitude and the remainder of the time should be either in climb or descent. Although improvements are being made continuously to the current ATC system to reduce flight delay and to keep the aircraft at the higher more fuel efficient altitude longer, coordination problems between the high density traffic sector controllers still occur. When this happens nonoptimum altitude profiles must frequently be used in the interest of maintaining safe separation under high workload conditions.

A program has been initiated to determine the traffic loading of the air routes and navigation fixes in the high density flight corridor between Washington National and LaGuardia Airport in New York. This will be followed by a definition of the required functions to provide automatic coordination of the direct flight routes and to provide the fuel efficient profiles. This program will be integrated with the automated control program described a moment ago and these two programs are expected to produce fuel savings on the order of about .28 billion gallons over the time period of 1986 to the year 2000.

Airports are the second area of the national airspace system where improvements programs are currently being defined. Throughout the time period from the present through the year 2000, FAA forecasts indicate continued growth in demand at all of the Nation's major airports. During the same time period, we currently foresee few new major airports. Hence, the development program will continue to focus on providing additional capacity improvement items.

The upgraded third generation system provides many improvements including the microwave landing system, weight vortex avoidance system, wind shear avoidance systems, independent operations to close-spaced parallel runways, automated ground control systems and continued evaluation of fog dispersal systems. The advanced system development program is examining the capacity to be gained, for example, from advanced four dimensional area navigations systems using precision guidance from the microwave landing system.

Mr. MILFORD. Could I interrupt you there?

The fourth dimension?

Mr. BLAKE. The fourth dimension is time. The system that bears that name delivers the aircraft over a precise path in the three dimensions to an approach gate or runway threshold at a precomputed time to maximize runway capacity.

Mr. MILFORD. Thank you.

Mr. BLAKE. These systems, the 4D plus the microwave landing system guidance will also make possible the use of advanced approach modes being investigated by NASA such as the decelerating and delayed flap type of approaches.

Although the airport capacity studies prepared by the U.S. Congress in 1974 indicated that expansion of the airside to keep up with demand appeared feasible at a number of airports, landside congestion was already serving to constrain growth at several of the major airports and we feel it becoming a controlling factor at many if not most of the major airports in the mid-1980 time period.

Hence, a program has been initiated to accurately model the landside of the airport and its interface with the surface transportation mode. This program will define and evaluate advanced concepts of passenger, baggage and cargo handling. This program is being conducted in complete coordination with the intermodal research program which has been initiated by the Office of the Secretary of DOT at the Transportation Systems Center.

Turning now to aircraft—the outlook for aircraft operations during the 1986–2000 time period include growth, continued growth of cargo, feeder and SST operations with possible introduction of some STOL aircraft into the fleet; the introduction of quieter and more fuel efficient aircraft and a continued improvement of current aircraft and aircraft systems.

The advanced system development program, which contains many joint NASA/FAA projects, will examine improved cockpit systems, automated flight management, advanced hazard detection and warning systems, integrated data entry and processing systems and many advanced concepts such as fly-by-wire, composites, and propulsive lift.

One of the programs in this area will conduct an examination of advanced hazard warning systems. Such a system will replace the multiple warning and alerting lights, aural signal flags, and instrument markings with a single system. This would monitor aircraft operation and prioritize the checklist items the pilot must execute in the event of a failure or emergency condition.

This system envisions use of a single aural warning signal, computer generated voice, annuniciation of the problem category, and a cathode ray tube or equivalent display of the checklist items in the priority order of their needed execution. This provides additional safety over current systems as the aircraft configuration is monitored as a function of flight phase to assure that no critical checklist item is ever omitted.

Improved displays of navigation and safety data are being investigated with NASA using both simulation and the terminal configured vehicle which is the NASA Boeing 737 test aircraft.

This program is investigating the safety and the performance benefits to be obtained using a cathode ray tube to present terminal area navigation information in graphic or pictorial form in conjunction with display of terrain and obstructions when aircraft operate below normal flight altitudes. Severe weather information from the airborne weather radar system can also be presented in true reference in RNAV routes to permit improved selection of weather avoidance routes. Selected traffic information can be transmitted from the ground air traffic control system to advise pilots of aircraft operating in their vicinity. These and other functions are being investigated as a part of this program.

The preceding two programs have application in both present and future aircraft. In addition, FAA and NASA are planning to initiate a joint program to conduct a full and comprehensive human factors evaluation of all cockpit stations and to develop and evaluate advanced flight control displays, cockpit hazard warning system, integrated data processing, control and display systems, and automated systems management and fault isolation displays for the flight engineer. This program will establish the technical data base from which industry can develop safer cockpits and control systems for our next generation of aircraft.

Each of the programs which we have just looked at very briefly support one or more of the goal areas of the Agency as shown on this vugraph. These improvements and others yet to be defined by the advanced systems program form the basis for the next generation of improvements for both the national airspace system and aircraft systems.

Although our benefit assessment work is just now starting indepth, the preliminary look has already identified significant benefits for many of the programs presented today. Some of these representative benefits are shown here on our last vugraph.

I would like now to introduce Mr. Robert Wedan, Deputy Director of the FAA Systems Research and Development Service, who will describe the current status of several of our major programs.

Bob?

STATEMENT OF ROBERT W. WEDAN, DEPUTY DIRECTOR, SYSTEMS RESEARCH AND DEVELOPMENT SERVICE

Mr. Wedan. Thank you, Neal.

Mr. Chairman, this committee has been briefed in the past on the upgraded third generation system, therefore, my purpose today is to update you on the status of these programs. Time permitting the selection of a few.

I have brought a few of the hardware items with which we work. They are on display on the tables over here. I have also put together a few film strips in addition to the vugraphs to bring out the points of this briefing.

After the hearing if there is any interest in speaking with the individuals who have direct responsibility in the development of these systems and subsystems, then these people will be available near the equipment that they are concerned with.

The Upgraded Third Generation System does refer, as explained earlier, to the upgrading of the present traffic control system to handle the requirements of the 1980 and 1990 timeframe. This program has been described in terms of nine features. These nine features are described here. I will speak today, in the interest of time, only to those that are defined by a red arrow.

The first of these programs is the aircraft separation assurance program. This vugraph is a picture of an accident that occurred not too long ago in California just outside of the terminal controlled airspace. The purpose of our program is to prevent this sort of thing from happening.

We have developed a five-point program that is described in this vugraph. This program will be presented to a consolidated conference beginning next Monday to discuss this and the various points with the user community and the public for a 2-day timeframe. We expect through this process to obtain feedback and comments from the users that may modify our specific approach that I will be describing now.

The first of these points is conflict alert. This technique involves enhancing the present software in the en route and terminal system so that where the controller is responsible for resolving a conflict, the computer software will be used to aid him in the process. If a conflict does develop, then the display of the aircraft will be furnished. There will be a flashing display where the aircraft are identified on the controller's display which will call his attention to the conflict that is developing. It will aid him in bringing his attention to the problem to help him resolve the problem quickly.

The next one is a fairly simple step. It involves adding surveillance equipment where currently surveillance equipment does not exist and this has essentially been accomplished for those areas where wide-bodied jets operate. The flight plan requirement is an encouragement on the part of the commercial operators to use IFR flight plans where they can instead of VFR to put these aircraft under the surveillance of the ATC system.

I would like to spend a little bit more time on the next three. The extended use of transponders and altitude encoders. The picture on the right is familiar to 70 percent of aircraft owners today. In the lower part of the picture is the ATC transponder. Above it is an altimeter. This system works in a cooperative fashion with ground interrogators. The altimeter is shown because a modification has been designed and made available to the marketplace that would provide altitude information to the transponder that, when interrogated, altitude is reported to the ground. We are encouraging through this step the

80-582—77——2

extended use of transponders in airspace beyond the current requirement which is above 12,500 feet and in the high density terminal controlled airspace. The basic reason for this is that in order to resolve a potential conflict the first thing that must be known is where the aircraft is in the airspace. This is the means by which we can determine the position of the aircraft.

Mr. WYDLER. Is that something FAA developed?

Mr. WEDEN. No; this was developed by private industry during the 1960's.

Mr. WYDLER. What do you have to do with it?

Mr. WEDAN. The rulemaking process of the equipment is based on a concept that was originally developed during World War II for IFF operations. That technique was adopted by the FAA during the 1960's as part of the Project Beacon concept and this is the means by which radar can be enhanced so that information on the aircraft's position can be determined by ground systems.

Mr. WYDLER. All you are doing in effect is taking something that private industry developed and saying, why don't we use it? Right?

Mr. WEDAN. That is correct. We are saying we would encourage the extended use of this beyond what is currently required. What I am speaking of here is rulemaking. We are not talking about new development in this particular case. We are talking about rulemaking.

I would like to expand on the need for this——

Mr. WYDLER. What does the rule provide? Does it require it?

Mr. WEDAN. Presently the rule states that aircraft operating at 12,500 feet and above must carry operating transponders with altitude encoders. The terminal control areas require transponders today in order to operate in their airspace.

Mr. WYDLER. OK.

Mr. WEDAN. The next technique is described as a Beacon Collision Avoidance System or BCAS. The photograph on the right gives a rough idea of how this system works. This system basically has two modes of operation. The first mode is an air to air interrogation. The present system is based on ground based equipment for interrogating aircraft in the air and receiving replies from the airborne transponders. The BCAS system is based on a concept in one mode of interrogating aircraft in the airspace from aircraft so equipped. The second mode is to listen to the replies from transponders in the air based on interrogations from the ground. This system known as BCAS would supply CAS information to aircraft so equipped. The added feature is indicated by the instrument in the upper right hand corner of this vugraph. This is a modification of the rate of climb instrument. What it would tell the pilot is that there are aircraft above his flight path or below that represent a threat to him. In some cases these aircraft would not only restrict their rate of climb but actually ask the pilot to dive or climb his aircraft to resolve the conflict.

I have equipment over on the table on your right to indicate roughly how this would work. This is one of the concepts displayed. It shows in the upper segments of the rate of climb instrument that the aircraft climb rate should be reduced to the level indicated by the limit of the light band around the upper part of the instrument.

The next switch position is a "do not climb," in fact a mandatory command to descent to resolve the conflict. The third is the same in the upper direction, the next position. This is the same information as described, but in this case it says that there is an aircraft below and the aircraft should restrict its descent rate. Next is an indication that says there are aircraft both above and below the aircraft and that he should not climb or dive because of conflicting traffic.

This technique is currently being experimented with at NAFEC.

Mr. MILFORD. The interrogation is done by the aircraft transponder itself?

Mr. WEDAN. There are two modes of operation. One mode of operation—the equipment listens to the transponder from other aircraft in the airspace and decides which aircraft are conflicting with him and would provide information on a display such as this.

Another mode of operation which would be used in a low density condition is that the air carrier would transmit signals just like the signals that are transmitted from the ground and listen to the replies. This is not transponder equipment. It is new equipment and is called BCAS equipment. It is collision avoidance equipment that would be developed for purposes——

Mr. MILFORD. Wouldn't that work on a transponder principle though?

Mr. WEDAN. It operates on exactly the same principle. In other words, the reply expected would be the reply from the transponders that currently exist. There would be no change to those transponders with this concept.

Mr. WYDLER. Did you develop this equipment?

Mr. WEDAN. This equipment has been developed in part by the FAA and there is also a private industry approach to the design concept.

Mr. WYDLER. Well, I do not understand that answer. Did you develop this equipment that you just showed us here or did somebody else develop it?

Mr. WEDAN. Yes, sir. This particular design was developed by the FAA.

Mr. WYDLER. And are you going to order this installed by rulemaking on aircraft?

Mr. WEDAN. We are in the middle of a research development program to determine the technical design characteristics of such a system. The concept would be to provide prior to the introduction of intermittent positive control which I will get to in a moment, a collision avoidance system capability that is a backup capability to the conflict alert technique which is based purely on controller actions. For example, it would provide protection——

Mr. WYDLER. What are you going to do with this equipment? That is what I am asking you.

Mr. WEDAN. One of the applications would be to provide this equipment or to have each of the air carriers that carry passengers for hire, require those aircraft to carry this equipment on board their aircraft.

Mr. WYDLER. In other words, all commercial flights would have to have this equipment, is that what you are saying?

Mr. WEDAN. That is basically the concept.

Mr. WYDLER. The concept. What does that mean? Have you got a rule in formation or something like that or have you asked them to put it in? I do not understand what is going to happen.

Mr. WEDAN. I indicated before we are planning a consolidated planning meeting this next Monday, at which time we will offer to the public the proposal. The proposal would state that this equipment would be developed and that the rule that would be associated with it would be that the carriers of certain type of aircraft would be required to carry this equipment.

Mr. WYDLER. When do you think that would happen?

Mr. WEDAN. I will show you a schedule in a moment. We believe that if we maintain the schedule that we will be able to begin implementation by 1980.

Mr. WYDLER. Of this equipment you just showed us?

Mr. WEDAN. Yes.

Mr. WYDLER. So when you are talking about something like the intermittent positive control, when do you think that might come about?

Mr. WEDAN. Approximately 2 years later—1982.

Mr. WYDLER. Alright. Go ahead.

Mr. WEDAN. I would like to move on to the intermittent positive control concepts. This I did show the committee at the last briefing. It, too, adds a third element to the pilot's instrument panel. Starting at the upper left-hand side of the Vugraph on the right, the altimeter would be unchanged. In the lower part is a DABS transponder. This transponder is the modification over the type of transponder that we have today in 70 percent of the aircraft fleet in the following sense—that this transponder can transmit and receive digital data messages. The significance of this is that the ground system can determine if a conflict exists and transmit this message up to that transponder and the transponder then would drive the display to indicate what the situation is. I would like to describe the situation in two steps.

Directing your attention to the right-hand side of the Vugraph, the first step is where an aircraft is beginning to intrude the airspace of your particular aircraft. This display then would show that as aircraft in the nearby vicinity in terms of lights that would turn on. There are two lights. The one to the right tells the pilot that there is another aircraft in his 3 o'clock position and because it is the center of three lights it says the other aircraft is coaltitude with him. Now what he does with that is to try to visually acquire that other aircraft, and if he does he will resolve the conflict using the rules of the road that exist today.

Another similar display would show a light at the bottom of the dial. That says another aircraft is in his 6 o'clock position, but at a lower altitude—500 to 1000 feet below him. Again, it is warning information. Now if the situation deteriorates so that we are closer to a possible collision, the next step in the display—at least it has been experimented with so far—is that these lights would then flash as an alert and an aural alarm would sound out to call the pilot's attention to look at the display. He still has one more chance then to resolve the conflict himself. In the event that the situation deteriorates even further, then an arrow would show in the center of the dial. In this case that would be a green arrow that is a mandatory command for that aircraft to turn left. It is not possible to see it here, but I will show you in the display in a moment that there is a red X. This red X says not only turn left, but be sure you do not turn right or descend because of the conflicts of these two aircraft.

Now the display is shown on the table on your right, and we will walk through the sequence very briefly here. These two red lights are just as I showed you on the display on the Vugraph. There is an aircraft in my 3 o'clock position, same altitude, and there is one at my 6 o'clock position, below me. Now the situation involving the aircraft in my 3 o'clock position has deteriorated. I still have an opportunity to resolve the conflict if I can see him. If I ignore the display and the situation deteriorates further, I then have a green arrow saying you are required to turn left.

I would like to explain this action further by a short film clip. This film clip will show how this operates in a typical situation. You will hear the terms interceptor and drone used. The drone—you can imagine yourself as a pilot of that airplane, and you will be seeing the instrument panel for the drone pilot. The interceptor is coming up and is going to collide with you in an assumed situation. You will also see a picture of the ground display as a controller on the ground would see it. Once again, you will see both modes of operation—the PWI is the warning information and then finally the mandatory control.

[At which time a short film clip on IPC was shown.]

Mr. WEDAN. This is an actual flight test. This has been in operation for a number of months. Mr. Chairman, you and any members of your committee who are interested in going up to the Lincoln Laboratory, our contractor for this development program, are invited to go along to personally observe this technique and operation.

I would like then to summarize this area by the status chart indicating where we are today. The first thing I would like to point out on this chart—the user conference which will propose or present the 5-point program to the user community. If the program continues the way I just described it, then a key date on the right hand side on the operation of BCAS, the beacon collision avoidance system would be in 1980 for implementation of the technique.

On the bottom the schedule is indicated for the Intermittent Positive Control technique where ground implementation or the ground system part of this system would begin in 1982. We currently have a contractor to develop three of the prototypes and operational experiments will begin in about a year and a half.

I would like to then move on to our wind shear program.

Mr. WYDLER. How much is that program projected to cost overall?

Mr. WEDAN. I would like to supply total figures for the record of particular contracts that we have at the moment for development of three prototype ground stations. As I recall it is about $12 million, but the cost of the total set of activities I would have to put together for you. I would be happy to do that.

[The information requested follows:]

The following tables are cost breakdowns of the FAA Airborne Separation Assurance Program. They include expenditures to date, projected future research and development costs, and estimates of the cost of implementation as of October 4, 1976. For reference purposes, a cost breakdown of the Airborne Collision Avoidance System (ACAS) is included.

EXPLANATION OF TABLES SHOWING COST BREAKDOWN OF THE ACAS

Table I—Conflict Alert.—All costs are FAA. Enroute conflict alert implementation is nearing completion. Terminal conflict alert is still primarily in the research and development status.

Table II—Transponders and Altitude Encoders.—All costs are borne by the users. The air carriers and military have already made the investment for this equipment on a voluntary basis. The general aviation costs reflect the investment necessary for this group of users to complete equipage of altitude encoders and transponders.

Table III—BCAS.—The costs are FAA's until a BCAS National Standard is published. At that time, the users will buy BCAS equipment from industry built to the BCAS National Standard. BCAS user costs are the costs associated with equipping only those aircraft capable of carrying 10 or more passengers.

Table IV—DABS and IPC.— FAA costs are the research and development of the DABS/IPC system and the incremental IPC costs associated with the DABS ground sites. The users' cost is for both a DABS transponder and an IPC display after voluntary system implementation begins.

Table V—ACAS.—The ACAS costs are included to permit reference to alternate forms of equivalent protection. For example, BCAS permits purchase of collision avoidance equipment to be optional and provides equal protection at substantially less costs. The higher costs for ACAS are generated as a result of the necessity for all aircraft to carry collision avoidance equipment for the system to be effective. This equipment is necessary irrespective of whether or not they want the protection.

Table VI—Summary.—Summary costs are self-explanatory. However, ACAS is not directly comparable in either cost of capability to any of the other programs or any combination of them.

TABLE I.—CONFLICT ALERT: COSTS

[In millions of dollars; fiscal years]

	Prior to fiscal year 1976	Fiscal year 1976	Fiscal year 1977	Fiscal year 1978	Fiscal year 1979	Fiscal year 1980	Fiscal year 1981 through fiscal year 1985	Totals
Conflict alert:								
Terminal:								
FAA costs:								
R. & D.		0.3	0.6	0.5	0.2			1.6
F. & E.		.1	.1	1.7	1.7			3.6
Total		.4	.7	2.2	1.9			5.2
En route:								
FAA costs: R. & D. (total)								1.9
Total								7.1

TABLE II.—TRANSPONDERS AND ALTITUDE ENCODERS: COSTS

[In millions of dollars; fiscal years]

	Prior to fiscal year 1976	Fiscal year 1976	Fiscal year 3977	Fiscal year 1978	Fiscal year 1979	Fiscal year 1980	Fiscal year 1981 through fiscal year 1985	Totals
Transponders and altitude encoders: User costs: Air transportation:								
Military					5.5	3.7		9.2
General aviation					42.6	41.4		84.0
Total					48.1	45.1		93.2

TABLE III.—BCAS: COSTS

[In millions of dollars; fiscal years]

	Prior to fiscal year 1976	Fiscal year 1976	Fiscal year 1977	Fiscal year 1978	Fiscal year 1979	Fiscal year 1980	Fiscal year 1981 through fiscal year 1985	Totals
BCAS:								
FAA costs: R. & D. (total)		2.0	4.5	6.8	3.5	1.9		18.7
User costs: Air transportation:								
Public							113	113.0
Federal							52	52.0
Private							142	142.0
Total							307	307.0
Total								325.7

TABLE IV.—DABS AND IPC: COST

[In millions of dollars; fiscal years]

	Prior to FY 1976	FY 1976	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981 through FY 1985	Totals
DABS and IPC:								
FAA costs:								
R. & D.	20.4	8.2	10.4	13.8	7.8	4.2	1.3	66.1
F. & E. (150 sites)					5.0	20.0	50.0	75.0
Total	20.4	8.2	10.4	13.8	12.8	24.2	51.3	141.1
User costs:								
Air transportation (100 percent)						15.6	47.7	63.3
Military (100 percent						40.7	172.1	212.8
General aviation (30 percent)						15.6	72.9	88.5
Total						71.9	292.7	364.6
Total								505.7

TABLE V.—ACAS: COSTS

[In millions of dollars; fiscal years]

	Prior to FY 1976	FY 1976	FY 1977	FY 1978	FY 1979	FY 1980	FY 1981 through FY 1985	Totals
ACAS:								
FAA costs: R. & D. (total)	19.0	0.7						19.7
User costs:								
Public air transportation (100 percent)								56
Federal air transportation (100 percent)								22
Private air transportation (100 percent)								49
Other Federal aircraft (100 percent)								229
Other general aircraft (0)								277
Aircraft without avionics								0
Replace radar altimeters (DOD and General Aviation)								86
Total								719
Total								719

TABLE VI.—SUMMARY OF AIRBORNE SEPARATION ASSURANCE PROGRAM: COSTS

[In millions of dollars]

Program	Total
Conflict alert	7.1
Transponders and altitude encoders	93.2
BCAS	325.7
DABS and IPC	506.7
ACAS	739.0

Now the wind shear program. First of all, I would like to show you two types of accidents that have occurred in the past year. This is an accident that occurred at Stapleton in Denver on August 7 of last summer where an aircraft lifted off but was unable to sustain flight and dropped back to the ground. This was due to a thunderstorm—wind shear associated with a thunderstorm at Stapleton Airport. On the right is Eastern 66 which is an approach and landing type of wind shear accident. This is the type of accident that we are addressing in this program, too.

The next vugraph shows the three major parts to the program. First of all we are developing equipment and techniques that involve the pilot and displays to the pilot and equipment that he has on board his aircraft now or can be modified to help him plan his approach or takeoff to prevent this type of an accident. The second is the development of equipment that can be placed on the ground for the measurement of wind shear. The third area is to improve on the techniques which have already been developed by the National Weather Service and in a cooperative way to improve on our prediction capability for those wind shears particularly associated with weather fronts.

This photograph is an unusual photograph. It shows the gust front type of wind shear activity associated with a thunderstorm. The picture on the right indicates a gust front that precedes up to a number of miles ahead of a thunderstorm that is approaching an area. Normally that gust front cannot be seen, but in this particular case there is sufficient dust picked up by the gust front which made it visible. The point of the picture on the left is to indicate approximately how big and how wild that particular impact is or effect is.

There is another type of wind shear associated with a thunderstorm we believe, and that is associated with the heavy rainfall in the center of the storm. We are concerned with measurement of both.

An instrument I would like to show in the next vugraph is a pressure change sensor which was developed in a cooperative effort with the Wave Propagation Laboratory of NOAA. This device measures the change in pressure which we believe is very closely correlated with the type of wind shear that we saw preceding the thunderstorm.

This instrument does not measure wind or pressure. It measures the change in pressure as this gust front passes over head. We have the device over here to your right, and by creating a slight pressure jump with the finger on the end of the tube, the detector senses that change in pressure and indicates an alarm. In this case an aural alarm. This pressure jump detector is currently being tested at Chicago O'Hare. We have a large number of these located around the airport, and the experiment is intended to show that you can not only detect the pressure jump associated with the gust front, but can also track its progress as it moves toward the airport. As a result of that the controller can take action such as change the runways or perhaps even close a runway down if it is hazardous.

Another device that would be aimed toward ground installation was also developed by the Wave Propagation Laboratory at their laboratories in Colorado. This was based on acoustic techniques. This device generates a high energy short period of time sound pulse. The pulse is directed into the air. If a shear exists, part of that sound energy is refracted or reflected back to the ground and there is a sensor, in this case, located in the ground. It is in the ground to protect it from ambient noise. Such a system has been in operation at Wave Propagation Lab. It indicates not only the presence of a wind shear, but also its altitude. We are currently installing this system for experiments at Dulles Airport.

Turning now for a moment to some of the work associated with cockpit activities. This is a photograph of a simulator that we are using with a contractor. In this case it is a DC–10 simulator. One of the experiments that we are gaining some experience with involves a display of ground speed at the point where the aircraft is flying on his approach. This ground speed would be a bug that would be driven around the face of the airspeed indicator, and the pilot by comparing that bug with the airspeed indicator would have a measure of wind, at least the wind in the direction toward the runway. He could then compare that wind information with the wind information given to him by the ground local controller and get an idea of the degree that the wind is changing during his descent. If he has that information it helps him decide how to plan his approach to accommodate for that shear. That process could be made a little bit more automatic and we have experimented with the displays as shown on the right which in this case was on the upper right-hand corner of the pilot's display which gives him a direct indication of the shear.

We have also experimented with flight path indication as another helper to the pilot, and we have completed one phase of these experiments. We are now moving into another phase of more refined analysis in cooperation with the Ames Research Center of NASA using their simulator, and are also beginning flight tests.

This is a summary of the status of this program. A year ago we created the wind shear program office, and because of common technology we coupled it together with our wake vortex program, and I will talk about that in a minute.

We have begun tests at O'Hare, which is not on the chart, and also at Dulles. We expect the outcome of this program to result in the development effort on ground based equipment to be completed by June of 1978 and airborne equipment about that same time frame. January 1979 is our operational date of all of these techniques.

Now I would like to move on to wake vortex, and to introduce this I would like to show a short film clip. This film clip shows two encounters. The films were taken in cooperation with NASA at flights out on the west coast. What you are going to see are two separate aircraft showing an encounter with the vortex. Now in this case the vortex is created by a large aircraft. The vortex is made visible by smoke and the aircraft will first be seen—in the first case it is a Lear jet—searching for the vortex. When he encounters it you will see rolling maneuver result. The second one will be a T–37. The interesting thing here is that the aircraft has completely rolled over.

[A short film clip of a vortex encounter was shown.]

Mr. Wedan The FAA program has been addressing principally the region of flight associated with approach and landing. If an aircraft were rolled in the fashion shown here close to touchdown, it might be quite destructive. We have been running a number of tests at JFK and have determined that the behavior of vortices can be predicted based on fairly simple measurements and in particular the measurements of wind, wind direction and velocity. What we are, of course, concerned with is making sure that the space between aircraft is always in a comfortably safe region. Now the slide on the left indicates the direction that the equipment design has taken. We have found that by very simply measuring the wind as shown near the tower on the left hand side of the left chart, wind direction and velocity are the key to determining what the spacing rules should be. The instrument on the right hand panel is the display that would be presented to the local controller. It would tell him what the winds are, their direction and speed for the end of any runway that he should select as well as the gust factor and a small computer would drive a light on the upper right hand corner of that instrument advising him what space he is to use either the normal 3-mile separation or a greater separation.

This display device is shown on the right hand table for your inspection after this meeting. The one point I wanted to make is that this is a predictive technique. In the event that a vortex unpredictably remains in the area and creates a threat, a backup system would be provided by a ground wind sensor line that is indicated on the lower part of the chart. This sensor line is an array of simple wind anemometers shown in the picture on the right. If a vortex is present, the anemometer sounds an alarm telling the controller to take immediate action to remedy the situation.

That system is currently under operational suitability tests at O'Hare. The status of the program—We will complete the operational suitability testing at O'Hare by December of 1976 allowing an operational decision early next year. Assuming the decision is accomplished on schedule we will then begin implementation at other airports as well.

Now I would like to talk very brifly about one specific aspect of our automation program the Minimum Safe Altitude Warning program or MSAW. I have again a short film strip that introduces the subject, but basically the concept is to prevent an aircraft from hitting ground objects either in the terminal area or on route.

[At which time a short film clip on MSAW was shown.]

Mr. WEDAN. This service of course is not restricted to the jet aircraft indicated there, but to any aircraft that is equipped with a transponder with mode C or this altitude encoded information and which is in communication with ATC. The status of the program indicates where we are now. The technique is being evaluated under operational circumstances at Los Angeles. We expect evaluation to be complete by December of this year. We expect that all Arts III sites for terminal protection will have this capability available by the middle of next summer. The program is also including the enroute control and this chart indicates the completion date expected for the en route system, March of 1978.

Mr. GOLDWATER. How many planes can the system handle at one time?

Mr. WEDAN. The capacity of the Arts III computer, I do not have that number off the top of my head, but I can supply it.

[The information requested follows:]

The Minimum Safe Altitude Warning (MSAW) function of ARTS III can be enabled for each "Mode C" equipped aircraft that has an associated full data block (FDB). In a single terminal area, this would relate directly to the FDB capacity of the ARTS III for that area. For example, if the FDB capacity were 150 returns (airplanes) and the transponders on all these airplanes were active in a "Mode C" configuration, then MSAW would operate for all 150 airplanes.

The last subject is the microwave landing system program. If you have seen any benefits of MLS in the past, I would just like to remind you of two of these benefits offered which will show up in a movie that I would like to show at this time. The movie deals mainly with one benefit, namely, operational flexibility from curved approaches. This is the first system that will give us a guidance capability and permit us to fly in such a way that we could eliminate noise sensitive areas, and things like this. The other point I wanted to call your attention to is elimination of channels, e.g., channel limitations that we currently have with the VHF instrument landing system. We have a problem in terms of the growth capability of ILS because of frequency congestion. This system will reduce the impact of that problem.

This program of course started with a national plan in 1971. We have completed the selection of a technique—the time reference scanning beam technique as a U.S. standard. We expect to be in a position to have production specifications available next year. This is an international program, one of several in the R. & D. area. It involves the coordinated effort with our European friends through the international civil aviation organization (ICAO). This is an international competition. There are other systems other than the time reference scanning beam that are being proposed by other nations. These proposals are currently being considered by the all weather operations panel and we expect their recommendations will be available by February of next year. Our program, the one I am speaking of here, assumes that the committee will adopt the time reference scanning beam.

Mr. WYDLER. Suppose they accept the Doppler system?

Mr. COCHRAN. We now know of a technical problem with the Doppler system, until that is resolved we would have a significant problem in going along with the Doppler technique. We would need a resolution of this major technical problem before we could accept it.

Mr. WYDLER. Well, I understand that, but what would you do if the international organization decides they like Doppler better?

Mr. COCHRAN. And the technical problems were all resolved and we could accept it, then I——

Mr. WYDLER. That is the way most technical problems are solved. Let's assume it is solved and they decide they like the Doppler system, what would happen then?

Mr. COCHRAN. If they went with the Doppler system and it met all our requirements, then I feel the country would probably have to adopt the Doppler system.

Mr. GOLDWATER. What if it did not meet all our requirements?

Mr. COCHRAN. If it did not meet requirements then I do not think we should.

Mr. WYDLER. How many people vote on this—how many countries vote on that?

Mr. COCHRAN. Eventually all of our members of ICAO will vote on the proposition.

Mr. SHEFTEL. In the initial step with this working panel that Bob mentioned there are 10 members. There are eight countries and two organizations. The organizations are IATA and IFALPA. In the second step is the AIRNAV commission. This conference has 30 members. Then the final step is called worldwide and actually there are 60 member countries.

Mr. WEDAN. Mr. Chairman, I had planned to finish this discussion with a short film that was put together that does describe the time reference scanning beam technique and the program status as of now. The film will take close to 15 minutes. It is at your pleasure, we can show it now or defer it. If we show it it will be the first time that this film has been shown outside of the FAA. I think it is a very interesting film.

Mr. MILFORD. In case we run into an afternoon session, would it present a problem to anyone.

Mr. COCHRAN. It does not present a problem to me.

Mr. MILFORD. Then let's go ahead and see the film. Sometimes a film helps us to better understand what we are talking about.

[At which time a film clip on MLS was shown.]

Mr. COCHRAN. Well, we thank you for your patience and your attention to the presentations we have made to you, and we hope that they have answered some of your questions. We realize that in the process you may have some other questions, and that you may have some questions that are not connected with the presentations that we have made today that could cover other aspects of our program. We are faced each time that we come before you here with sort of a challenge to put as much into our presentation for the amount of time that we have available to us. But I would like to make another effort. I know it has been mentioned to you several times, about our ongoing and active work. It is continuing and going on. It is available for your review and if you let us know when you can participate, we would love to take you on a trip to Boston to the Lincoln Lab to see the DABS IPC work. I think it is a must for the people who are on this committee if it is possible for you to make it. Then I think some of the work in MLS when we have flight demonstrations such as the one the chairman participated in at NAFEC. We had aircraft flying the curved approaches and the automatic landings and things of this nature. Then hopefully we will shortly have at NAFEC our phase III equipment which will be nearly like production type microwave landing system equipment. We will have avionics that we can install on a variety of aircraft, and we would like to demonstrate to the members of the committee and have them see firsthand the potential possibilities of these systems. So, Mr. Chairman, we are at your disposal now to try to answer any questions. If we cannot furnish you the answer, we will furnish the answer for the record.

Mr. MILFORD. Thank you, Mr. Cochran.

I would like to accept your invitation. As a matter of fact I have made a note here. Our plans during the month of November and December are to do a considerable amount of traveling. Those members who can find the time to travel will visit not only FAA R. & D. facilities and installations, but also NASA. I would appreciate very much if you would supply us with a list of each FAA R. & D. project including the names of contractors where you have contractors involved, and the geographical location of where the actual work is being performed so that during November and December we can visit as many of these as possible. I, for one, learn a lot more kicking tires and looking at the actual hardware and talking with the people that develop it than I do in the very brief periods of time we have for formal hearings. We hope that a considerable number of our subcommittee members will take advantage of travel to get out and visit these installations. It would assist us if you would provide us a list. It also helps us to understand exactly which projects are being carried out.

Mr. COCHRAN. Yes, sir, we would certainly supply that for the record and to you.

Mr. MILFORD. Since these plans are now in the process of being drawn up, your compliance as quickly as possible would be appreciated.

Mr. COCHRAN. We will do it right away, and then we will offer also to have at your disposal some of the members of this team that we have here today to go with you if you feel it is required. If you do not want us along that is fine, too, but we are at your disposal.

Mr. MILFORD. Let me go into MLS just a little bit. From the outset I would like to say that I strongly encourage U.S. participation in ICAO and strongly encourage international cooperation in all air navigation matters, not only the selection of a landing system, but in all other matters.

But I am becoming concerned because our own national interests are coming to the forefront. We in this country have a crying need, as soon as we can get them, for small community systems for our growing commuter aircraft services. We have a national need, in many of our airports, to minimize the noise problem that we are facing. Our military has a need, that is becoming critical. In both Alaska and off the east coast, increased offshore oil developments are beginning to demand some type of air navigational and landing systems. With these in mind it appears to me that the United States is facing a critical need for a new type of landing system of the microwave type. I for one have no personal prejudice, one way or the other, concerning the debate between the TRSB and the Doppler. I am not personally a technician capable of evaluating these two systems. In that respect, let me get into some questions.

How much have we spent to date on MLS?

If you do not have a figure you can supply it for the record.

Mr. ALBRECHT. We have got some figures. Through 1976 we have spent $68 million——

Mr. MILFORD. $68 million total?

Mr. ALBRECHT. $68,106,000.

Mr. MILFORD. That is total to date?

Mr. ALBRECHT. That is total to date through 1976.

Mr. MILFORD. That would be through the two prototype systems that we——

Mr. ALBRECHT. Basically, yes.

Mr. MILFORD. The Bendix and the Texas Instruments systems.

Mr. ALBRECHT. Right. Now we have forecast and supplied to you what we expect the total expenditure to be. It is of the order of $110 million through 1980. We can give you that breakdown if you would like.

Mr. MILFORD. As I understand it, internationally we have pretty well settled on one of two types—the TRSB and the Doppler system. Is there any other system in contention here?

Mr. SHEFTEL. There is a German system which is a different technique from either of these two. There is the French system which is more than a landing system. It encompasses other functions. Both of these other systems are not as sophisticated a state of development as the Doppler and the TRSB, and the deliberations of ICAO have really boiled down to these two. Although the other countries have not continued to tout their systems in the working group, we feel they have not abandoned their interests.

Mr. MILFORD. But then for all practical purposes we have boiled down to a Doppler or TRSB selection?

Mr. SHEFTEL. That is correct, sir.

Mr. Milford. Now, I have heard recently that there is a technical problem that has arisen with the Doppler system. Can you briefly explain what that particular problem is?

Mr. Sheftel. Under certain conditions of physical objects on an airport which cause reflection, microwave reflections, there is an interference phenomenon that is manifest in Doppler which is not manifest in TRSB. This was discovered recently by simulations, computer modeling of the two systems, using the actual physical geometries of some existing airports—Los Angeles, JFK, O'Hare among others—and from this study work which was completed, as I said, sometime during this past summer, it was found that it would be difficult to conduct some of the category II operations and category III operations under these circumstances. It could also interfere with some of the curved paths. This is as I say inherent in Doppler. Now this was done under modeling and the information that we obtained has been presented to the working group. The British have it, they are in the process of reviewing it and they will explain their positions, we expect in November, it is a special meeting to consider this subject. We consider it limiting enough so that it will be questionable whether we would locate a facility like Doppler in an airport like Los Angeles because of its constraints.

Mr. Milford. In a recent trip to the Farnborough International Exhibition I had an occasion to visit the British equivalent to our NAFEC. They had installed and were operating their Doppler system. In briefings there I was told that they had resolved or would present a resolution to this particular problem that was uncovered in the Lincoln Lab test, which I believe you were referring to there.

Mr. Sheftel. Yes, sir.

Mr. Milford. Aside from that multipath problem, and assume that they could do as they have stated and resolve it, are Doppler and TRSB essentially equal in cost and performance?

Mr. Sheftel. They are very close. I believe it would be accurate to say that our position on this issue up until the time that the socalled flaw was uncovered through the simulation, I mentioned, was rather ambivalent. Although we felt that there were some significant advantages in TRSB, if the international body voted rather decisively for Doppler, we were of a mind that we would propose that policy here. We do not feel that way any more.

Mr. Milford. Again presuming that the British can satisfy technically a solution to this problem, are all aviation requirements satisfied by either of these systems?

Mr. Sheftel. Yes, sir, I think they would be.

Mr. Cochran. It would depend to some extent on the kind of information that was supplied when you say they worked out a solution to this problem. The solution that was worked out would have to reconcile the sort of theoretical problems that exist with multipath in the doppler system. In other words, it would not be satisfactory to just demonstrate it at a specific location or a number of locations that the system was capable of coping with those particular locations. You would have to resolve the issue with respect to the theory to make sure, don't you agree with that?

Mr. Sheftel. Yes.

Mr. MILFORD. Does any manufacturer or manufacturers stand to realize a significant profit in either type of MLS selection? In other words, would the selection have any sort of an impact on the balance of trade of either England or the United States?

Mr. SHEFTEL. I do not feel it would be important in terms of balance of trade. There may be advantages, but I believe they would be very short-term ones. The first jump kind of thing. The first buy might be an advantage to the company which was most familiar with it, but like in the case of ILS as time went on many suppliers got involved.

Mr. MILFORD. So there would not be any significant advantage whether the U.S. system won or the British system?

Mr. SHEFTEL. Very short term and I do not believe it is very significant.

Mr. MILFORD. Would our companies be just as capable of building the Doppler system as the British companies of building TRSB?

Mr. SHEFTEL. Of course, the company that has built TRSB is better prepared to build that than Doppler. Though he could compete much better if he were bidding on a quantity in a TRSB arena than he could with Doppler, it would be short term.

Mr. MILFORD. In FAA's evaluation of these two systems before it reached the international stage, did you have American companies build a Doppler system and submit it for testing?

Mr. SHEFTEL. Yes, sir. We developed the Doppler system. It was an idea that was born in the United Kingdom, and we exploited it. For a period of time our program pursued both the TRSB and the Doppler, and we did tests and evaluations, and that is how we finally did the discrimination and decided on TRSB on the merit of work we had done ourselves. We did give some of our equipment to the British, and they began their program from that point. They used some of our equipment and built from there.

Mr. MILFORD. You mentioned that the alleged defect in the Doppler system turned up in, I believe, a computer test of some type?

Mr. SHEFTEL. Yes, sir, a computer modeling of the system performing in the real environment.

Mr. MILFORD. In other words, you did not actually take the equipment and install it at an airport and test it as such?

Mr. SHEFTEL. No; that has not been done although we did go to the airports in question and make some individual measurements just to be sure that some of the inputs to our model were correct like the reflectivity factors of the interfering objects.

Mr. MILFORD. Of course, there is obvious differences of opinions in the international group. Would FAA have any objection to allowing the British to take their system and install it in an actual field that supposedly presents this problem and test it there?

Mr. SHEFTEL. We were very informally approached on that possibility, and we advised the British that we were willing to discuss such a test.

Mr. MILFORD. Again, let's get back to our own national interests, which gives me great concern. If the multipath problem were solved by the British would the FAA agree then to abide by a simple majority vote in ICAO rather than a near unanimous decision? In other words, it appears from observations and reports I have received from the technical group that we are going to lose either way we go in the sense that we cannot get a unanimous vote out of the group.

Mr. SHEFTEL. In a simple majority vote—there are a number of voting stages—now if a simple majority vote took place in this present group which is a working group of the all-weather operations panel consisting of the 10 members that I mentioned, a simple majority like a 6-to-4 vote. The ICAO process is not yet completed. It has to go to the Air Navigation Conference Commission—30 members. It is possible that a group like that would turn the vote back and say that they would not settle for a 6-to-4 vote. This is some conjecture that is going on right now. Would they act on a 6-to-4 vote and their action in effect be taken as their endorsement of the panel, its findings, and then go to the worldwide vote? So it is not a question of the United States being able to make a decision based on a simple majority vote of this current group.

Mr. MILFORD. Well, in effect you are telling me that we may be facing a stalemate situation with no decision at all.

Mr. SHEFTEL. There would be policy decisions possible along the way. We could decide to act after the first vote took place in this panel. For example if a simple majority were to come out in our favor, it is a policy option which has not been made yet that we might proceed nationally based on a simple majority. That is an option that has not been decided, but it is there.

Mr. WYDLER. If the Chairman would yield—what would you do if the British decide that they do not want to go along with your system and they are going to keep using the doppler system?

Mr. SHEFTEL. They have made that statement that if we won they would not go along with our system.

Mr. WYDLER. What happens then?

Mr. SHEFTEL. I guess that did not answer your question.

Mr. WYDLER. No.

Mr. SHEFTEL. If our system did win and they said they would not go along with it, we would implement our system. The effect if they are not going along with it does not have that great an impact on us as far as implementation in their country.

Mr. MILFORD. Again, I would strongly encourage international participation to the very maximum extent we can. Again, at the same time, we have also got to recognize our own national need which is becoming very pressing, and I would simply hope that we could get a decision from our international group and that the United States or England or anybody else would not be forced with the situation of having to go on and move because of the apparent inability of our international groups to resolve it. The All Weather Group is a technical group. Their decisions are to be based on technical merit as opposed to any nationalism or politics. Is that basically correct?

Mr. SHEFTEL. That is the way it is supposed to be. I think we could speculate otherwise. In fact I think there is good basis to speculate that there are other things motivating this group than purely technical consideration and that is not putting them down. For whatever national reasons specific members of the group, like the countries that are touting their own devices which are not yet developed to a sufficient state of sophistication, may be motivated to delay the process for their own benefits. Maybe they would have a crack at it if the process were to drag out.

Mr. WYDLER. Would the gentleman yield to me? Why would the U.S. Army go along with that kind of procedure by the British?

Mr. SHEFTEL. The Department of Defense in general is pretty much working hand and glove with FAA on this subject of the international resolution.

Mr. WYDLER. Do I understand that on the voting on this matter in the steering committee that the U.S. Army voted—Mr. Kendell, Lieutenant Colonel, U.S. Army, voted in favor of the Doppler?

Mr. SHEFTEL. What steering group is that. There is no Army member in this working group we are talking about.

Mr. WYDLER. This is a central assessment group.

Mr. COCHRAN. This was back during the technical selection.

Mr. WYDLER. This was sometime ago.

Mr. SHEFTEL. Yes. After the phase I mentioned earlier where FAA had developed both the Doppler and the TRSB and tested them, and they had this technical assessment group which consisted of members from industry and Government. At that stage it was a very close race. That is when I mentioned we were somewhat ambivalent——

Mr. WYDLER. All that might explain this fact that apparently a lot of military thought the Doppler was better. It might explain that maybe the British are not just doing it for nationalism reasons. They may really feel it is a better system. There is quite a lot of feeling in this country that the Doppler is better, too.

Mr. ALBRECHT. That has to be past history because I think you will find the Army and DOD are solidly behind the TRSB technique at this point.

Mr. SHEFTEL. Now, one of the benefits of all this time passing in this very vigorous competition is that we have done more learning about both systems than we would have if we had just ended the process at that point. The vigorous competition has forced us to do a lot more in-depth testing. This is really where the flaw in the Doppler came out. We may not have done that work before implementing had we not had this competition.

Mr. WYDLER. The thing that bothers me about your position is that you take the position that if you do not like the way it comes out at the vote, you may not go along with it. Then you say that if the British do that with the Doppler system, that is pure nationalism. I am a little confused why one is different than the other.

Mr. SHEFTEL. I would not say we would not go along with it arbitrarily.

Mr. WYDLER. They would not say they would not go along with it arbitrarily either. Neither side is going to say that is their reason, but I mean that is what it comes down to. If you are not going to, you are either going to be bounded by the international agreements or you are not. In other words, what the devil do they mean?

Mr. SHEFTEL. Well, the decision is ahead of us, I think you would say. We have not decided not to go along with it. The decision can be made as near as November of this year when they will be a first straw man vote of that working group. We will begin to get a first indication in November, early December, from that working group as to how they are going to vote. They are being polled, straw man polled.

Mr. WDYLER. Look, I am all for the United States of America. But I agree with the chairman here. It sounds a little fishy to me when you are telling me quite frankly that you are eliminating the Doppler on a computer readout of some kind, and I think that if you want to do it on that basis maybe it does have these weaknesses you talk about, but before you make that the total answer to your problem which I can see it to be, you should do exactly what the Chairman suggested anyway, and that is give it a real field test. Not do it on the basis of some computer——

Mr. MILFORD. I did not mean to suggest that they have eliminated anything. I do not think they have. The thing that I am suggesting is that we need to get a decision here from our international group. As I understand it, you will abide by whatever that decision is if it comes out.

Mr. SHEFTEL. I think we would have to examine what it is. If they eliminate—I think Mr. Cochran mentioned earlier—if they put this major technical issue to rest, then we could abide by it.

Mr. WYDLER. Why don't you put it to rest. That is what we are suggesting. Put it to rest in a solid way, so you don't come in with a lot of computer readouts and say, here satisfy us that this is not so. How can they do that. Maybe the way they can do it is give you a real test.

Mr. COCHRAN. Let me see if I can clarify that particular point. In the first place, there are some theoretical configurations that went into the formulation of the modeling. These theoretical considerations were studied indepth by all of the parties in the process including the United Kingdom people and ourselves. We agreed on the modeling technique and the way that we would examine the system against these models. So it is not something that we have come about arbitrarily or a one-sided thing. Now there are some very deep studies that have occurred with respect to this. An examination of this model has shown some deficiencies that relate to the theory of operation of the two systems. Until those sort of problems are reconciled, then this is not something that we can just disregard. We have to look at that in terms of the kind of solution that comes up. A simple demonstration at one location under some limited circumstances because of the configuration of that particular location might not be sufficient to demonstrate that the problem had been solved. So it would take more than just a simple demonstration. There has to be some connection between that demonstration and the theory that is involved in the modeling and theory that is involved in the generation of the signal formats themselves. So that is the only consideration I am making there.

The United Kingdom people first came to us, tentatively, from several layers down. Their top people have not asked us to test the system as far as I know. We certainly would consider a test properly—but until we are formally asked, we are certainly not going to do it, because we do not think that we would be considered objective in doing such a test unilaterally. So our test would be little more than what our model has demonstrated if we did it ourselves. If they did not have a hand in it, and I suspect that when they have done their studies and they have looked at it, they will come to the same conclusion. The analysis has been made and furnished to them. By the way, the first people who knew about this outside of ourselves were the British. We have furnished the analysis to them before we brought it up in the working group meeting. So we did not try to subvert the technical considerations at all. We have a harmonious relationship with the working level and the other people's working level with the United Kingdom people. We are on a first-name basis working back and forth. We have a technical disagreement at this point. Both of us are attempting to resolve that technical disagreement with our best efforts.

Let me also say this. Insofar as I know, we are the only country right now with a pressing need. It would be highly desirable in my view that our civil system and our military system be compatible systems, so that we can make compatible use of the equipment in joint use of airports and things of this nature. This cooperation has increased in the past and is expected to increase even more in the future. It would be highly desirable that we do that. Our military people have a need for such a system. It is incumbent upon us as a country to try to move ahead with it. We also have the only place in the world where we have a frequency channeling problem because we have numerous ILS's in some of our locations. In fact, I suspect that in places like Chicago, Los Angeles, and in the New York area, we may have more ILS's in those particular locations than some nations have in their entire country. We do have a frequency problem. We also have a number of developing airports who want ILS systems. We therefore, have a compelling need to get on with it. Many, many of the nations in ICAO have absolutely no need. Their needs through the year 2000 can be satisfied with an ILS. They have very few systems and their problems are limited. For example, curved approaches are not important to many of them. So they could continue the existing process for some time. So we do have that difference. Our country has a big need, and I agree with the chairman that we have a national interest in getting on with the program.

Mr. Milford. I will withhold additional questioning for a later time so that some of the other members here could—Mr. Goldwater?

Mr. Goldwater. You stated that the demonstration in itself would not prove anything.

Mr. Cochran. No, sir. If I stated that——

Mr. Goldwater. Well, the point I want to make here is that there seems to be some sort of international stalemate as to which is the better system, and there is still some disagreement even in this country insofar as to which is the best system.

Would not the best approach or an approach to solving this be to in essence demonstrate both systems side by side at more than one location throughout the United States? It would be catastrophic if we violated the international process that has been established and imposed our might and our will upon other nations when we perhaps could arrive at this through some sort of arbitration or in essence actually demonstrating the system side by side based on the same theory, the same formula, the same input. Why can't you do that?

Mr. Cochran. Well, I will answer that. I cannot give a real simple answer to it, but I will attempt to keep it as short as possible.

In the first place, we went through a comparative process a very very rigorous comparative process between doppler and TRSB.

Mr. GOLDWATER. Those are on paper?

Mr. COCHRAN. No, sir, we did it in practice, too. We built as many doppler systems as we did TRSB in the technique selection phase, and we did a thorough job. We had very competent contractors who were just as competent as the two contractors that we have now working on the TRSB technique.

We had four contractors at that time—two supporting the Doppler technique and two supporting the TRSB technique. We flew them, we analyzed them from a theoretical viewpoint. We did every conceivable kind of test to attempt to discriminate between those two systems. We involved I think almost totally all of the people in this country that were familiar with instrument landing systems, precision guidance systems. We had consultants, the corporations had consultants, we had advisory committees, we had steering committees, we had executive committees that involved any number of people, and we went through a very, very well defined and layed out process. Now the decision did not come off unanimously in favor of TRSB at the decision point, but it did influence—as the discriminators were sufficiently great enough for the group—the technique selection group to select the TRSB system over the doppler. That is after we did parallel testing of these two systems. I think we should not overlook the fact that we have tested very thoroughly doppler systems in this country ourselves. We made a comparison and the group charged with the selection made the selection. A review group composed of senior officials in FAA, the Department of Transportation, NASA and the Department of Defense reviewed that selection and decided that the selection was a correct one.Th e administrators of NASA, FAA and the man charged with that responsibility in the Defense Department concurred with that review group. So the technique selection was a totally national process that involved a close comparison of these two systems.

Mr. WYDLER. Well, I suppose what we want you to do is do it over again until you come up with the doppler. [Laughter.]

Mr. WYDLER. I know there is a lot of money involved in these arguments and there is a lot of pressure coming from every direction on everybody concerned and I suppose you will never resolve the fact of which one is better, but I wish you would possibly listen to what the chairman said about this new unique problem that you raised about the doppler because there should be something more than just theory that is thrown at the other side. I would be a little upset about that myself.

Mr. COCHRAN. Well, let me explain my position on that, and I will admit that it is my own opinion and it is well founded I hope, I trust that it is. It is founded on experience from the ILS system with which I have been involved in for some 27 or 28 years. I have been involved in some phase of the technical work involving the electronic ground system during that period of time. I have been involved in it from a development phase, from an installation phase and from a maintenance phase. So I know a lot of its problems.

One of the things I have come to appreciate over that period of time is that the theory is important. It is hard to imagine 20 years from now what the sites will look like. What kind of siting conditions we will be faced with. It would be hard for instance when we started with ILS's to understand a row of hotel buildings or other things we have got in Los Angeles—parallel on the runway.

It would be hard for us to have understood the size of the terminal buildings at the new Dallas-Fort Worth Airport and the size of a hotel sitting up just a few degrees off the center line of the runway. We have been faced over the total history of the ILS system with severe multipath reflection problems which have challenged us and caused us to spend many, many dollars, and many, many flight hours resolving problems at local sites. We knew that from the theory from the beginning. I am just pleased that we will recognize some theoretical flaws early on in this system and fully reconcile it prior to the adoption of a system that has a great potential for the future. We are talking about a system, Mr. Wydler, that I believe, if it is adopted—and it will be adopted, whether it is done this year or some other year ahead of us—when it is adopted, it will probably be around and used for 30 to 35 years.

Mr. WYDLER. Well, I just wanted to make clear—my remark about the Doppler was facetious. You are the gentlemen who are charged with this responsibility, and I agree we should try to get on with this. You are giving us the period of 24 years for its implementation. I presume this will be part of the FAA research and development budget for that period of time.

Now, what I would like to try to get to is rather put it in terms of what you are doing this year and are going to do for the next 24 years—what was it that you did last year, what was it that you did in years past that was implemented or came to you and became useful to the aviation industry last year? Would you tell me what that was?

Mr. COCHRAN. You mean not connected with the microwave landing system?

Mr. WYDLER. No, no, in general. The microwave, I have heard enough about that piece of equipment. [Laughter.]

Mr. COCHRAN. All right. Well, I will point to one or two things, and then I will let my compatriots point to some others, but in the first place I think the conflict alert, the business of providing an alert to the controller when two airplanes are possibly going to conflict——

Mr. WYDLER. That was implemented last year?

Mr. COCHRAN. Yes, sir. It was fully implemented in the airspace above 12,500. We are still doing development work down to the ground.

Mr. WDYLER. OK.

Mr. COCHRAN. But we have done that. We have deployed the wind shear equipment that we have been working on.

Mr. WYDLER. But that is part of something that is going to be ongoing as I see it, for many, many years.

Mr. COCHRAN. Correct. But it is done. We also have out of that the wake vortex problem which is a parallel problem. We will be providing wake vortex advisories at O'Hare field very shortly. Those advisories with the proper monitoring should allow us to close up the spacing between aircraft and result in a significant increase in the number of aircraft operations and a reduction in delays at O'Hare. That proposition is very close to being——

Mr. WYDLER. I understand your ongoing programs, I mean the ones that were explained to us here today, but what I am trying to drive at—I am trying to look at what this all results in. I am just trying to get a picture in my own mind. What did we accomplish that came to fruition last year?

Mr. COCHRAN. You mean installed?

Mr. WYDLER. Yes; you did it. Give me an idea of what we did really come out with as a product. That is the only way I can think about it because we talk about these things—we are going to be developing this program over the next quarter of a century and so on. It is hard to really understand what the result of it all is.

Maybe you could put into the record a listing of the things that you feel were accomplished last year as a result of prior years R. & D. work of the FAA.

Mr. COCHRAN. Well, I had a number of them I wanted to tell you about, maybe I did not tell you about the right ones. I told you about some that you were already familiar with, but we did finish the development on a new beacon antenna—the first 10 of which are now in the process of being deployed. The first one was deployed just about a month ago at Washington National, and the other nine will be deployed. There will then be a procurement of about 150 of those. That resolves some beacon reflection problems for us in the terminal area and that is one end product.

[The information requested follows:]

1. In July 1975, we completed the initial automation of our 20 EnRoute Air Traffic Control Centers with Stage A.

2. The U.S. submitted their proposal for the MLS International Standards to ICAO. All world-wide proposals will be evaluated this year.

3. Minimum Safe Altitude Warning (MSAW) for the terminal area became operational at Dulles.

4. EnRoute Conflict Alert for 12,500 feet and above was completed and is functioning at all centers.

5. The Meteorological and Aeronautical Presentation System (MAPS) was operationally tested at the EnRoute control center at Leesburg, Virginia.

6. The Baseline National Automated Data Interchange (NADIN) Communication system was completed. Work is proceeding for the documentation of enhancements.

7. Wind Shear/Wake Vortex test equipment has been installed at Chicago. R&D efforts will continue based upon results of this evaluation.

8. Provided Airport Surface Detection Equipment (ASDE–2) modification for field systems resulting in the drastic reduction of the background clutter.

9. Completed Human Factors evaluation of the EnRoute controller display background lighting as it relates to eye strain and fatigue.

Mr. WYDLER. How far down the road is this automatic landing system that you keep proving you can do over and over again—when do you think we will ever put that into operation?

Mr. WEDAN. 1979 is the date that we are planning now to have that in operation.

Mr. WYDLER. You mean actually a commercial jetliner coming into an airport with zero visibility will turn the machine on and it will land the plane?

Mr. WEDAN. 1979 is the date the equipment will begin to appear.

Mr. COCHRAN. You mean for the microwave landing system?

Mr. WEDAN. For MLS.

Mr. COCHRAN. Now, we have got to be careful about what we are talking about. There are many, many coupled approaches being made today where the aircraft are currently flying with the aircraft coupled to the instrument landing system and some of them can fly to the point of touchdown, and it is currently in operation that way in some places. Many of the category II approaches being made today, that is where you are going down to runway visibilities of around 1,200 feet, are being made in a coupled mode.

Mr. WEDAN. I would like to give you an example of one output here that is really part of a longer range thing, but it does represent a discrete output.

We have a program dealing with airport surface traffic control, and one of the major problems that we have today is with the existing radar equipment. We are out to develop a new capability in the radar that has better rain penetration for example. The existing inventory had to be modified because of its poor reliability. We did produce fixes in terms of kits that were taken out to the field and the tube type chassis were replaced with solid state components. Things of this nature raised the operational capabilty of the existing radar prior to the time that the new radars will be developed and deployed.

Mr. WYDLER. A lot of your work as I was listening to it was to increase the number of aircraft that could be landed on a particular runway so they can come in closer together, if I understood what you were explaining. How is that going to fit in with trying to reduce jet noise? Is not that just the opposite effect to your increasing the frequency of the planes coming in on the flight path over the people around the airports?

Mr. WEDAN. Of course, the microwave landing system program is directed to that problem. We have been provided an alternative to the approach paths to the different types of aircraft involved that would tend to reduce the noise, the total integrated noise, even though there is a larger number of aircraft being landed.

Mr. WYDLER. You can explain that one to me at length sometime as to how that one will work. Let me understand—you are shortening the distance between the planes, I guess that is basically what you are doing. You are putting them in closer together. Is not that going to create all kinds of problems with this wake vortex problem that you are studying?

Mr. WEDAN. The wake vortex program was intended to determine when there is a hazard associated with wake vortices, and if there is, then the aircraft spacing is stretched out to a larger distance. If there is not a hazard, then other factors would be the determining reason for spacing an aircraft, for example, how long it takes an aircraft to land and get off the active runway. That is a limiting factor that would prevent aircraft being spaced closer than we have today.

We have got to be out of this room at 2 o'clock and we do have a few other things we want to get on the record. If extending our hearing does not present a hardship, we will just keep on going through the lunch hour.

Mr. Cochran, we did not discuss to any extent this morning Aerosat, and I do have some questions on that.

First of all, I would appreciate it if you would supply for the record and update including background on Aerosat, the status of it, the history of it, and where we are now and where we are going with Aerosat.

Mr. Cochran. Yes, sir, I will supply that for the record.
[The document follows:]

STATUS REPORT ON AEROSAT

Background

Communications between civil aircraft operating over the broad expanses of the Atlantic, Pacific, and Indian Oceans and the Air Traffic Controller responsible for the airspace in which the aircraft fly is currently accomplished primarily by High Frequeny (HF) radio. Sophisticated air traffic control systems using the direct pilot to controller communications and radar separation that we have over the United States do not exist over such oceanic areas and over the major land masses of the developing continents of Africa and South America. HF is also used in these land areas. In these areas, communications used between pilot and controller to assure a safe, comfortable, and to the maximum extent possible, fuel efficient flight utilizes a system which dates back to World War II days. The pilot, calling on what is oftentimes unreliable HF radio, talks to a radio operator who in turn relays the position report or message to the controller. In the event the pilot cannot reach the radio operator due to poor transmission conditions, which occurs frequently and particularly during solar magnetic storm activity, he tries other frequencies, and sometimes a second or third ground radio station which then must relay the message to the proper controller.

International civil aviation authorities recognized that such a cumbersome and unreliable communication link would not support the continued growth of international aviation. In particular, it would not safely permit the closer spacing of aircraft in altitude and distance which is necessary to support the projected growth of aircraft movements in the busy oceanic air lanes. The International Civil Aviation Organization (ICAO) in the 7th Air Navigation Conference of April 1972, called on member states to address this technical communication problem over the oceans and encouraged them to develop a reliable and efficient means of assuring positive communications between aircraft and the ground. AEROSAT is the resulting international civil aviation cooperative program adopted by the United States, Canada, and nine European countries represented by the European Space Agency (ESA). It is specifically designed to respond to the ICAO need for experimentation, test and evaluation of satellite technology as a means to accomplish this major jump in improved communications and air traffic control over the oceanic areas. We believe, however, that such a system is also usable over land areas where ground facilities are currently inadequate.

Agreements to conduct the AEROSAT program are described in a Memorandum of Understanding (MOU) which was signed in 1974. The entire Atlantic Ocean basin including the land masses of Africa and South America will be the site of the AEROSAT test and evaluation program which will commence soon after the first AEROSAT satellite is launched in late 1979. Ground facilities will be placed in the United States, Canada, and Europe within the framework of a coordinated international effort involving airlines and the ATC activities of civil aviation authorities to insure that the AEROSAT test and evaluation effort will provide test data results applicable to the evolution of a system for eventual operational usage. The FAA will lease the AEROSAT satellite capability necessary from a common carrier (COMSAT General) who will be a co-owner along with ESA and Canada.

Benefits

The high frequency (HF) air ground communication system employed in the North Atlantic (NAT) today for air traffic control purposes is organized into frequency families to cope with the uncertainties of HF communications. Oceanic traffic growth projections indicate that the four frequency families currently employed in the NAT will saturate by the early 1980's. Congestion in the HF spectrum will limit expansion of the HF system to five frequency families which will extend its useful life to the mid to late 1980's, assuming the demand for ATC and operational control communications does not exceed the current forecast.

The economic penalties incurred by international civil aviation today as a result of flying non-optimum routes and altitudes in the North Atlantic is estimated at $7–10 million annually. These penalties are estimated to double by the mid-80's and to double again by the mid-90's if the capacity of the NAT track system is not increased in the vicinity of the most desirable flight paths. The planned adoption of minimum navigation standards will permit the introduction of reduced lateral separations and closer in-track spacings which will increase the NAT track system capacity to some extent, but not enough to curb the continued growth of economic penalties. Dramatic increases in system capacity achieved through reduced separation standards and user acceptance of these reduced separations between aircraft require an improved ATC system supported by reliable real-time satellite communications and surveillance. While the introduction of single-sideband improves the situation, it is not expected that the improvement will be sufficient to enable attainment of this benefit.

Technical disagreements exist over the choice of some of the operating frequencies. In order to resolve these issues, FAA has assured Congress and the U.S. airlines that the VHF frequency band will be evaluated side by side with L-band to provide comparative test data. The AEROSAT test program is designed to permit this comparison.

The potential benefits to be derived from a satellite-based ATC system in the oceanic airspace include improved communication services, more efficient utilization of the airspace, as well as reduced fuel and time penalties. Furthermore, the present nature of oceanic ATC and the fragmentation of the oceanic airspace into many Flight Information Regions (FIRs) is due in large part to the limitations of the HF communications system. A satellite-based system could reduce the number of oceanic FIRs to the practical minimum, thereby significantly reducing the total cost of the oceanic ATC system and consequently moderating the current rapid growth of en route user charges.

Preliminary studies have indicated that a satellite-based ATC system deployed in the Atlantic and Pacific during the late 1980's could result in an estimated annual cost savings of $77 million—the majority of this savings being due to the consolidation of oceanic ATC facilities. These savings are in addition to reducing the annual cost penalty due to flying non-optimum routes and altitudes. Consolidation of facilities without implementation of satellite communications does not produce savings since the increased cost of remoting HF radio communications equals the savings achieved through the consolidation of facilities. In addition, such a satellite-based ATC system could serve the needs of international civil aviation in the low density regions over major land masses such as Africa and South America, thereby diminishing the need to develop costly land-based en route systems. This feature provides an estimated cost-avoidance potential of several hundred million dollars which would alleviate future rapid cost growth of en route user charges.

Cost of the AEROSAT program

The principal cost elements of the program are the satellite development and launch costs which we share (47% for United States) with our international partners through our lease with COMSAT General and the cost of the U.S. test configuration consisting of the design and development of airborne and ground equipments, and the cost of providing test personnel and aircraft.

ESA and Canada will share (47% and 6% respectively) the remaining 53% of the satellite costs and each will construct their own test configuration each of which will be functionally equivalent. Costs expended to date by the FAA have totalled approximately $5.4 million out of a total estimated program cost of $125 million. Included in this total estimate is approximately $3.4–$4.0 million of anticipatory costs of COMSAT General which will be covered under the lease contract with them.

Our current information indicates that ESA's direct cost for their 47% share of the satellite system is approximately $56 million. Canada's estimated cost is approximately $7 million. FAA's cost (as reflected in our estimated budget requirements) is approximately $87.5 million; somewhat higher than ESA's because they are owners, we get our 47% share through our lease with COMSAT General and we must completely pay for the cost of adding VHF capability to the satellite (it is a U.S. only requirement).

FAA's cost for the airborne equipment, ground equipment and test program is estimated at $37.5 million. We have no information on ESA's and Canada's estimates and can only assume similar figures since their responsibilities on the program are similar to ours in these areas.

MILESTONES AND SCHEDULE

U.S. Reaffirmation to International Participants. January 1976.
Co-owners Release RFP For Space Segment. March 1976.
FAA Releases RFP to COMSAT General. August 1976.
FAA Receipt of COMSAT General Proposal. October 1976.
Co-owners Complete Negotiations with GE-COSMOS for Space Segment. October 1976.
FAA Award of Avionics Contract. November 1976.
FAA Award of Communication Center Contract. November 1976.
FAA Sign Lease with COMSAT and Co-owners Award Contract for Space Segment. January 1977.
Launch of First Satellite. December 1979.
Begin AEROSAT Test Program. February 1980.
Launch of Second Satellite. August 1980.
Complete Test Program. February 1983.
Issue Report and Recommendations. December 1984.
Provide Draft Standards and Recommended Practices to ICAO. January 1985.

Effect of program delay

The possibility of significantly delaying (say by one year) the AEROSAT program was considered. In view of the fact that the co-owners have already entered into negotiations with the GE–COSMOS team on the basis of the U.S. reaffirmation to the program back in January, a further U.S. imposed delay at this time would probably be catastrophic to the program. As a result:

Reinstitution of another program to meet ICAO's needs would realistically take 5–10 years. We would be then be unable to provide timely technical inputs to ICAO to meet the projected need for an operational system to alleviate saturation of HF communications in the mid-late 80's and to reverse the current trend in user charge growth.

Further U.S. delay or withdrawal after the difficult and protracted negotiations leading up to and following the signing of the MOU would be viewed by our foreign partners as a breach of faith. It would be cited, by them as evidence that the U.S. does not take seriously its stated interest in cooperative international space programs.

The credibility of the future use of the MOU as a vehicle for international agreements of this type would be eroded. It could be necessary to resort to treaty arrangements in the future.

Other current international cooperative ventures could be negatively impacted. A feeling of suspicion and distrust could conflict with our desire to effectively implement our agreement with Europe on the development of the Space Shuttle.

If the program were not, by some chance, cancelled by our partners, the actual portion of the program dollars spent in the U.S. would further decrease. The developing technological capability in Europe during the delay period would enable Europe to retain much of the 3rd tier contracting on the space segment (the 47–47–6 share pertains to 1st and 2nd level only). It is felt that the delays incurred up to the current time have already substantially eroded the U.S. portion. Further delays would erode it more.

If program were cancelled, it would take many years to re-establish; quite possibly in a manner similar to INMARSAT. In the meantime, other countries would probably become involved; notably the Soviet Union. This would substantially reduce the influence of the U.S. in establishing the technical and operational characteristics of the oceanic system and our general influence in developing international aviation standards. The result would be that U.S. industry would be in a weaker position to supply operational avionics equipment on the international market and our balance of payments would suffer.

Consideration of alternatives

The goals of the AEROSAT program are to develop and test complete satellite-based oceanic ATC systems. In order to do this, a multiple channel satellite capability of sufficient power to operate with the small, low gain aircraft antennas and operating in the allocated VHF and L-band frequency bands is required. Alternative techniques which do not provide this capability will not permit the development of necessary operating procedures and technical system data.

The FAA has examined the potential alternatives to achieving AEROSAT program goals. These have included all commercial, military and experimental satellites existing or planned with coverage over the oceanic areas. Many of the potential alternatives were unsuitable because they have been designed to work with relatively large, high gain antennas at fixed locations on the earth or on large, slow moving vehicle (i.e. ships). MARISAT, INTELSAT, the domestic communication satellites, DSCS and FLEETSATCOM all fall into this category. In addition, most of these operate in frequency bands which cannot, by international regulation, be used by aircraft. None of them provide both VHF and L-band capability of sufficient power to permit the frequency performance comparison necessary.

NASA's experimental satellites (ATS–1, 3, 5, & 6) have been used in the past to conduct technology experiments and to establish the basic feasibility of providing communication services to aircraft. The satellites, in addition to being near the end of their useful lifetime and of marginal reliability for future experimentation, do not have sufficient capability nor the proper coverage of the aircraft routes in the Atlantic to support the necessary system experimentation.

The FAA also examined the capability offered by GPS/NAVSTAR as a potential alternative and has found it largely unsuitable. GPS is designed to provide signals for navigation only and provides no communication capability. In order to provide the benefits previously outlined, at least two-way communications to the aircraft and probably surveillance are needed. GPS, therefore, does not satisfy the requirement. It is not considered feasible to augment GPS to provide communications to aircraft for two major reasons: the additional power needed on GPS would nearly double its weight, requiring an entirely new satellite design, and the GPS orbit, configured to provide worldwide coverage for navigation, is unsuitable for communications. AEROSAT will use a geostationary orbit, as do virtually all communication satellites, which simplifies the control needed. The signals radiated by GPS can, however, be used in combination with the AEROSAT communication capability to provide a form of surveillance for ATC purposes. We are planning a comprehensive experiment with this combination of systems during the AEROSAT Test Program.

Mr. Milford. Briefly here I would like to know exactly what our requirements are for Aerosat?

Mr. Blake. I think there are probably three main areas where we feel substantial improvement is needed in the control of traffic in the oceanic airspace. As you know, we use high frequency air ground communications systems in the North Atlantic, for example, as well as throughout the world to control traffic in the oceanic area. This high frequency radio system has been organized into families of frequencies to accommodate the time of day and time of year variations in the high frequency communication, but at best it is a poor system and lacks the reliability you need for high capacity in the oceanic area.

Our projections, based on the current four families of frequencies, indicate that we will reach saturation in the North Atlantic area during the early 1980 time period.

Mr. Milford. Excuse me. That saturation presumes one-on-one voice communications?

Mr. Blake. It presumes that we will continue the current type of air traffic control system and methodology that we are using——

Mr. Milford. And you reach saturation when?

Mr. Blake. With the current four families, we will reach it in the early 1980 time period. Now in examining the possibility of additional frequencies it does appear that one more family may be available which will put off the data of this saturation to the mid to late 1980's.

Mr. Milford. Now let me again interrupt you right there. The original projections involving Aerosat were made when, in the 60's?

Mr. BLAKE. Yes.

Mr. MILFORD. And at that time the projections had anticipated considerably greater growth in air traffic than has proven to be the case, as evidenced by the present equipment excesses. Is that same projection the one that would reach saturation, or have we reprojected it?

Mr. BLAKE. No, the figures that I will give you today are the results of the current forecast not the previous one. There are two other areas that we feel are important as well as the frequency saturation one.

The economic penalties incurred by the international air carriers today as a result of flying nonoptimum routes and altitudes in the North Atlantic are currently estimated at about $7 to $10 million annually. We expect these penalties to double again by the mid-1980's and to double one more time by the mid-1990's if the capacity of the North Atlantic route system is not increased.

Mr. MILFORD. May I interrupt you there because that statement bothers me.

Why are not the air carriers concerned about this penalty? They above all should recognize a loss of income and become more disturbed about it than anyone else. Yet the air carriers, the ones I have talked to, are very much opposed to this project.

Mr. BLAKE. We are looking ahead and fully realizing the development time that it takes to bring any of these programs to fruition, and I might point out that while the loss today is $7 to $10 million, approximately one-third of that loss accrues to American carriers. As the traffic continues to grow this will become more significant in the late 1980 time period. The only way we can see for increasing the system capacity and getting user acceptance of the reduced spacings, both laterally between the routes and between aircraft on the routes is to provide reliable satellite communications and surveillance in the high density parts of the oceanic area. While the traffic has dropped off, the need for such improvement is still in the late 1980 time period.

A third area which is becoming important, and one which the airlines are beginning to feel, is the real economic pinch relating to user charges. The present nature of our oceanic air traffic control, and also the fragmentation of the oceanic airspace in the many flight information and control regions is due in part to the limitations of the high frequency communication system. A satellite based system could significantly reduce the number of oceanic control centers to a practical minimum, thereby reducing significantly the costs of providing these air traffic control services in the oceanic areas which would moderate the rate of growth of user charges to that type of service.

Now preliminary studies have indicated that a satellite-based ATC system deployed in the Atlantic and Pacific during the late 1980 time period could result in estimated annual savings of about $77 million and the majority of these savings are due to consolidaiton of the oceanic facilities. I should point out though that the consolidation of facilities without implementation of the satellite communication link would save you practically nothing as you would eat up the savings in the cost of remoting the communications from the few remaining centers to the places where the high frequency communication stations must be located to cover the airspace. So these three areas I think all point to the same objective of providing communications and surveillance capability in the late 1980's, and we feel we can meet the demand, reduce the route separations, provide the more optimum tracks if this plan continues to be followed.

Mr. MILFORD. You testified earlier about the updated system where data links would come into play in the transmission of air traffic control instructions. Could not data links run just about as well on high frequency as VHF or other frequencies?

Mr. BLAKE. Well, the problem here is one of reliability of your communications link. One of the reasons why the longitudinal separation between aircraft on oceanic tracks is about 120 nautical miles is the fact we have to be able to operate safely during periods when we lose communications over perhaps as much as one-half of the transatlantic trip.

With reliable communications which we are not able to achieve with high frequency radio, we feel we can reduce these separations considerably for a gain in capacity and travel. So it is more a matter of reliability than it is whether you send information in digital form or by voice. Obviously, to the extent you can send it in digital form you will utilize whatever communication channels you have more efficiently. Certainly when you get reliable satellite communications you can have a large number of aircraft with the digital data link system.

Mr. MILFORD. Last year the subcommittee asked FAA to investigate the possibility of making Aerosat compatible with Navstar. What is the result of this investigation?

Mr. BLAKE. We have taken really two very significant steps in this area. The first one relates to the Aerosat test program with the first Aerosat satellites. We are planning to include in the experimentation that we do using Aerosat a modified set of avionics equipment in the test aircraft which will allow us to accept the signals from the GPS satellite system to generate the navigation position in the aircraft and to relay that back through the Aerosat communication channels to provide a more accurate position to the ATC control centers.

Now the second step we have taken and here we are looking at the followon operational system, the one that will be deployed in the late 1980's or early 1990's.

We have established an interagency task force and we have included in that task force members from NOAA, from NASA, from various areas in the Department of Defense, and from the Office of the Secretary of Transportation and from the Department of Commerce, the Maritime Group. This group is considering the various alternatives that may be available for the consolidation of satellite services for operational systems for the late 1980 time period. This group will be meeting through the next several months and will come up with some joint program recommendations at the end of that time which we will be able to pass on to you. So the action has been started.

Mr. MILFORD. Last year this subcommittee asked the FAA to work out alternative funding arrangements for Aerosat so that the FAA R. & D. program would not have to bear the brunt of this funding. Have you arrived at some arrangement with OMB and if so, what are they?

Mr. ALBRECHT. We share your concern in this area very deeply. We have been working in an attempt to work out an arrangement with OMB. We have not been successful yet. Discussions are continuing. We feel we have until the first part of October to come to a suitable arrangement if we are going to be consistent in our dealings with our European partners. We cannot sign up for the Aerosat program until we know that it is considered a separate item above and beyond and not part of our normal R. & D. program. This has to be true both for 1978 and for the coming years. OMB appreciates our position.

We need assurances that our basic R. & D. program will be protected and the Aerosat support will not be track limited. If that is not true then Aerosat will become a low priority program as far as we are concerned. So we are working the problem as hard as we can. We hope within the next week or two we will have it resolved. But our position has to be very hard in this area.

Mr. MILFORD. The entire committee is not sitting here today. Therefore, I cannot speak for the committee. If I were to make a guess, I would say that it is going to be mighty hard to get Aerosat authorized if FAA's present R. & D. programs are pushed to a back burner. I would fight it tooth and toenail.

Mr. ALBRECHT. Well, we would concur with that position. At our present fiscal 1978 submission level, given total approval, no critical programs would suffer, but if there is any reduction in that level, that reduction would have to come from Aerosat. Basically Aerosat is a go-no-go program. You either do the whole thing or you do not do any of it. So we feel that we really need to get concurrence from OMB, recognize it for the duration of the program as being above and beyond and separated from our normal budget submission.

Mr. MILFORD. Mr. Cochran, you stated that great cost savings will accrue to the airlines because of Aerosat. I wonder how this would be possible if the program is experimental only and not operational. Is it true that the airlines withdrew their objection to Aerosat only because the program was made nonoperational?

Mr. COCHRAN. Well, let me answer this way by saying in the first place what we propose to do is an experiment. We do not propose to go operational with a system that we are talking about funding now out of the R. & D.

Mr. MILFORD. But this would not satisfy what this gentleman presented as being one of the benefits.

Mr. COCHRAN. Well, what we think is that we would obtain the kind of information and the kind of knowledge that we need in both the technical sense and in the operational sense. We would have experimented on how the satellite would be used and developed it to the point that we would be in a position to deploy it when the traffic justified. What we would do in the step that we are proposing to take now—essentially an experiment.

Mr. MILFORD. With the experiences that we have had already, in communications satellites, is it necessary to put one up in the sky and actually experiment as opposed to putting an operational system up? I mean, this is not really something now is it?

Mr. BLAKE. To some extent our application is in fact new. We do need the Aerosat satellite to establish both the technical and the operational requirements for the operational system. As you may recall we have agreed at the request of the airlines to look into the two frequencies of operation—one in the VHF frequency band and another in the L band or higher frequency band.

We have not yet done the test to make a final selection between these two frequencies for the various voice and data link services that I have given. We further need to test the satellite configured ATC system to determine the operational use of switching and the various ground facilities that go in such a system.

Part of the preliminary examinations of the task force that we have assembled was to look at some of the longer range things. This task force also examined what could we do now with available satellites launched for other purposes. I think the finding has been that there really are no satisfactory alternatives that would allow us to run the experiments necessary to define the operational system. There are also none planned at the present time that meet the FAA's unique requirement for a system that will allow us to talk to aircraft which are maneuvering and which have a very limited antennae installation and require a fairly high powered transmissions from satellites to establish and maintain communications.

Our additional requirement is that we are quite different from existing communication systems. where you are trying to communicate from one point on the ground to another specific point on the ground. Our system requirements are for a satellite which can talk to aircraft anywhere in the oceanic airspace. This again requires a rather unique antennae system and quite a high powered satellite.

We have not obtained this type of service with any of the existing or planned satellites. We believe that the Aerosat program is still a requirement if we are to proceed with essentially no risk into an operational system in the late eighties.

Mr. COCHRAN. About the only thing I could add to that is that there are certain experiments that need to be performed concerning the use of the satellite in the next generation—the so-called fourth generation air traffic control system has a potential role for a satellite. We intend to perform experiments to obtain information that will allow us to develop understandings possibly applicable in that fourth generation air traffic control. This involves using satellites for navigation, surveillance, and communications all at one time. I think that Aerosat will allow us to make those tests in this period.

Mr. MILFORD. Another question that becomes a little obvious, too; if Aerosat is really needed why would you then give it low priority, if outside funding was not received for it?

Mr. COCHRAN. I would say this about that. What we would attempt to do of course is to solve the No. 1 problems first.

As we told you when we briefed you, and as we have told you almost every time we have been up here—we try to look at things in a priority order—safety first. We do all of those programs that are safety related and we have funded everyone of those first, so we always take care of those. The second think we look at is capacity. We feel we need to develop, right after safety, the ability of our airports and systems to handle aircraft that are coming into the system and the traffic that will be generated consistent with the philosophy to put the minimum restraint possible on flight in the United States. We also want to maintain a vigorous air system whose continuance requires that we generate a continually increasing capacity. Capacity in oceanic areas are a part of that problem, but they are not the biggest and most pressing part of that problem. Those problems do not overtake us quite as fast as some of our current capacity problems do.

Then of course the last thing we look at is the economics of the situation—those things that we can do that will improve the economic benefit to the users and to ourselves. That is sort of our priority item and therefore when we talk about the benefits of the Aerosat, we are in the third priority item and I think that we have pretty well wrapped them up.

One of the things that presses on us right now and makes it sort of a time critical decision is that we do have an international treaty or agreement with partners on this system. We have done that. A lot of people can look back on that decision in the same way you can look back on the choice for the technique of the MLS. You have made the decision and now you are in the business to some extent supporting a decision that you made in the past. There was good reason for making the decision at that time. And there is good reason in the minds of those that participated in it and a good reason for making a treaty with overseas friends to support it. It was a national decision at that time, involving the executive and the legislative branches of our Government.

We now find our partners saying we can do it. We have the support and the money to do it. Are you going along with us or not? If we say, no, we are not. We would rather wait 2 years or 3 years and then do it. We have a good deal of indication that at that point they will not necessarily support it. They have put together a support base now which can carry out their part of the program. We would find ourselves with them not being able to do it. That is how I see the situation right now.

Mr. Milford. Using your own example, that was given awhile ago on MLS, we very correctly stated that we have been learning a lot as we have been going along. As one of you observed, in the interim we learned a lot. As is often the case in fast-moving technology, an idea conceived 5 years ago may already be obsolete.

In respect to these treaties, would it be feasible or prudent to go back and take another look at Aerosat, because of new developments in the interim? NAVSTAR, for example, was not in existence or was a highly classified project when we first gave consideration to Aerosat. Certainly that concept could make us take another look. Would it be feasible or wise to consider this?

Mr. Cochran. Well, I want to indicate that the agreements that we signed are not very old agreements. They were signed just a year or 18 months back. We had a review not too long after that, a fairly high level review involving NASA, the State Department, the FAA, and the Department of Transportation and with coordination from other elements of the Government concerning the necessity for going ahead with the program. So we have reviewed it.

Mr. Milford. Sometimes a little bit of knowledge is a very dangerous thing and I am going to admit going in that I have a very little bit of knowledge on this. But, as recently as the last Farnboro exhibition, I had a chance to sit around and sip sasparilla with a few of our foreign counterparts. I got the distinct impression in these unof-

80-582 O - 77 - 4

ficial and off the record conversations that the aeronautical folks themselves did not have a great deal of interest in Aerosat.

It seemed to be more of a project that was being encouraged by the space types, rather than the working aeronautical groups. Whether in England or some of the other countries that are participants in this, the aviation people did not seem very excited about it. I stated at the beginning that this is a little bit of knowledge but I am wondering if you have received similar impressions with your conversations with our counterparts?

Mr. COCHRAN. Well, we have had some indications of varying degrees of support from different members of the partnership. The formal position of the partners in the cooperative partnership has been to support the program. That is the formal position of the nations that are involved. Now, this program is like a lot of other programs that are aimed at the problems in the future, the 1980's, late 1980's and early 1990's. It is a long-range program. It has got a long payoff and therefore many people are willing to defer 1 year, 2 years, 3 years, programs like this. Our own problem with that is that we and one or two other nations pay most of the penalties for the delay. That is where we are. Whether we could restructure that program at some later date, and who the partners in such a restructuring would be, I could not say. That is not to say that it is impossible to do because it certainly can be done, in fact, I am sure that it would be. However, right now our considerations have to be based on decisions that we are currently sort of living with and have. They were not made several years back. They are fairly current.

Mr. MILFORD. OK. I am going to defer further questions and go to Mr. Goldwater because he has a bill on the floor in a short while.

Mr. GOLDWATER. Carrying on with Aerosat—that program does concern me somewhat, too.

What is the total amount of dollars that are in the budget for 1977?

Mr. COCHRAN. For 1977?

Mr. GOLDWATER. For 1976 and 1977?

Mr. ALBRECHT. We will supply those numbers. It is on the order of a few million dollars but the big bite takes place in 1978.

Mr. GOLDWATER. Alright for 1977 it is a couple million dollars.

Mr. COCHRAN. Let me see if I have it.

Mr. GOLDWATER. And what is the big bite for 1978?

Mr. ALBRECHT. It is on the order of $25 million.

Mr. GOLDWATER. And do you know how much we have spent so far on it off the top of your head?

Mr. COCHRAN. I would say probably the total is somewhere around $7 or $8 million. I will correct it for the record if I am wrong.

Mr. GOLDWATER. It is my understanding that this once launched will not be an operational type navigational system, that it will be for research?

Mr. SHEFTEL. That is correct.

Mr. GOLDWATER. Just to explore this concept?

Mr. COCHRAN. Yes, sir, that is correct.

Mr. GOLDWATER. You are looking at $38 to $40 million in essence.

Mr. COCHRAN. No, sir, the program is larger than that.

Mr. GOLDWATER. That is the U.S. share.

Mr. ALBRECHT. The total U.S. program value for Aerosat is on the order of $125 million.

Mr. GOLDWATER. Do we know how much other countries are putting in?

Mr. COCHRAN. The funding scheme is 47 percent United States, 47 percent European space agency, and 6 percent with the Canadians.

Mr. WEDAN. That is for the cost sharing for the space segment jointly owned. The cost associated with the ground equipment and the airborne equipment we are not familiar with, but there is no reason to believe that it is not fairly close to our own. But that will be owned by the individual countries.

Mr. GOLDWATER. Our portion is $125 million, so you are looking at $250 million total—$300 million. If $125 million represents 47 percent?

Mr. WEDAN. It is close. This is assuming that the cost or the degree of equipment that the European countries would put into airborne equipment and ground stations were the same as ours, the answer would be yes.

Mr. GOLDWATER. How many satellites are we talking about?

Mr. WEDAN. Two.

Mr. GOLDWATER. Yet it is a research vehicle and not an operational one?

Mr. WEDAN. That is right.

Mr. GOLDWATER. I guess, of course, it has to be asked if that is worth the expenditure of that kind of money, and I think the question that Mr. Milford was pursuing I believe, was about Navstar, the military worldwide navigational system. Is that somewhat duplicative in your mind?

Mr. COCHRAN. No, sir. I will defer to Mr. Blake, but I do not believe it is a duplicative.

Mr. BLAKE. No, while you were out we discussed the fact that we have set up an interagency task force to look at all these satellite programs which may in the future offer possibilities for consolidation into one service. The Aerosat as we see it is an experimental system. It provides communications. Now we have modified the Aerosat program so that we can accept in the airborne equipment navigational signals from GPS. These signals will then be converted in the aircraft to navigation position and they will be sent back by the Aerosat communication channels to the air traffic control centers to establish the aircraft position. So these satellite systems are complementary in that the GPS/Navstar provides navigation position. Aerosat provides a communications initially by voice and later by data link to the control centers. Most any satellite configuration that we have examined to date has these two types of channels.

Now we will be looking at it as a part of our longer range activities for perhaps use of what might be added to the type of satellite in the orbit that GPS has. Could we also add, for example, some surveillance functions? However, those satellites are in the proper type of orbit for that type of service, whereas the communications facilities and satellites prefer to have them in stationary orbit. You do not have the problem of traffic and of switching communications over a large area.

Now the task force which will be starting this fall will arrive at some joint program recommendations. It is too early yet to give a report on that.

Mr. GOLDWATER. Now wait a minute. The task force is going to do what?

Mr. BLAKE. Well, we are asking them specifically to help us look at the follow-on—the operational systems for both oceanic traffic control and for possible use in satellites over the continental United States, and to see what possibilities exist for perhaps changing some of the programs underway to produce some additional services for ATC purposes. In general the objective is to look at what degree we can consolidate our program and share the various satellite systems.

Mr. GOLDWATER. Why will you not wait until that report is in before we continue on with it?

Mr. BLAKE. Because it has really nothing to do with Aerosat. The early look was to see if there was any satellite currently in being or any satellite proposed for this next time period which could be used for the Aerosat purposes, and there is no such vehicle available to us. As we mentioned a few moments ago, our requirements are somewhat unique. Most of the satellite systems are for communications between two points on the ground or between a point on the ground and a large ship at sea with a fairly large antennae. Our requirement is for a satellite system that will see the whole oceanic area to communicate with aircraft anywhere within the oceanic area and to communicate with aircraft which do not have the ability to carry a large antennae system. This dictates the type of satellites now available to us for use in this program.

Mr. GOLDWATER. It is my understanding that the Navstar program will have room aboard that you could in fact utilize for this same function.

Mr. BLAKE. Well, we have looked at the possibility of combining an Aerosat communications function with a navigation function. Now the weight of our part of the satellite is the same as or slightly greater than the currently envisioned weight of the navigation function. So we are not talking about adding a small transponder to an existing satellite. We are talking about a whole new design. As you know the GPS program is well underway and scheduled, and to go back and redesign it to carry a fairly substantial communications capability would be a delay of several years. So it would be a whole new program.

Of course, the other problem we would have, there would be a limited number of satellites available in the beginning and they will only be in the oceanic area for small periods at a time, so we would not be able to conduct the operational part of the experiment until there was a sufficient number to provide essentially continuous coverage of the oceanic flights.

Mr. GOLDWATER. You conducted a review this last year?

Mr. BLAKE. Yes, during this past year and we have started—we mentioned we have started a task force which includes people from NASA, from NOAA, from the Department of Defense and the Department of Commerce, of course, are interested in the Marisat satellite, and this group will continue to meet through the fall and early winter and will be looking at followon satellite systems for the late 1980 time period.

Mr. GOLDWATER. Would it be possible to have a copy of that review?

Mr. BLAKE. Yes, sir, after the committee has completed its deliberations we will be publishing a report.

Mr. GOLDWATER. What is the timeframe on that?

Mr. BLAKE. We hope to have our draft report by the first of the year.

Mr. GOLDWATER. The first of the year?

Mr. BLAKE. Yes.

Mr. GOLDWATER. You will have it in time for our deliberations next year.

Mr. BLAKE. We hope so, yes.

Mr. GOLDWATER. Mr. Cochran, on collision avoidance—last February 9 Mr. McLucas wrote a letter to Mr. Cannon and in essence saying that the Honeywell System was the better of the three that were evaluated for airborne CAS. In the letter there was in essence a statement that a report summarizing the comparative testing now in printing will be forwarded to you within one month. Do you have that print?

Mr. COCHRAN. I do not have it with me but I am sure we have it. The report has been completed and it is available.

Mr. WEDAN. Yes, sir, I believe so.

Mr. COCHRAN. I thought we had made it available here to the committee, but maybe we did not.

Mr. GOLDWATER. Possibly you have and I have just not——

Mr. COCHRAN. We will certainly furnish it.

Mr. GOLDWATER. I appreciate that.

[The report requested above follows:]

Report No. FAA-RD-76-17

ANALYSIS, FLIGHT TEST & EVALUATION OF HONEYWELL, MCDONNELL-DOUGLAS & RCA AIRBORNE COLLISION AVOIDANCE SYSTEMS (ACAS)

January 1976

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FEDERAL AVIATION ADMINISTRATION
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16. Abstract

As part of its Aircraft Separation Assurance Program, the FAA has evaluated three Airborne Collision Avoidance Systems (ACAS) designed and built by Honeywell, McDonnell-Douglas and RCA. The evaluation consisted of analyses, simulations and maneuver selection logics developed by the Air Transport Association's ACAS Technical Working Group as a standard for comparison. The results show the Honeywell system superior from both a cost and technical performance standpoint.

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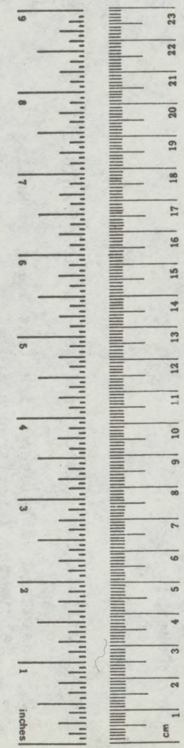
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

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

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

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

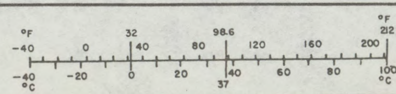


TABLE OF CONTENTS

Table of Contents --continued--

Table of Contents --continued--

ANALYSIS, FLIGHT TEST & EVALUATION OF HONEYWELL, MCDONNELL-DOUGLAS & RCA AIRBORNE COLLISION AVOIDANCE SYSTEMS (ACAS)

I. INTRODUCTION

Since the late Fifties, FAA has been searching for an Airborne Collision Avoidance System. Up until the late Sixties, the State-of-the-Art dictated a Time/Frequency (T/F) solution. In the early Seventies, advancements in the State-of-the-Art gave promise of a low cost Interrogate/Transpond (I/T) approach. For the last several years, we have been in the final stages of analyses, test, and evaluation of both kinds of systems, specifically the Honeywell and RCA I/T systems and the McDonnell-Douglas T/F system.

As a result of the analyses and hardware evaluations done to date, it has been concluded that, from a cost and technical standpoint, the Honeywell system is the best of the three systems tested.

II. THREAT EVALUATION AND MANEUVER SELECTION LOGICS

A. Background

In late 1966, FAA was about to issue a competitive Request for Proposals for a T/F ACAS for test and evaluation purposes. The Air Transport Association (ATA), in a letter to the FAA Administrator, requested that this planned procurement be cancelled and offered the following alternate:

> The ATA would create an ACAS Technical Working Group (TWG) composed of representatives from the major avionics firms, interested Government agencies, and industry experts in the T/F technology. This group would convene and jointly prepare an ACAS specification to which interested manufacturers would build equipment (at their own expense) for flight testing by the ATA.

In June 1967, the ATA published the results of the TWG's deliberations--Air Navigation and Traffic Control Report No. 117 (ANTC-117), "Airborne Collision Avoidance System, Statement of Airline Policy and Requirements and a Technical Description of the System."

Since that time, there have been many revisions to the document, the latest being Revision 10, dated May 12, 1971. ANTC-117 describes, among other things, the threat evaluation and maneuver selection logics to be utilized to assure safe aircraft separation. It is these logics to which the three manufacturers built their ACASs for air carriers and against which the systems are being compared.

B. Description of Logics

1. General

The threat evaluation and maneuver selection logics described in ANTC-117 are intended to insure separation of aircraft within the following aircraft performance profiles:

Horizontal Acceleration	-	1/2 G
Vertical Acceleration	-	1/4 G
Vertical Rate	-	5000 ft./min.

Hence, separation assurance was to be provided to pairs of aircraft whose maximum relative horizontal acceleration did not exceed 1 G, whose maximum relative vertical acceleration did not exceed 1/2 G, and whose maximum relative vertical closure rate did not exceed 10,000 ft./min.

In order to achieve this degree of separation assurance, several algorithms involving measured values of separation distance or range (R), separation closing rate or range rate ($\dot{R}$), altitude difference (Δh), and the rate of altitude closure ($\dot{h}$) of the aircraft in which an evaluation of the threat is being made, are used to generate various cautions and commands to pilots. These cautions and commands cause the pilot to perform certain avoidance or escape maneuvers: to limit or stop turning (also known as roll-out), to limit vertical speeds, and to change altitude. Because relative bearing is not available, escape maneuvers are in the vertical plane.

The algorithms which provide cautionary or command criteria are of two types: (1) horizontal threat criteria, or those based on R, $\dot{R}$, and (2) vertical threat criteria, or those based on Δh, $\dot{h}$. In principle, since R represents the slant range between aircraft, the R, $\dot{R}$ criteria alone should be sufficient to provide alarms needed for protection against collision. However, it has been found that the use of altitude data is required to reduce the threat volume, and hence the alarm rate, to manageable proportions, and to determine the proper direction for vertical avoidance maneuvers.

The measurement of R, $\dot{R}$ and Δh is accomplished by means of RF communications between aircraft. The arrival time of a communications signal (one-way in the case of T/F, two-way in the case of I/T) is used to calculate R, while $\dot{R}$ is obtained from sequentially differencing R measurements and dividing by the time interval between measurements. Each aircraft measures its own altitude and communicates it in digital steps of 100 ft. to other aircraft. Each ACAS equipped aircraft measures its own altitude rate ($\dot{h}$) but does not communicate this data to others. In order to determine the ultimate escape maneuver, the higher aircraft climbs, the lower of the two dives. To solve the co-altitude problem, the first aircraft determining that a threat exists which requires a climb or dive, chooses a maneuver and biases its altitude transmission 200 ft. in the direction of the maneuver. This insures the other aircraft will make a complementary maneuver and not a cancelling one. In the unlikely event of a three aircraft encounter, the higher climbs, the lower dives, and the middle aircraft flies level.

2. <u>Horizontal Threat Criteria</u>

In the early days of ACAS development, it was proposed that an R, $\dot{R}$ algorithm be based on a quantitity TAU (T), defined by:

$$T = R/\dot{R}$$

representing the time to collision for two aircraft on a non-accelerating collision course. It has since been realized that because of measurement errors and the possibility that aircraft may be accelerating, a modification to this idea was necessary. Thus, ANTC-117 adopted three alarm algorithms based on R, $\dot{R}$. These algorithms, sometimes known as the modified TAU criteria, are as follows, and are depicted graphically in Figure II-1:

$$R + T_2\dot{R} \leq Ro_2 \quad *$$

$$R + T_1\dot{R} \leq Ro_1$$

Where T_2, Ro_2, T_1, and Ro_1 are designated constants. In the first algorithm, known as the T_2 warning criterion, the constants have the values:

T_2 = 40 secs.

Ro_2 = 1.8 nmi. (10,940 ft.)

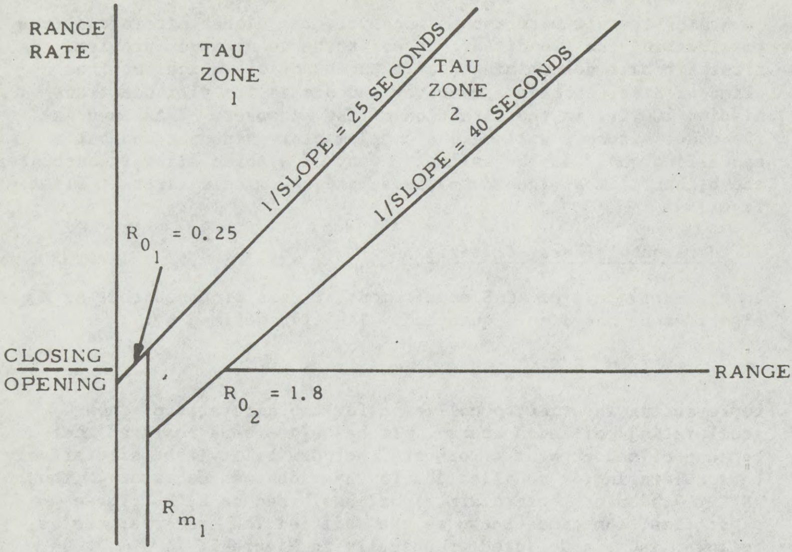
In the second algorithm, known as the T_1 alarm criterion, the designated constants have the values:

T_1 = 25 secs.

Ro_1 = 1/4 nmi. (1,520 ft.)

TAU_2 is chosen sufficiently far in advance of T_1 to enable aircraft which receive T_2 warnings to reduce their vertical and horizontal rates and accelerations before reaching the T_1 zone. TAU_1 is chosen

* Positive $\dot{R}$ corresponds to increasing range



R_{0_1} = 0.25 NMI = 1,520 FEET

R_{0_2} = 1.8 NMI = 10,944 FEET

R_{m_1} = 0.5 NMI = 3,040 FEET

RANGE AND RANGE RATE THREAT EVALUATION
FIGURE II-1

sufficiently small to reduce the number of commands, yet sufficiently large to enable aircraft receiving T_1 commands to make a safe vertical escape maneuver. TAU_1 time allowances have been made for pilot reaction, aircraft reaction, missed communications, system cycle time (round time), and maneuver time to acquire safe separation.

Thus, if two aircraft are co-altitude (within 600 ft. for altitudes below 10,000 ft. or within 800 ft. for altitudes above 10,000 ft.), and if measured values of R and $\dot{R}$ satisfy the T_2 criterion, the pilot is commanded to limit his turn rate and ascent or descent rate. Compliance with this command reduces the relative trajectory of the two aircraft so that the encounter is approximately horizontal and non-accelerating. Then conditions are assumed to be suitable for the safe use of the more restrictive T_1 criterion. Similarly, if a co-altitude situation exists and the measured values of R and $\dot{R}$ satisfy the T_1 criterion, vertical commands (climb or dive) are issued.

The third horizontal threat algorithm is:

$$R \leq R_m \quad (3{,}040 \text{ ft.})$$

and is called the minimum range criterion. Its purpose is to protect against the case of very slow closure rates which would not trigger a T_1 alarm but which in the presence of measurement errors and possible accelerations, might not leave enough time available for a safe escape maneuver. Thus, a climb or dive maneuver is directed when the slant range between aircraft is 1/2 nmi. or less.

3. <u>Vertical Threat Criteria</u>

The T alarms are implemented only if the encountering aircraft are co-altitude, or it is predicted that they might become co-altitude within thirty seconds. Again, co-altitude is defined to mean that their vertical separation is less than 600 ft. at altitudes below 10,000 ft. and less than 800 ft. at altitudes above 10,000 ft. This definition is based on: (1) an altimeter system error allowance of ± 150 ft. (3 sigma) below 10,000 ft. and ± 250 ft. (3 sigma) above 10,000 ft.; (2) the assumption that a safe vertical separation between aircraft is 150 ft.; and (3) what is intended as an allowance for an undetected vertical drift rate of 500 ft./min.

According to ANTC-117, if an aircraft is climbing or diving at a rate greater than 500 ft./min., it is required to extend its co-altitude protection boundary in the direction of its motion by a predicted co-altitude increment. This is determined by multiplying the aircraft's own $\dot{h}$ by 30 seconds.

In addition to the co-altitude zone wherein the T alarms become effective, relative altitude buffer zones are established out to

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± 3400 ft. In each of these zones, vertical altitude rates are limited, from 2000 ft./min. in the farthest zone, to successively lower values as the zones get nearer. The vertical threat criteria is shown graphically in Figure II-2.

4. Landing/Departure Mode (Desensitization)

ANTC-117 also includes a Landing/Departure Mode, known as desensitization, where the T_2 zone, and the dive, and the do not turn commands are inhibited. This is to keep the number of commands and ATC interaction manageable since ATC intentionally brings aircraft close together in this area for landing and departure, and to prevent aircraft from diving into the ground. This mode is shown graphically in Figure II-3.

5. Logic Difference between Three Systems

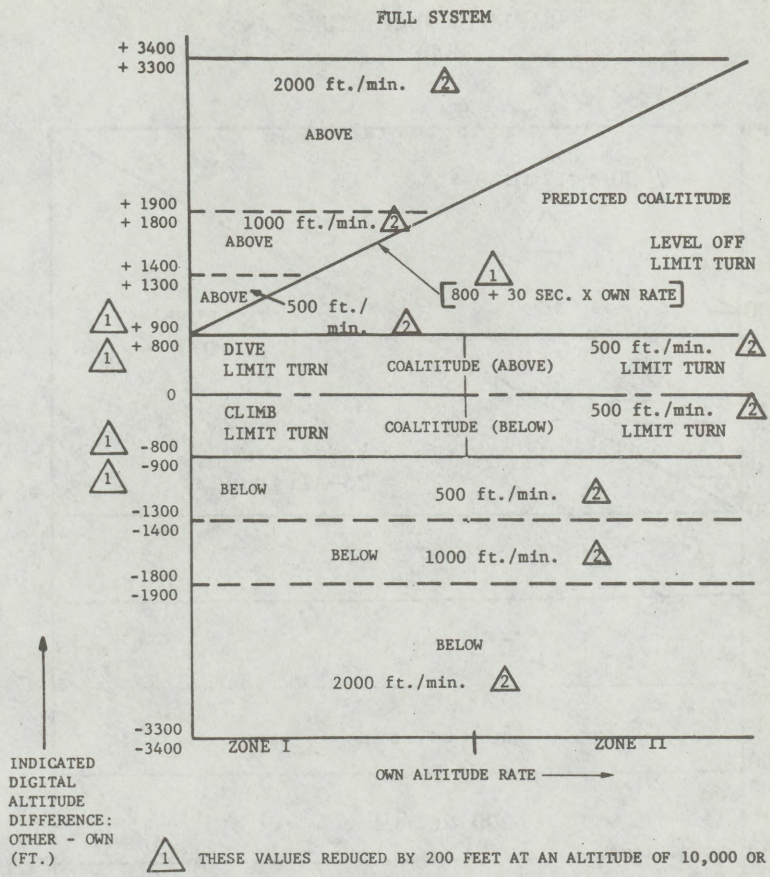
As discussed previously, ANTC-117 was written around a T/F system for airline use. While it allows the existence of ACAS equipments with limited capabilities (to spare general aviation the expense of a full ACAS), it does not describe these systems in the same detail it does the full ACAS. Hence, the major differences between the logics of the three systems under evaluation are in their general aviation equipments. However, since the air carrier equipments are faced with the greater technical problem (longer ranges, higher powers, more fruit, etc.), it is their performance which is used as the primary criteria for comparative evaluation.

III. EQUIPMENT DESCRIPTIONS

A. General

As discussed previously, the three air carrier ACASs under evaluation utilize R, $\dot{R}$, Δh, and $\dot{h}$ to evaluate whether the degree of threat is sufficiently high enough to require a mandatory maneuver. Essentially, the systems determine if a co-altitude situation exists between aircraft (or if the involved aircraft are climbing or descending, whether a co-altitude situation will exist in 30 secs.), and whether the time value of $R\text{-}Ro/\dot{R}$ is equal to or less than a predetermined value. If so, appropriate instructions are given to the pilot.

The systems are all cooperative and use the RF frequency band provisionally allocated to the ACAS function in the U.S. (1592.5 MHz to 1622.5 MHz). Altitude data input is obtained from the ATCRBS altitude encoder and the air carrier equipments utilize two antennas (top and bottom) and the same display (a modified instantaneous vertical speed indicator shown in Figure III-1). The general aviation version of each manufacturer is compatible with its carrier version. Additional detailed information on the three systems (over and above the following basic descriptions) can be found in FAA Reports FAA-RD-73-151 and FAA-RD-75-151



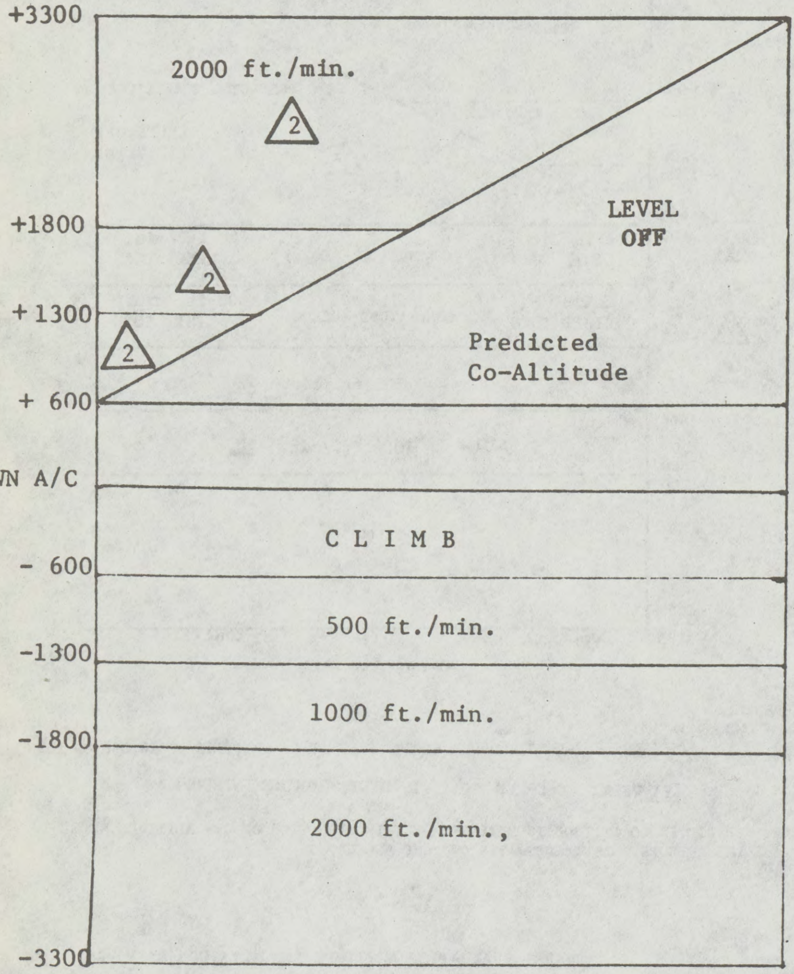
1 THESE VALUES REDUCED BY 200 FEET AT AN ALTITUDE OF 10,000 OR LESS

2 VERTICAL SPEED LIMIT IN DIRECTION OF INTRUDER

NOTE: PREDICTED COALTITUDE IS EXTENDED ONLY IN DIRECTION OF OWN ALTITUDE RATE. THIS FIGURE ONLY ILLUSTRATES OWN A/C ASCENDING.

THREAT EVALUATION ALTITUDE AND ALTITUDE RATE
FIGURE II-2

LANDING/DEPARTURE
MODE



ZONE I

2 Identical to Full System
FIGURE II-3

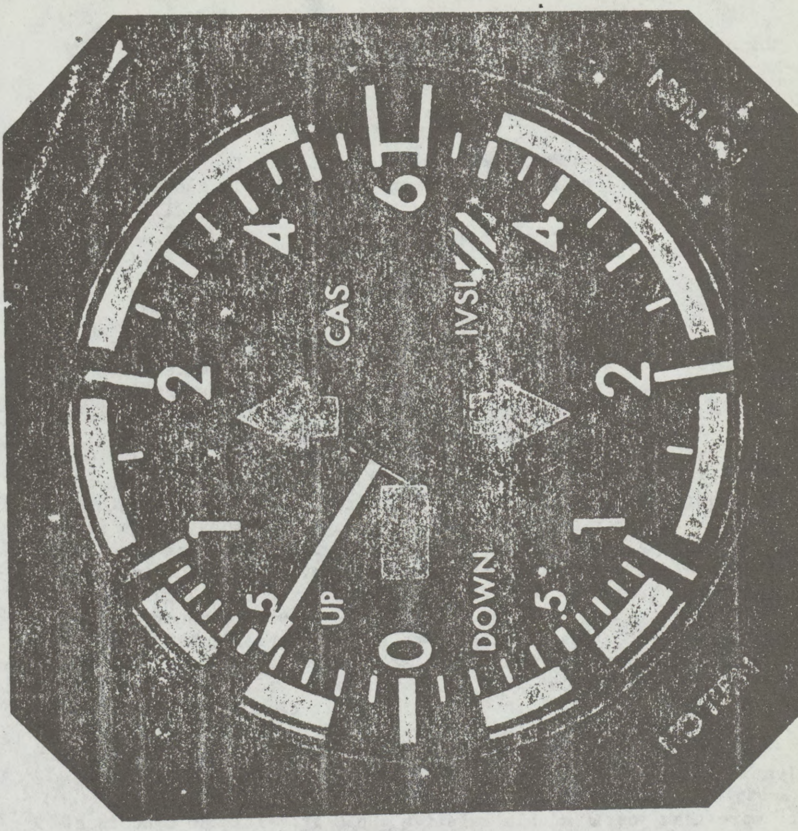


FIGURE III-1 CAS/VSI Indicator in Test Mode.

for the Honeywell system, Reports FAA-RD-73-143 and FAA-RD-75-143 for the McDonnell-Douglas system, and Reports FAA-RD-73-152 and FAA-RD-75-152 for the RCA system (see Appendix A).

B. Basic Description of Honeywell ACAS

The Honeywell ACAS, Avionic Observation of Intruder Danger Systems (AVOIDS) consists of an air carrier version (AVOIDS I) and a general aviation version (AVOIDS II). They are single frequency (1.6 GHz) I/T systems utilizing identical signal formats. The AVOIDS II equipment has less transmitter power, a simplified threat logic and less equipment redundancy.

The AVOID systems are able to handle high traffic densities through the use of pulse coded RF energy in a specific timing sequence (See Figure III-2). An aircraft in the interrogation mode emits pulse coded information in the form of two pulse pairs. The time separation between the two pulses in the first pair is 0.5 usec. and in the second pair is 0.6 usec. The separation between the first pulse in each pair is 35.5 usec. plus 2.0 ns./ft. of encoded altitude, referenced to -1000 ft. MSL. Aircraft receiving this interrogation compare the altitude of the interrogating aircraft with their own altitude to determine if they are within ± 650 ft. of the interrogating aircraft. If they are, a response is required and a single pulse is emitted by the responding aircraft after a fixed delay. The interrogating aircraft can then determine the range to the intruder by subtracting out the fixed turn-around delays when the responses are received. The fixed delays are incorporated to minimize the deleterious effects of reflected signals (multipath). The different time separation between pulses in the first pulse pair and pulses in the second pulse pair allows the pairs to be discriminated from each other, and also prevents an aircraft from responding to other first pulse pairs after it has received an initial first pulse pair. The range obtained is stored in a specific memory location for further evaluation.

Since more than just a single relative ± 650 ft. altitude band is of interest to the interrogator, he interrogates several bands during each epoch (3.7 secs.) by changing his encoded altitude. The AVOIDS I equipment uses eleven altitude bands below 9600 ft. and ten above, to search out ± 3200 ft. of altitude. The AVOIDS II equipment uses five bands to cover ± 1250 ft. in altitude (See Figure III-3 and III-4). The use of more than the minimum number of ± 650 ft. bands is primarily to limit fruit, since a limited altitude is involved in each interrogation, and to obtain a more accurate altitude positioning of a threat.

Multiple interrogations and responses result in the establishment of dynamic range data. The AVOIDS I system provides a 102,400 ft. range capability--2,048 fifty-ft. range bins--and the AVOIDS II provides a 25,600 ft. range capability--512 fifty-ft. range bins. This data changes from interrogation to interrogation from epoch to epoch. If an aircraft shows a closing rate, its range bin location will move inbound with time.

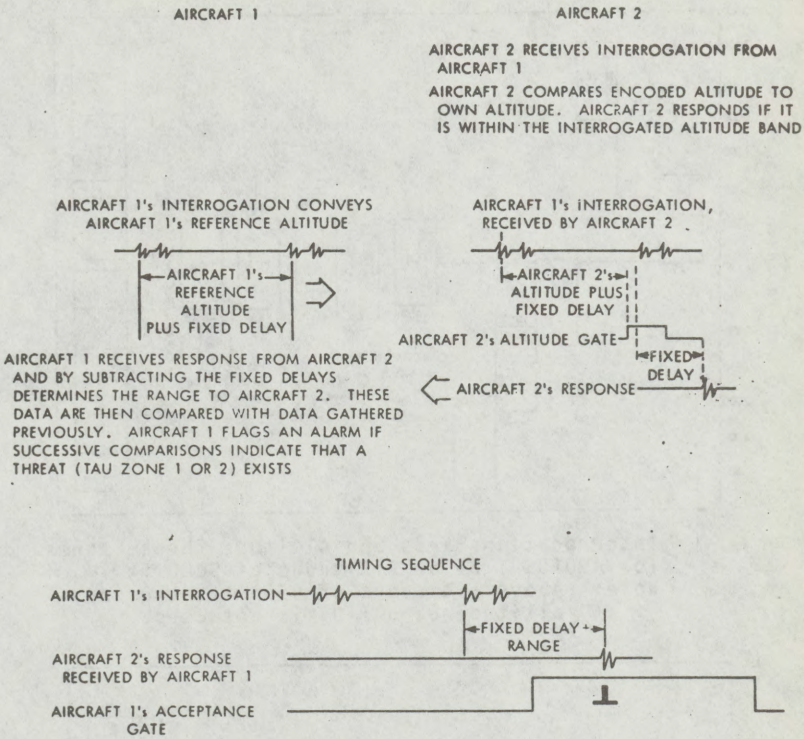


FIGURE III-2

HONEYWELL INTERROGATION/RESPONSE SEQUENCE OF EVENTS

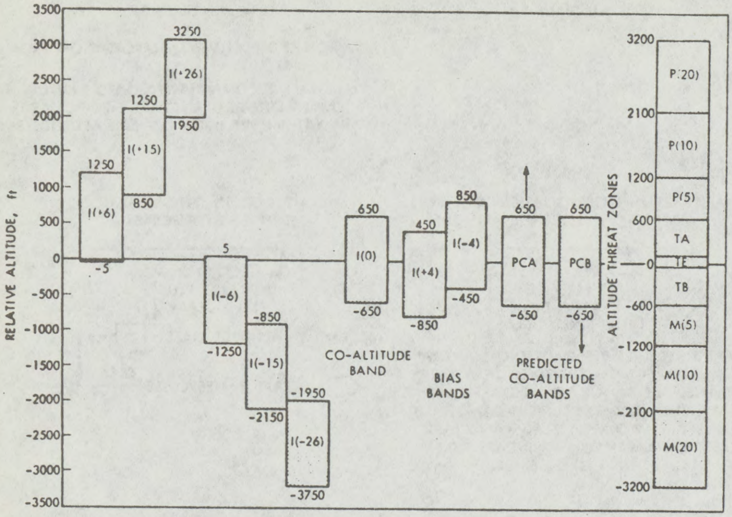


FIGURE III-3 Interrogation Bands and Altitude Threat Zones for AVOIDS-I Below Altitudes of 9600 ft
Note: Above altitudes of 9600 ft, the co-altitude band I(0) is not used.

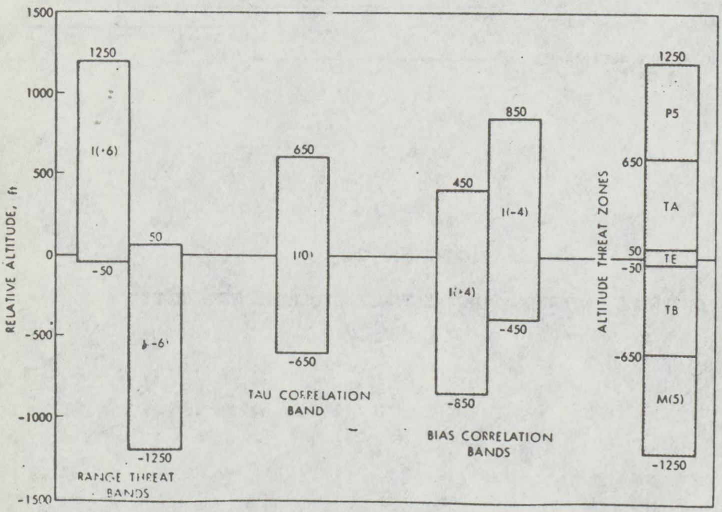


FIGURE III-4 AVOIDS-II Interrogation Altitude Bands

	AVOIDS I	AVOIDS II
FREQUENCY BAND	1592.5 MHz to 1622.5 MHz	Same
OPERATING FREQUENCY	1.6 GHz	Same
POWER OUTPUT		+ 58 dBm
BELOW 10K ft.	+ 58 dBm	
ABOVE 10K ft.	+ 62 dBm	
RECEIVER	Dual RF/IF	Single RF/IF
RECEIVER SENSITIVITY	- 74 dBm	Same
ANTENNA	2 (Top and Bottom)	Same
ROUND TIME	3.7 secs.	Same
Evaluation Logic	Essentially ANTC-117	Maximum Range 25,600 ft.; Max. $\dot{R}$ Detectable 903 ft./sec.; T_1 & T_2 (Ro_1 & Ro_2 = 0), R_{m1} = 2500 ft.; Rm_2 = 6000 ft.; T_3 = 2500 ft. $\leq R \leq$ 6000 ft. & -80 ft/sec $\leq \dot{R} \leq$ 50 ft./sec.; No predicted co-altitude.; Altitude constrained to 14,750 ft.

TABLE III-1 AVOIDS I/AVOIDS II COMPARISON

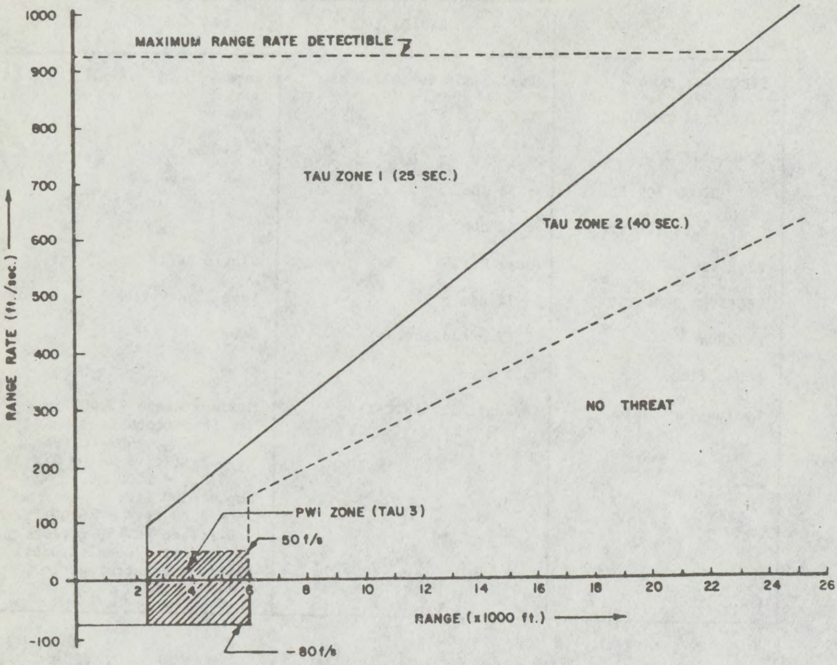
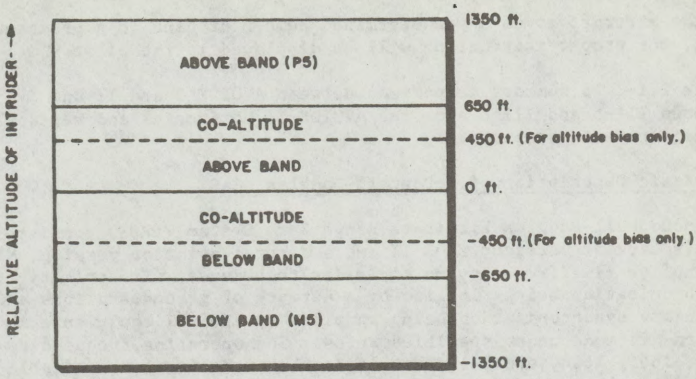


FIGURE III-5 AVOIDS II THREAT ZONE



NOTE: ALTITUDES SHOWN ARE ACTUAL RELATIVE ALTITUDES, NOT DIGITAL ENCODING ALTIMETER ALTITUDES.

FIGURE III-6

AVOIDS II ALTITUDE THREAT ZONE

If the aircraft moves a predetermined number of bins in a predetermined time, the proper instruction will be displayed to the pilot.

Table III-1 is summary comparison between AVOIDS I and II and Figures III-5 and III-6 show the AVOIDS II horizontal and vertical threat criteria respectively.

C. Basic Description of McDonnell-Douglas ACAS

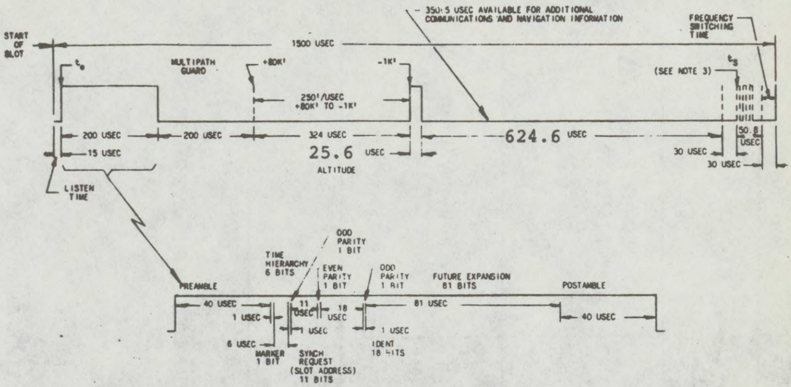
The McDonnell-Douglas Eliminate Range Zero System (EROS) consists of an air carrier version, EROS II and a general aviation version, MINI-CAS. It employs time/frequency multiplexing techniques, with primary time synchronization being supplied by a network of ground stations and secondary synchronization being supplied by EROS II equipments in an air-to-air mode under specified rules. The operating frequencies are 1600, 1605, 1610, and 1615 MHz. A back-up mode is also available which is an asynchronous I/T mode for use in low traffic density areas where time synchronization is not available. The message formats of both systems are compatible, with the MINI-CAS having less transmitter power, a simplified threat logic, a transmission capability on only one frequency and no air-to-air biphase modulated data link.

The method in the synchronous mode by which the necessary information is exchanged is based on the requirement that all participating aircraft carry, as an integral part of the ACAS, a clock whose time is the same (within fractions of a microsecond) as the clocks carried by all other aircraft. This being the case then, a time-ordered sequence is set up as follows:

The system utilizes a three-second cycle called an epoch. Each epoch is divided into 2000 equal time slots of 1500 usec. each. In theory, each participating aircraft is uniquely assigned a time slot for transmitting purposes so that at any instant in time, one and only one aircraft will be transmitting. The start of these transmissions occurs at the precise beginning of each assigned time slot. Therefore, when an aircraft transmits in its assigned time slot, all other aircraft in communication range are listening. Since all aircraft have the same time, and know the start of each time slot precisely, listening aircraft can compute the range to the transmitting aircraft by measuring the time it takes for the transmission to arrive. The listening aircraft then computes the closure rate by sequentially differencing successive range measurements and dividing by the time interval. It determines relative altitude by decoding the altitude information which is encoded by pulse position modulation in the transmission. With this information (R, $\dot{R}$, Δh, and own $\dot{h}$), the listening aircraft are able to evaluate the collision situation in accordance with ANTC-117. The system then cycles through the remainder of the 2000 time slots (transmitting sequentially on frequencies F_1, F_2, F_3, F_4, F_1, F_2, F_3, F_4. . .) and starts over again. Figure III-7 shows the message format. It is identical for both systems with the exception that MINI-CAS has no biphase modulation. Figure III-8 shows the MINI-CAS vertical threat criteria (the horizontal

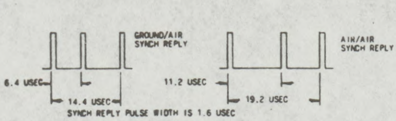
C.A.S. MESSAGE FORMAT

ATTACHMENT 1 - PAGE 1
R/8



NOTES-

1. "SLOT TIME" - START OF SLOT.
2. t_o - LEADING EDGE OF DOPPLER BURST (15 MICROSECOND AFTER SLOT TIME).
3. t_s - NO ERROR SYNCHRONIZATION RECEIPT TIME (LEADING EDGE OF SYNCHRONIZATION TRIPLET). OCCURS 1419.2 MICROSECOND AFTER SLOT TIME.



4. ALL RANGE, ALTITUDE, BUM RESPONSES AND SYNC TIMING TAKEN AT 50 PERCENT VOLTAGE POINT OF LEADING EDGE OF RESPECTIVE PULSES(S).
5. THE SYNCH REPLY TRIAD SHALL BE TRANSMITTED BY THE SYNC DONOR SUCH THAT IT WILL BE RECEIVED AT THE INTERROGATING AIRCRAFT AT A TIME CORRESPONDING TO DONOR SLOT t_S 1404.2 USEC AFTER DONOR SLOT t_O (SEE ATTACHMENT 1 PARA. 2.8 FOR SYNCHRONIZATION ACCURACY) THIS IS THE ZERO ERROR CASE,
6. THE PREAMBLE AND POSTAMBLE SHALL BE TRANSMITTED AT THE SAME PHASE.
7. EACH BIT OF THE BIPHASE MODULATION; INCLUDING THE MARKER BIT, SHALL BE TRANSMITTED AS NRZ SPACE AS FOLLOWS: FOR LOGIC LEVEL 1 THE PHASE OF THE 1 USEC BURST IS IDENTICAL TO THE PHASE OF THE PREVIOUS 1 USEC BURST. FOR A LOGIC 0 THE PHASE OF THE 1 USEC BURST DIFFERS BY 180° FROM THE PHASE OF THE PREVIOUS 1 USEC BURST.
8. BIPHASE DATA TRANSMITTED MOST SIGNIFICANT BIT FIRST.
9. WHEN BIPHASE DATA IS TRANSMITTED, THE UNUSED EXPANSION BITS MAY BE TRANSMITTED OPTIONALLY AS CW OR BIPHASED, CLOCKED AT A 1 MHZ BIT RATE.

FIGURE III-7

MCDONNELL-DOUGLAS MESSAGE FORMAT

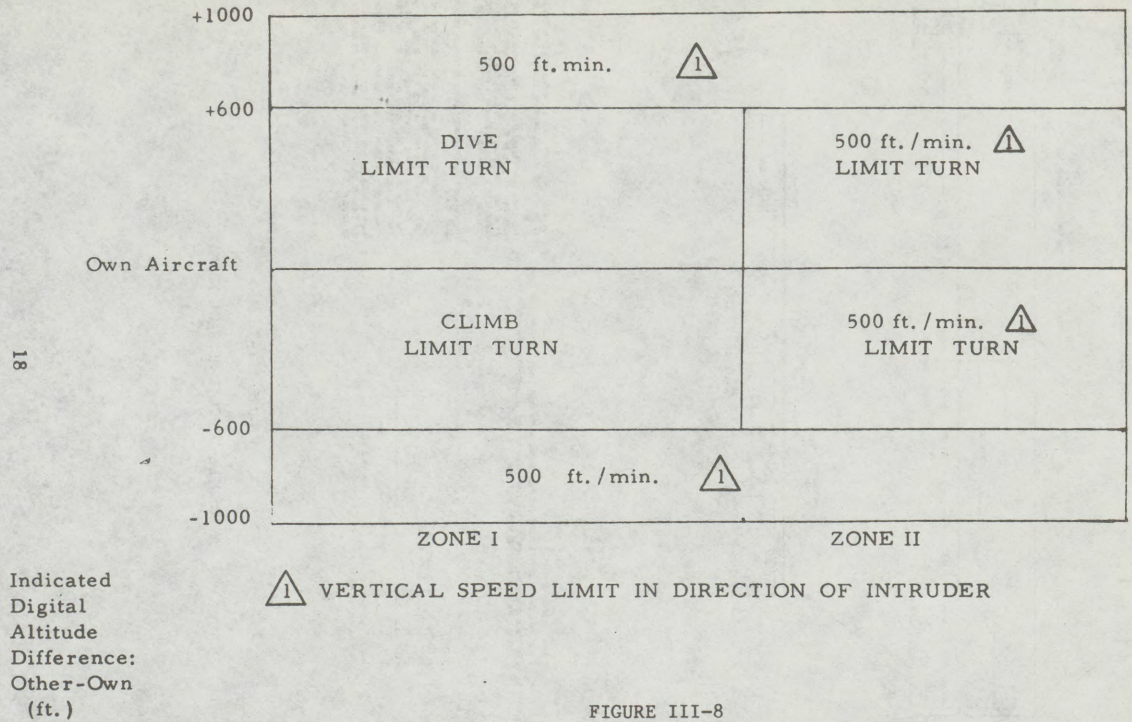


FIGURE III-8

MCDONNELL-DOUGLAS MINI-CAS ALTITUDE THREAT EVALUATION criteria corresponds to ANTC-117 with the exception that Ro_1 is zero) and Table III-2 is a summary comparison between EROS II and MINI-CAS.

D. Basic Description of RCA ACAS

The RCA Separation and Control of Aircraft using Nonsychronous Techniques (SECANT) is basically divided into two major categories: (1) equipments which provide full ACAS protection in accordance with ANTC-117 called VECAS (Vertical Escape Collision Avoidance System), and VECAS GA/M (General Aviation/Military); and (2) equipments of lesser capability but compatible with all other equipments. These are called Proximity Warning Indicator (PWI) and Remitter.

RCA intends the VECAS equipment for air carrier and large business aircraft, VECAS GA/M for smaller, high performance general aviation and military aircraft, and PWIs and Remitters for low performance general aviation aircraft.

Basic performance for the VECAS and VECAS GA/M equipments is identical. VECAS GA/M is lower in cost because shorter antenna cable runs permit economies in transmitter and receiver designs and because of possible economies in processing logic for fewer simultaneous targets.

PWIs simply indicate the presence and approximate direction of other aircraft, contain no evaluation logic and have less range (power). A Remitter is simply the transponder portion of a VECAS GA/M which responds to interrogations of VECAS and VECAS GA/M equipments.

The interrogation wave form of VECAS and VECAS GA/M is shown in Figure III-9 and consists of two 1 usec. pulses separated by a time interval. Altitude is encoded on the time interval as a constant delay proportional to barometric altitude (as in both the Honeywell and McDonnell systems). The interrogators "address" a series of altitude bands by changing the time interval by fixed amounts (2 usec/500 ft. below 10,000 ft., 2 usec/1000 ft. above 10,000 ft.). From 30,000 ft. up, a single delay is used. This technique is similar to the altitude band addressing in the Honeywell system.

The transponders decode the two-pulse interrogation and reply with a single pulse if the decoded 500 ft. (1000 ft. above 10,000 ft.) altitude layer includes the altitude of the transponder. Thus, only transponders which receive interrogations addressed to their altitude layer respond. This reduces the number of overall replies and eliminates garble from transponders at the same slant range but in different altitude layers.

In addition to altitude encoding, the other principal means of reducing fruit are frequency multiplexing and data correlation. Within the frequency band 1592.5 to 1622.5 MHz, VECAS and VECAS GA/M equipments

	EROS II	MINI-CAS
FREQUENCY BAND	1592.5 MHz to 1622.5 MHz	Same
OPERATING FREQUENCIES	1600, 1605, 1610, 1615 MHz	Transmit 1605 MHz Receive All Four
FREQUENCY CONTROL	Cesium Beam or Crystal	Crystal
MODULATION	Pulse and Biphase	Pulse Only
POWER OUTPUT	1000 Watts ± 3 db	150 Watts ± 3 db
RECEIVER TYPE	Double Conversion Superheterodyne	Single Conversion Superheterodyne
RECEIVER SENSITIVITY	-88 dbm, nominal	-78 dbm, nominal
RECEIVER NOISE FIGURE	8 db, maximum	13 db, maximum
ANTENNA	2 Vertical Polarized Stubs (Top & Bottom)	One Vertical Polarized
EPOCH TIME	3 or 6 secs.	Same
EVALUATION LOGIC	Full ANTC-117	Tau One and Tau Two, No Predicted CO-altitude Only one ± 400 ft. Off-altitude band. Altitude constrained to 10,000 ft., Altitude Rate to 1,000 ft./min.

TABLE III-2 EROS-II/MINI-CAS COMPARISON

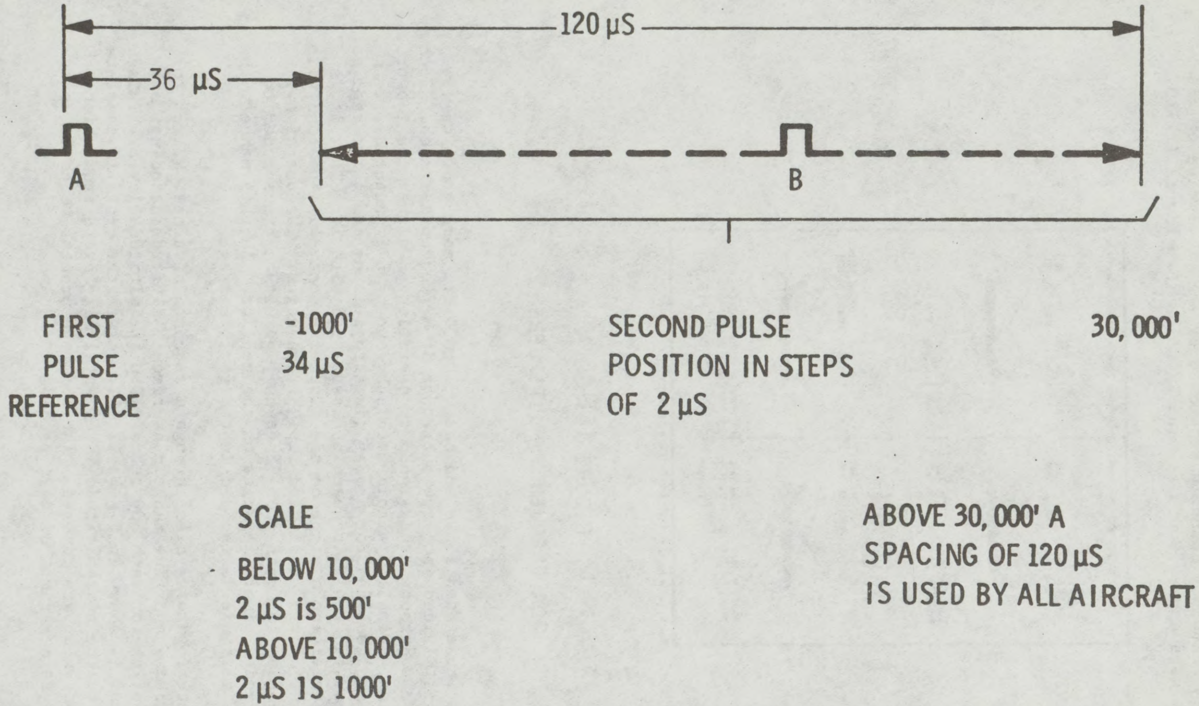


FIGURE III-9

RCA PULSE PAIR ALTITUDE CODED PROBES

80-582 O - 77 - 6

operate on 24 frequency channels separated by 1 MHz. Twelve of the channels are used above 10,000 ft. and 12 below (See Figure III-10).

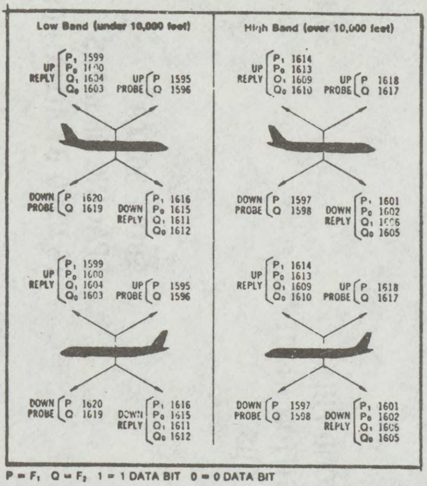
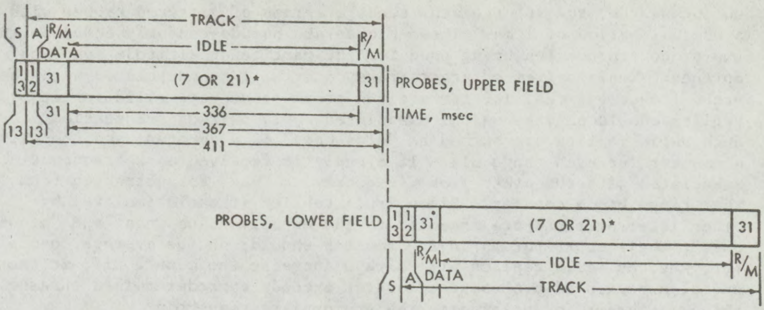


FIGURE III-10

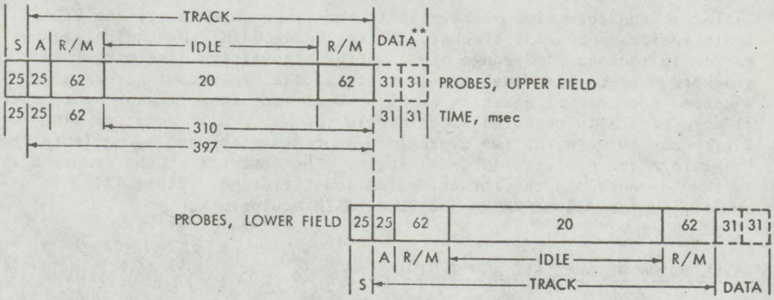
RCA FREQUENCY MULTIPLEXING

Within an altitude band above and below 10,000 ft. each group of 12 frequencies is divided into two subgroups of 6 frequencies each. Each of the latter subgroups is assigned to operation on either the top or bottom antenna. Finally, within each subgroup of 6 frequencies, 2 frequencies are assigned for probes (interrogations) and 4 for replies. Each probe has two reply frequencies associated with it. That is, a transponder receiving a probe on one given frequency will respond with a reply on one of two associated reply frequencies. The use of two reply frequencies for each probe frequency permits a transponder to superimpose coded binary messages on the replies. In this manner, the transponders altitude is encoded in the reply message.

The VECAS interrogator cycles through a sequence of steps: search for targets, tracking and fine range measurement, altitude decoding, and threat evaluation for each 500 ft. or 1000 ft. altitude layer. This timing diagram is shown in Figure III-11. After the cycle is completed, it proceeds to the next altitude layer until all layers from which threats can develop are covered. The complete process to cover up to 10 layers takes a maximum of 4.26 seconds.



(a) NEW VECAS



(b) OLD VECAS

LEGEND:

S = RANGE SEARCH
A = TRACKER ACQUISITION
R/M = RANGE MEASUREMENT

*Number of idle probes is seven for operation below 10,000 ft, 21 above 10,000 ft. Data = synchronous data transmission always on first R/M, and only on second R/M after detected error on first R/M. At end of second R/M there is a 2-msec evaluation.

**Data transmission only if track detects alarms, in which case other field transmissions are delayed 62 msec.

FIGURE III-11

TIMING DIAGRAMS FOR NEW & OLD RCA VECAS FOR RANGE SEARCH, TRACK, & DATA

During search, the interrogator sends a series of jittered probes with a nominal period of 1 ms. These probes are pseudo-randomly coded on the two-probe frequencies being used for the particular altitude zone and antenna. Replies from a target transponder will be correlated with the probe frequency; that is, for a given probe frequency, valid target replies should only be on the associated reply pair of frequencies. Such valid replies are summed as "plus ones" in a counter, and there is a counter for each range bin. If a reply is received on a frequency associated with the other probe frequency, a "one" is subtracted from that range bin's counter. Since fruit replies (those stimulated by other interrogators) are expected to add equally "plus ones" and "minus ones", their contribution in the counter should, on the average, cancel out, whereas valid replies will always increase the count. If, at the end of a series of probes, the counter exceeds a predetermined threshold value, a target is declared in the appropriate range bin.

Following the detection of targets in the range correlator, the VECAS logic assigns one of 32 trackers (16 for VECAS GA/M) to acquire each target in the occupied range bins. After acquisition of a target by a tracker, a precision range measurement is made by averaging the ranges measured for each of a series of 31 probes. The range measurement, with 31 more probes is repeated after a delay of about 0.37 seconds. The difference between the two averaged measurements is used to estimate the range rate for use with ANTC-117 logic. The altitude of the transponder is then decoded and the threat evaluation performed. Table III-3 is a summary comparison of VECAS and VECAS GA/M equipments.

IV. DESCRIPTION OF ANALYSES AND TESTS

A. General

The three ACAS systems have undergone testing involving mathematical analyses, computer fast-time and real-time (with controllers in the loop) simulations, and hardware bench and flight testing. Some of the analyses and simulations were applicable to all the systems as they were directed at ANTC-117 logics. Other analyses and tests were specifically directed to the individual systems. This section of the report presents a brief description of the analyses and tests conducted and a summary of the results. For a more detailed treatment of the analyses and tests, the reader is referred to the reports listed in Appendix A, "References".

B. ACAS/ATC Simulations

In an effort to quantify and better understand the interaction between ACAS and the air traffic control system, NAFEC has performed both fast-time and real-time (with controllers in the loop) simulations. ANTC-117 logics existing at the time of the simulations were utilized and hence were applicable to all three systems.

	VECAS	VECAS GA/M
FREQUENCY BAND	1592.5 MHz to 1622.5 MHz	Same
CHANNEL BANDWIDTH	1 MHz	Same
NO. OF CHANNELS	24	Same
PULSE WIDTH	1 usec	Same
RADIATED POWER PROBE	16 watts	Same
RADIATED POWER REPLY	16 watts	Same
RECEIVER THRESHOLD (at antenna)		
Probe (below 10,000 ft.)	-85.5 dBm	Same
Reply (below 10,000 ft.)	-88.5 dBm	Same
Probe (above 10,000 ft.)	-91.5 dBm	Same
Reply (above 10,000 ft.)	-94.5 dBm	Same
ANTENNA	2 (top and bottom)	Same
ROUND TIME	4.26 sec.	Same
NO. OF TRACKERS	32	16
EVALUATION LOGIC	Essentially ANTC-117	Tau One and Tau Two, Only one altitude rate limit (1000 ft./min.), Altitude rate to 4000 ft./min.

TABLE III-3

RCA VECAS/VECAS GA/M COMPARISON

1. Fast-Time Simulations

Briefly, traffic data was gathered from various ARTS facilities and stored in a computer. ANTC-117 logic was also stored in the computer such that when any of the ARTS tracks were in conflict with any other (in accordance with ANTC-117 criteria) the computer would record the number and type of these conflicts. This was an "After-the-fact" kind of investigation in that the ARTS tracks were not perturbed as a result of the ACAS logic. One of the major goals of these investigations was to determine where the Landing/Departure Mode (desensitization) of ANTC-117 should be initiated, from the standpoint of reducing interaction with air traffic control.

It is concluded that the switch point between full ANTC-117 logic and the Landing/Departure Mode should be different for each terminal area studied. In addition, it is necessary that the switchpoint for individual terminal areas should change in accordance with ATC procedures in effect. This makes the solution to the switching problem both difficult and awkward. Pilot and/or controller inputs to the system may be necessary.

2. Real-Time Simulations

Two lengthy real-time simulations, with controllers in the loop, were run to further explore the nature of ACAS/ATC interaction, and specifically the effect on the controller. The simulated ATC environment was a high density terminal area, patterned after Chicago O'Hare, which provided for simultaneous approaches to parallel runways. Various switch-points from full logic to Landing/Departure Mode were studied. These simulations were real-time, in that controllers were controlling the traffic, simulator pilots were flying the "aircraft" in accordance with controller instructions, and in the event of an instruction initiated by the ACAS logic, the computer would maneuver the aircraft in accordance with the instruction. Upon cessation of the ACAS instruction, the controller/pilot would regain primary control of the aircraft.

Not surprisingly, it was found that the further out from the runways the Landing/Departure Mode was initiated, the less interaction with ATC there was. With the switchpoint sufficiently distant, operations rates were unaffected and controllers readily adapted to the situation. However, no attempt was made to determine what level of protection the various switchpoints afforded. Again, one conclusion reached is it is highly unlikely that a standard optimum switchpoint procedure for all terminal areas will be practical. The "how" of the switchpoint will be difficult and awkward.

C. Institute for Defense Analyses (IDA) Review of ANTC-117

Under contract to the FAA, the Institute for Defense Analyses conducted an independent assessment of the adequacy of the threat evaluation and maneuver selection logics as described in ANTC-117, Revision 10, for the aircraft performance parameters specified. (Report No. FAA-RD-75-72, See Appendix A) Major conclusions were: (1) the threat criteria do not allow sufficient time for the required escape maneuver in all circumstances; (2) the alarm criteria for threat evaluation will probably result in alarm rates which are intolerable by any standards, i.e., several T_1 alarms per minute for an aircraft in dense traffic at the center of the 1982 LAX Basin, and (3) a single modified T alarm criterion could provide as much protection in encounters among ACAS equipped aircraft. Such a single T criterion would have a smaller alarm rate than that resulting from the T_2 warning now specified.

D. Institute of Telecommunications Sciences (ITS) Radio Altimeter Interference Study

Within the United States, the Radio Frequency band 1592.5 to 1622.5 MHz is provisionally assigned for the collision avoidance function. Two foot-notes to the OTP "Manual of Regulations and Procedures for Radio Frequency Management" apply to this band. They are as follows:

Foot-note US39. "Within the band 1535 to 1660 MHz, radio altimeters are permitted to use only the portion 1600 to 1660 MHz and then only until such time as international standardization of other aeronautical radio-navigation systems or devices requires the discontinuance of radio altimeters in this band."

Foot-note US39A. "The band 1592.5 - 1622.5 MHz is allotted provisinally, but on a primary basis, for the collision avoidance function, noting the continued use of existing altimeters in the band 1600 to 1660 MHz."

Since radio altimeters present one of the major possible sources of RF interference to the ACAS systems, the Institute of Telecommunications Sciences, with FAA funding, undertook a test program to determine how severe this interference would be. The tests are not yet complete. Results of the reduction of data collected to date follows.

1. Systems Tested to Date

(See Table IV-1, next page)

Military Altimeters

Model	User	Nominal Operating Frequency (MHz)	Emission Type	Peak Power (dBM)
AN/APN-133	USAF & USN	1640	Pulsed CW	47-48
AN/APN-155	USAF	1630	Swept CW	30
AN/APN-159	USAF & USN	1630	Pulsed CW	58-60

Civilian Altimeters

Model	Manufacturer	Nominal Operating Frequency (MHz)	Emission Type	Peak Power (dBM)
TRN-70	Bonzer	1630	Pulsed CW	30
GAR	In Flight Devices	1630	Pulsed CW	37

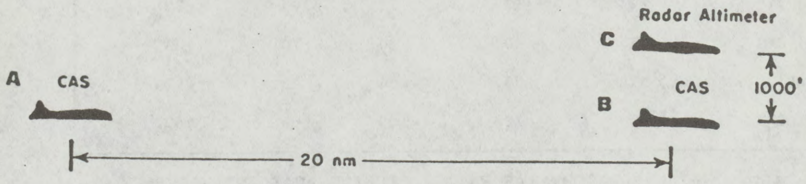
TABLE IV-1

(EQUIPMENTS TESTED TO DATE)

2. Methodology

The ACAS equipments were "hot bench" tested in the laboratory with each of the above altimeters providing interference in stepped levels to determine the Interference to Signal (I/S) level at which each ACAS failed because of interference from a specific altimeter. Interference signal levels sufficient to cause ACAS performance degradation were determined by reducing digital data tapes recorded by instrumentation connected to the ACAS. Failure of the ACAS being tested was determined to be the I/S ratio at which essential information was missed by the ACAS due to the interferring signal.

These laboratory measured I/S ratios were then used to show separation distances at which interference to the ACAS would occur from the various altimeters, in accordance with the scenario shown in Figure IV-1. Aircraft A and B are both equipped with an ACAS. Aircraft C is equipped with a radar altimeter. Aircraft A is overtaking aircraft B & C, who are flying at the same heading and velocity. Free space transmission loss was used as well as estimated antenna patterns and gains.



Scenario 1

FIGURE IV-1

In addition to the above tests, the problem of co-location of ACAS and radar altimeters on the same aircraft was investigated in a limited manner to determine the magnitude of the problem. This is important since for ACAS to be effective, all aircraft should be equipped. This was accomplished experimentally by equipping two NAFEC Gulfstream aircraft with the McDonnell-Douglas EROS II and MINI-CAS systems, one aircraft with the Bonzer TRN-70 altimeter and the other with the AN/APN-155 military altimeter. The altimeter antennas were mounted on the bottom of the aircraft, about 10 ft. from the bottom ACAS antenna. Coupling between the altimeter antenna port and the top ACAS antenna port was measured in flight and showed 78 db and 81 db isolation on the two aircraft. Isolation between the altimeter antenna and the bottom ACAS antenna was 55 db and 63 db respectively. The experiment was performed by flying the two aircraft, initially separated by 12 nmi. horizontally and 500 ft. vertically, at each other until they "met." The course was flown once with the ACAS operating normally and neither of the altimeters turned on. A second run was made with the Bonzer altimeter turned on and a third run was made with the Bonzer off and the AN/APN-155 on. The experiment was first performed with the EROS II in operation and then repeated for the MINI-CAS.

3. Results

The results of the testing discussed previously are shown below:

a. Laboratory Tests

Table IV-2 lists the I/S ratios at which the various ACASs failed due to interference from the indicated altimeters, as measured in the laboratory.

	AN/APN-133	AN/APN-155	AN/APN-159	Bonzer TRN-70	In-Flight Devices GAR
EROS II	29	12	26	-3	35
MINI-CAS	45	30	30	20	33
VECAS	> 53	> 35	> 54	26	> 42
AVOIDS I	> 58	12	> 63	8	> 60

TABLE IV-2 LABORATORY I/S RATIOS CAUSING ACAS INTERFERENCE

b. Laboratory Tests Extrapolated to Separation Range

In accordance with the scenario shown in Figure IV-1, Table IV-3 shows the theoretical separation distance in nautical miles that could exist between the two ACAS equipped aircraft for the ACAS to operate properly in the presence of a specific radar altimeter. Distances less than these values result in satisfactory ACAS operation. For example, using the values shown for EROS II and the APN-133, from 20 nmi. separation to 9.5 nmi. separation, interference occurs. At less than 9.5 nmi. separation, the ACAS signal becomes strong enough to override the interference. Separations shown as greater than 20 nmi. simply means that from separations of 20 nmi. and in, the I/S ratio is always such as to insure proper ACAS operation. At some point greater than 20 nmi., the I/S ratio will become large enough to cause ACAS malfunction.

	APN-133	APN-155	APN-159	TRN-70	GAR
EROS II	9.5nm	11.0nm	1.2nm	2.5nm	> 20 nm
MINI-CAS	> 20	> 20	2.5	> 20	> 20
VECAS	15.5	20	4.5	9.5	> 20
AVOIDS I	> 20	4.5	> 20	4.5	> 20

TABLE IV-3 I/S RATIOS EXTRAPOLATED TO SEPARATION DISTANCE

c. ACAS/Altimeter Co-Location Flight Tests

Both the EROS II and MINI-CAS, mounted on the same aircraft with the TRN-70, were seriously interferred with when the TRN-70 was in operation, over the entire course flown. Altitude, range, and range-rate information were either inaccurate or unavailable, rendering the ACAS display in both aircraft unusable. The interference from the APN-155 was less severe than that from the TRN-70, but the EROS II and MINI-CAS were rendered inoperable on the co-located aircraft.

4. Conclusions

Based on the available data, the radar altimeters tested do cause objectional interference to the ACAS systems, with the APN-159 and TRN-70 being the worst offenders. The EROS II is the most susceptible to the altimeter interference with the VECAS and AVOIDS I being less susceptible.

The experiment involving the co-location of ACAS and the radar altimeters on the same aircraft indicate a great deal more than normal isolation between the two systems would be required to make them operable on the same aircraft, if indeed it could be accomplished at all.

It is doubtful whether retuning or band limiting the altimeters would reduce the interference to a negligible level. The interference problem is one of degree; the only absolute solution would be removal of the altimeters from the band.

E. ARINC Research Corporation Cost Analysis

1. General

Since the choice of an ACAS system for a U.S. National Standard cannot be based on technical factors alone, ARINC Research Corporation, under contract to FAA, performed a cost analysis to provide a basis for assessing the economic impact of ACAS implementation on the various aviation communities. (Report No. FAA-EM-76-1, See Appendix A) Separate cost evaluations were developed for general aviation, commercial aviation, and the military. The classes of equipment studied included both the air carrier and general aviation versions of the Honeywell, McDonnell-Douglas, and RCA systems.

2. Methodology

The cost analyses required the development of detailed cost and reliability data peculiar to each of the ACAS systems and the development of ACAS implementation cost factors that apply equally to the three ACAS concepts. System costs based on these data were then evaluated with the aid of an economic cost model. The cost and reliability data describing each of the three systems provided the basis for the economic comparison of the systems. Since these data were critical to the success of the study, two different sources were used. First, the three manufacturers were requested to provide detailed cost and reliability data on their systems; then the general aviation versions of each of the systems were subjected to a uniform pricing evaluation by independent general aviation manufacturers, General Aviation Electronics (GENAVE) and National Radio Company (NARCO).

3. Results

Tables IV-4 through IV-8 show the ARINC cost data for one year in 1975 dollars. While the GENAVE and NARCO derived data were slightly different, they both maintained the same relative ranking, that is Honeywell is the least costly, RCA the most costly, and McDonnell-Douglas in the middle. This relative ranking was maintained even when a number of the basic assumptions and data inputs were varied. Costs associated with any required ground stations are not included.

TABLE IV-4 AIR CARRIER COSTS*

	Honeywell	McDonnell-Douglas	RCA
Electronics	$ 6,322	$ 7,004	$ 7,938
Installation	4,227	4,227	4,227
Non-Recurring	103	160	164
Recurring Logistics	337	302	358
TOTAL COST (ONE YEAR)	$10,989	$11,693	$12,687

* Costs include a simplex collision avoidance box, two indicators, and two antennas

TABLE IV-5 MILITARY (HI PERFORMANCE) COSTS*

	Honeywell	McDonnell-Douglas	RCA
Electronics	$ 5,776	$ 6,458	$ 7,392
Installation	8,252	8,252	8,252
Non-Recurring	391	514	471
Recurring Logistics	781	767	776
TOTAL COST (ONE YEAR)	$15,200	$15,991	$16,891

* Costs include a simplex collision avoidance box, two antennas and an average of 1.5 indicators (50% of the aircraft would have two, the other 50% one)

TABLE IV-6 MILITARY (LOW PERFORMANCE) COSTS*

	Honeywell	McDonnell-Douglas	RCA
Electronics	$ 591	$1,016	$1,175
Installation	2,479	2,479	2,479
Non-Recurring	100	208	196
Recurring Logistics	882	952	918
TOTAL COSTS (ONE YEAR)	$4,052	$4,655	$4,768

* Costs include a simplex collision avoidance box with an integral display and two antennas

TABLE IV-7 GENERAL AVIATION (HI PERFORMANCE) COSTS*

	Honeywell	McDonnell-Douglas	RCA
Electronics	$6,434	$7,320	$ 8,496
Installation	1,925	1,925	1,925
Recurring Logistics	22	19	24
TOTAL COST (ONE YEAR)	$8,381	$9,264	$10,445

* Costs include a simplex collision avoidance box, one indicator, and two antennas

TABLE IV-8 GENERAL AVIATION (LOW PERFORMANCE) COSTS*

	Honeywell	McDonnell-Douglas	RCA
Electronics	$ 930	$1,610	$1,863
Installation	226	226	226
Recurring Logistics	23	39	32
TOTAL COSTS (ONE YEAR)	$1,179	$1,875	$2,121

* Costs include a simplex collision avoidance box with an integral display and two antennas

F. Institute for Defense Analyses (IDA) Capacity Studies

1. General

In 1973, in an attempt to discover how the three proposed ACAS systems might work in a high-density environment, the FAA contracted with IDA to perform an independent study of the communication capacity capability of the systems when operating in a predicted 1982 traffic environment for the Los Angeles Basin. (See Appendix A for Report Numbers) Under this effort, IDA was enjoined from directing any effort to determine the adequacy or effectiveness of the ANTC-117 threat evaluation and maneuver selection logics. Rather, they were directed to put particular emphasis on the relationship between traffic density and missed alarms (accepting the hypothesis that an intruder is not a hazard when in fact he is, in accordance with ANTC-117) and false alarms (accepting the hypothesis an intruder is a hazard when in fact he is not, according to ANTC-117). Consideration was to be given to the ACAS systems' communications reliability and synchronous & asynchronous garble.

2. Traffic Environment

The traffic model used for evaluation purposes was a forecast of the instantaneous peak traffic in the Los Angeles Basin in 1982, as prepared by FAA's Aviation Forecast Division, dated April 27, 1971. It was a static model, and gave the three dimensional position of each aircraft with the LAX airport as the origin of the coordinate system. General Aviation, air carrier, and military traffic estimates were distributed into local vs. itinerant and IFR vs. VFR. The total traffic was 807 aircraft, classified by type and distributed in altitude as follows:

	< 10,000 ft.	> 10,000 ft.
General Aviation	599	127
Air Carrier	29	15
Military	20	17
TOTAL	807	

IDA reported on the analysis of the systems in 1974 and suggested modifications to correct some deficiencies uncovered. On-going work by the manufacturers themselves as well as hardware evaluation by the Naval Air Development Center of Honeywell and RCA air carrier equipment, led to additional changes in the systems. Therefore, FAA again contracted with IDA (July 1974) to revise the analyses in accordance with the changes made.

3. Results

a. General

Generally, the results of the IDA analyses show that any of the three systems can form the basis of an ACAS system, provided the ANTC-117 logics are valid. However, many detailed problems were uncovered, all of which could be remedied or alleviated with appropriate modifications.

b. Honeywell Analyses

Major conclusions reached as a result of the Honeywell analysis are as follows:

(1) Non-threatening aircraft with a range-rate which is close to that considered threatening were found to be the major cause of false alarms in the AVOIDS tracking filter. This is due to the fact that at range-rate close to threatening range-rates, the range bins associated with the TAU filter (which must all be full for further threat processing) can be nearly all filled by the non-threatening aircraft. This then makes it more probable that the remaining bins can be filled by fruit. As a result, the false alarm rate is sensitive to the distinction which is made between a false alarm and an alarm which is displayed too early in time or at too great a range, and the shape of the range rate distribution of non-threatening aircraft. Analyses has shown the total false alarm rate in the 1982 LAX Basin would be about one per hour if alarms issued within about four epochs of the T_2 boundary are excluded. This increases to about seven per hour if alarms issued within about two epochs of T_2 are excluded. These estimates assume all aircraft were exposed to the most dense traffic region of the LAX 1982 model and are therefore conservative.

(2) Due to transponder blockage, it is estimated that the probability of no delay in the T_2 warning is .97. The probability of a one epoch delay (i.e., 3.7 secs.) is about 0.015, the probability of a two epoch delay also about 0.015, and the probability of a delay of three or more epochs about 0.0007.

c. McDonnell-Douglas Analyses

Major conclusions reached as a result of the McDonnell-Douglas analysis are as follows:

(1) Use of range difference measurements for range-rate estimation introduces bias errors between the actual TAU alarm boundary in the range rate versus range plane. This leads, in most cases of level flight, to early alarms. However, situations resulting in false alarms do exist. Despite the fact that the error, at short ranges, exceeds the specified value by wide margins, there is only an 8 to 10 percent increase (depending on relative speeds) in the overall alarm rate.

(2) Reduced air-to-air synchronization relay range due to aircraft antenna gain nulls, a short rundown time in synchronous status due to limited airborne clock stability, and the backup mode interference/garble and alarm rates are all inter-related and manageable problems, if an adequate relationship between air carrier and MINI-CAS equipments is maintained throughout the aircraft population.

d. RCA Analysis

Major conclusions reached as a result of the RCA analysis are as follows:

(1) The probabilities of acquiring a non-existent target (false alarm) and of not acquiring a true target (missed alarm) are both less than 2% at the maximum hazard range and considerably smaller at closer ranges.

(2) While excessive roundtime has been reduced by the addition of many trackers, under certain circumstances, roundtime could still be excessive.

(3) Range error measurements may deteriorate by an unacceptable amount when multiple targets appear in a single range bin (interval of 500 ft.), an event which can occur with greater frequency than indicated by the traffic density because of the presence of virtual as well as true aircraft targets.

G. Flight Test and Evaluation Program

1. Participants

FAA, under interagency agreements with the Naval Air Development Center, Warminster, Pennsylvania, funded for the procurement, flight test and evaluation of the Honeywell and RCA air carrier and general aviation ACAS equipments. FAA directly procured the McDonnell-Douglas air carrier and general aviation equipments and performed the flight test and evaluation at NAFEC.

Subsequent to the flight test and evaluation of the AVOIDS I and VECAS equipments, system design changes were made to both and incorporated into the AVOIDS II and VECAS GA/M equipments which had not yet been delivered. Flight testing of the AVOIDS II equipment was completed at NADC by October 1, 1975. The VECAS GA/M equipment is currently undergoing bench testing at NADC. Flight testing of the EROS II and MINI-CAS equipments was completed at NAFEC in October 1975.

2. Commonalities

ANTC-117 logics were used as the basis for evaluation for all air carrier equipments. Identical flight test patterns were utilized

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for all equipments and range and range-rate calibration flights were performed on the Navy's Patuxent River phototheodolite range for the Honeywell and RCA equipment and at the NAFEC phototheodolite range for the McDonnell-Douglas equipment.

3. Differences

Besides the differences in test organizations and locales, there were minor differences in the test instrumentation. Both the Honeywell and RCA equipments were flown with simulators capable of injecting fruit into the system up to that level estimated for the 1982 Los Angeles Basin if all aircraft were ACAS equipped. Since the McDonnell-Douglas system does not suffer from a "mutual interference" problem, and since analysis did not indicate system capacity to be a problem, no such simulator was used in its flight test. The NADC testing also included slightly higher closing velocities.

4. Description of Flight Tests

The primary objectives of the flight tests were to:

a. Determine the communications reliability of the RF link as a function of range and antenna aspect angles

b. Determine the range and range-rate accuracies

c. Determine conformance with ANTC-117 TAU zone and altitude zone boundaries

d. Examine the capabilities of the vertical maneuver escape logic

To accomplish these objectives, a wide range of flight patterns were run covering closure rates of zero to approximately 800 knots. These patterns included traffic geometries encompassing 360° around the participating aircraft to test for adequate hazard detection in all directions. Flights above and below 10,000 ft. were flown as well as two and three aircraft encounters.

Aircraft used in the NADC tests were as follows:

TYPE	NUMBER	AIRSPEED
P-3A	1	190 to 350 knots
NC117	1	120 to 180 knots
RA3B	1	220 to 400 knots

Aircraft used in the NAFEC tests were as follows:

TYPE	NUMBER	AIRSPEED
Gulfstream	2	140 to 250 knots
Convair 880	1	190 to 350 knots

5. Results

a. General

Subsequent to the flight testing of the Honeywell AVOIDS I and the RCA VECAS, the systems' designs were changed. These design changes were incorporated in the Honeywell AVOIDS I and II and the RCA VECAS and VECAS GA/M. The data from tests of the modified equipments shows the Honeywell system change improved $\dot{R}$ accuracy and reduced the level of false alarms, and the RCA system change decreased the $\dot{R}$ accuracy.

b. RCA

(1) VECAS

The VECAS provided the necessary avoidance warnings in a manner consistent with the requirements of ANTC-117. The pilots were able to execute the necessary avoidance maneuvers.

The required communication range was exceeded for all encounter angles except the head-on case above 10,000 ft., which was marginal when extrapolated to a 1200 knot range-rate. Analysis shows that there was an imbalance in the theoretical threat range at the 10,000-foot altitude boundary. Aircraft on opposite sides of this boundary do not have the same theoretical communications range.

Round reliability (proper commands and advisories) from the point at which initial communication range was established to the point of closest approach was greater than 90% for all encounter angles for most simulated traffic conditions, and without the benefit of round-to-round memory. The tolerance of the data link to fruit replies above 10,000 ft. was greater than 350,000 replies per second per field above threshold, and below 10,000 ft. was greater than 40,000 replies per second per field above threshold.

The accuracies of the trackers were:

TRACK TYPE	RANGE IN FEET		RANGE-RATE KNOTS	
	MEAN	1 SIGMA	MEAN	1 SIGMA
Half Track	142	95	0.88	20.5
Full Track	105	70	1.09	8.6

The warning time mean and standard deviations expressed as percentages of the TAU Two and TAU One thresholds, (theodolite reference) were:

TAU ONE	TAU TWO
Mean = -7.3%	Mean = -7.4%
Sigma = 13.7%	Sigma = 7.1%
N = 92	N = 87

From the above, it can be seen that the TAU Two warning times provided by the VECAS on 87 encounters were found to be 7.4% late on the average with a standard deviation of 7.1%. The TAU One warning times on 92 encounters were found to be 7.3% late on the average with a standard deviation of 13.7%.

The TAU Two advisories were generated at greater than 40 seconds before collision. The TAU One commands were generated within one round of the desired time. The minimum round-time was 4.5 seconds below 10,000 ft. and 6 seconds above 10,000 ft. The contribution to roundtime of each target is usually 0.3 second for test track plus either 0.4 second for half-track or 0.8 for full-track. The use of two trackers for co-half-zone targets in the same correlator sector reduced the roundtime contribution of these targets.

Multipath tracks of a real target occurred infrequently, and their effect on average roundtime was insignificant. Other multipath tracks occurred at low altitudes where the VECAS replied to its own interrogations.

(2) VECAS GA/M

The VECAS GA/M equipment is currently undergoing bench testing at NADC. Very little data has been reduced, but based on this data, and on factory acceptance, it appears that in redesign efforts to correct other problems, the $\dot{R}$ accuracy has suffered. The one sigma value now appears to be on the order of 40 knots.

c. Honeywell

(1) AVOIDS I

The AVOIDS I provided the necessary avoidance warnings to the pilots. The warnings were consistent with the requirements of ANTC-117, and provided the pilots with sufficient time to execute the necessary avoidance maneuvers.

The required communication range was exceeded for all encounter angles at the speeds flown, and for all extrapolated 1200 knot range rates above 10,000 ft. for all of the flights involving the NC117 vs. either the RA-3B or P-3. The same results were achieved for all of the flights involving the RA-3B above the P-3. For the flights involving the P-3 above the RA-3B, the communication ranges were marginal when extrapolated to a 1200 knot range rate, above 10,000 ft., at encounter angles of -120 and 180 degrees.

The pilot display reliability was 98.2%.

The air-to-air communications link when operating with fruit had an error rate which was too high and caused an excessive number of false alarms.

The range and range rate accuracies (Theodolite reference) were:

	RANGE		RANGE RATE	
GROUP	MEAN %OF RANGE	SIGMA FEET	MEAN KNOTS	SIGMA KNOTS
All Data	+2.5	154	+10	11
Data Without Fruit	+2.7	132	+ 9	10
Data With Fruit	+2.1	197	+13	13

The warning time mean and standard deviations expressed as percentages of the TAU Two and TAU One thresholds (theodolite reference) were:

TAU One			TAU Two		
Mean	=	0.4%	Mean	=	0.5%
Sigma	=	4.1%	Sigma	=	4.1%
N	=	47	N	=	48

(2) AVOIDS II

The AVOIDS II equipment was evaluated against itself and was also flown against the AVOIDS I equipment after it had been modified to improve its performance. Incomplete reduction of data recorded in the AVOIDS II vs. AVOIDS II flights indicates the equipment is performing in accordance with the logic implemented as shown in Figures III-5 and III-6. No false alarms were detected and multipath has not shown itself to be a problem. Communications reliability is on the order of 96.5% with the display reliability being greater than 99%. The range and range rate accuracies were:

	RANGE	RANGE RATE
Mean	83 ft.	9 knots
Sigma	94 ft.	7 knots

Warning times (expressed as percentages of the TAU Two and TAU One thresholds) indicate that 95% of the time, the TAU Two warning ranged from 14.5% late to 16.1% early. The TAU One warnings ranged from 11.8% late to 21.8% early.

d. McDonnell-Douglas EROS-II and MINI-CAS

Data reduction accomplished to date shows the EROS II equipment provided the necessary avoidance warnings in a manner consistent with the requirements of ANTC-117. The MINI-CAS operated in accordance with the logic implemented (no Ro_1 off-set, one off-altitude band only, and no predicted co-altitude band).

The air-to-air communications reliability for EROS II vs. EROS II was above 95% before TAU Two, and above 98% at TAU Two and TAU One. For the MINI-CAS vs. MINI-CAS, these figures were 96% before

TAU Two, above 98% at TAU Two and above 99% at TAU One. For the EROS II vs. MINI-CAS, these figures were greater than 91% before TAU Two, and greater than 97% at TAU Two and TAU One.

The range and range rate accuracies (theodolite reference) were:

	RANGE		RANGE RATE	
	Mean (nmi.)	Sigma (nmi.)	Mean Knots	Sigma Knots
EROS II	.03	.035	-5 to 10	15
MINI-CAS	.01	.035	-5 to 15	10

The warning time mean and standard deviations expressed as a percentage of the TAU One and TAU Two thresholds were:

	WARNING TIME			
	TAU ONE		TAU TWO	
	Mean	Sigma	Mean	Sigma
EROS II	-14.8%	9.6%	-1.3%	4.0%
MINI-CAS	- 8.1%	11.0%	-1.6%	3.7%

Both ground-to-air communication reliability for synchronization and synchronization accuracy were more than adequate.

V. SUMMARY OF ANALYSES AND TESTS

A. ACAS/ATC Interaction

The simulations performed at NAFEC and the analysis of ANTC-117 conducted by IDA, cast doubt on the validity of ANTC-117, at least insofar as acceptable alarm rates are concerned. More effort is necessary in this area and will require a trade-off between protection provided and the number of alarms tolerable. This problem is applicable to all three systems.

B. RF Frequency Compatibility

The radar altimeters analyzed present interference to the three ACAS systems, with the EROS II being the most susceptible. Co-location of an altimeter and an ACAS on the same aircraft is the worst situation and may be intolerable.

C. IDA Capacity Analyses

From a communications viewpoint and assuming the validity of ANTC-117, it appears that all three systems could operate satisfactorily in the Los Angeles Basin traffic model utilized. The McDonnell-Douglas system suffers from a bias error in the TAU measurement under certain circumstances which serves to increase the alarm rate. This error is insignificant in the Honeywell and RCA systems. The RCA system can, under certain circumstances, have an excessive roundtime and the fruit level is a function of the distribution of VECAS, VECAS GA/M, Proximity Warning Indicators and Remitters. Unlike the Honeywell and McDonnell-Douglas systems, not all aircraft receive positive commands. The escape maneuver is required to be accomplished by the VECAS and VECAS GA/M equipped aircraft.

D. ARINC Research Cost Analyses

The ARINC Research Company cost analysis shows the Honeywell AVOIDS systems enjoy a clear economic superiority over the McDonnell-Douglas and RCA systems.

E. Flight Test and Evaluation

The flight test and evaluation of all systems indicate they all meet ANTC-117 requirements. The Honeywell system was superior in performance to the other ACAS systems.

F. Summary Evaluation Table

Table V-1 is a summary of the three systems based on data available at the writing of this report.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. It is concluded that the Honeywell AVOIDS I and II systems are superior to the McDonnell-Douglas and RCA systems.

B. It is recommended that additional effort be made to optimize the ANTC-117 threat evaluation logic from the standpoint of protection vs. alarm rate. The problem of ANTC-117 compatibility with the ATC system needs additional effort. Analysis indicates the alarm rates attendant with current logic are too high and unsatisfactory, especially in high density terminals.

C. If an ACAS is to be implemented, it is recommended that action be started to remove the radar altimeters from the 1600 to 1660 MHz band.

D. If an ACAS is to be implemented, it is recommended that further effort be conducted to determine the mutual impact of other existing or planned services in or near the ACAS frequency band (i.e., AEROSAT, etc.).

	HONEYWELL	McDonnell-Douglas	RCA
GROUND STATION SYNCHRONIZATION REQUIRED	NO	YES	NO
ALL AIRCRAFT PROVIDED WITH POSITIVE COMMANDS	YES	YES	NO
COMMUNICATIONS ON ALL ANTENNA COMBINATIONS	YES	NO	NO
RANGE RATE ACCURACY	BEST	MIDDLE	WORST
DEGREE OF DESIGN MATURITY	HIGH	MEDIUM TO HIGH	LOW
COST	LOWEST	MIDDLE	HIGHEST

TABLE V-1

SUMMARY EVALUATION

APPENDIX A

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The question that concerns me here is that you have in your calendar schedule BCAS not being implemented until late 1979–80. Ground implementation does not start until 1982 for IPC and yet ACAS is available today. The question has to occur—why has the FAA established a standard around ACAS?

Mr. COCHRAN. Let me give you a partial answer and then I will turn it over to my experts here and we will talk it in some detail. We would like to have a special briefing on this subject, in fact next week we will have a meeting on the aircraft separation assurance program. It is a listening session and more or less a public forum where we discuss the various facets of the aircraft separation assurance program which ACAS, BCAS, and all that—that is the 27th of this month it takes place. I do not know what room it is in now.

Mr. WEDAN. Yes; it is in the auditorium on this coming Monday and Tuesday.

Mr. GOLDWATER. This is a public discussion about collision avoidance, separation?

Mr. COCHRAN. Anyway, we will let you know where that is going to be. It is in the Federal Register, but I just do not recall the exact——

Mr. GOLDWATER. Is this going to be a one-way discussion or is the public invited?

Mr. COCHRAN. Hopefully, the public is going to participate. They have been informed about the subject—what is going to be discussed.

Mr. WEDAN. It has been advertised in general as a public users conference. We will present our program pretty much as outlined in the letter to Senator Cannon and we expect to get top of the head type comments so far as immediate feedback plus written responses.

Mr. COCHRAN. What we have said here is that we have a 2-day conference. It will be held in the DOT conference room 2230, DOT Headquarters Building, 407th Street SW., Washington, D.C. The opening session will begin at 9 a.m. It says that it invites persons who wish to present their views and discuss things to submit their comments in writing. So they are supposed to have already submitted agenda items to be discussed. The second day we are hoping to have full discussion of the things that are raised on the first day that were raised by the interested parties. So I am sure that almost all issues will be raised on the first day.

Mr. GOLDWATER. If someone came walking in off the street could they sit in and listen or is this a prescreened forum?

Mr. COCHRAN. No, sir, it is an open meeting.

Mr. GOLDWATER. I might just walk in off the street.

Mr. COCHRAN. Alright, sir, we will be glad to have you. I would also like to make a further comment—and that is a discussion just between ourselves, whoever you would like to bring with you a limited number of people and a few of us and we'll sit down and talk about how we can get the various degrees, what the various threats are of a midair collision and those probabilities, the way of getting protection against these threats and the time frames in which we reasonably see the implementation of these various schemes to provide protection against those threats. I think those are the kind of things we would have to get down in detail to resolve completely the problems that you mentioned. But I would let Mr. Wedan answer your question a little fuller than the way I have answered it.

Mr. WEDAN. A judgment has been made with respect to ACAS in terms of the program that we are proposing to conduct, and the relationship it has to its alternatives, namely BCAS. I think that the major discriminating factor in comparing these two approaches is the cost to implement an approach and the time associated with that. If we were to pursue a program based on the ACAS, the Honeywell, or a similar type of system, it would require in order to provide the protection we are looking for, essentially a mandatory carriage of the equipment on board all aircraft. The cost associated with this would be substantial we believe in comparison to its alternative. The alternative BCAS is dependent on the existence of equipment which is already on a large share of the fleet both general aviation and commercial airliners. I am speaking of a transponder. The statistic I quoted earlier was that 70 percent of the general aviation fleet today is believed to be equipped with transponders, so——

Mr. GOLDWATER. What percentage?

Mr. WEDAN. Seventy. So we are talking about——

Mr. GOLDWATER. General aviation?

Mr. WEDAN. That is the number I have; yes.

Mr. COCHRAN. Now, that is not with altitude and coding.

Mr. GOLDWATER. Oh, OK.

Mr. WEDAN. Ten percent have the altitude and coding.

Now, of course, so far as the commercial aircraft are concerned, they already have a full 100-percent installation of that equipment. So a substantial part of the cost of a system of this type is already aboard this fleet and so the cost of implementing this system would be substantially less if we took advantage of that equipment as one of the underlying——

Mr. GOLDWATER. This is to the user?

Mr. WEDAN. Now, there is one other factor and that is that one of the modes of the two mode operation of the BCAS system permits one to listen in. It is not an active interrogation mode. It is one of sitting and listening in to the responses of the transponders operating in the air traffic control system. By that technique the aircraft so equipped could determine which of all the aircraft that he is listening to poses a threat to him. He can resolve that conflict. That seems to have some advantage in operating in certain parts of the airspace particularly as we move into the high density airspace. So we think that there is a technical advantage in the approach that we are taking now. If we stay with the ACAS type of approach it will probably be pretty much limited to the en route phase of flight, the less densely traveled part of the airspace. We are still faced then with the problem of resolving the conflicts in the terminal airspace.

Mr. GOLDWATER. The difference between BCAS and Honeywell and others is primarily that you have a down link to the air traffic control system. Has the FAA explored the ability of ACAS to also utilize the down link and to in essence give the air traffic controllers joint use of the information established or arrived at with ACAS?

Mr. WEDAN. I am not familiar with any studies that were directed to that specific question. I am sure it is technically possible to provide a link to the transponder equipment to the communications link with the ground. It would require modification of that equipment, I believe. Again, the answer to your question is I am not familiar with any study of this type.

Mr. GOLDWATER. I wonder if—maybe you have this information now, but we talk about costs and sometimes we are not being realistic about it. ACAS is fully independent of the ground air traffic control system as presented. The only cost there would be the cost of purchase to the user of a device that he would put in his airplane. No cost to the general public. No cost to the taxpayer. No cost taken out of airport trust funds. Versus BCAS and DABS and IPC. How much is this whole system going to cost regardless of who is going to pay for it?

Mr. WEDAN. Maybe I could correct one part of your question. The BCAS is independent of the ground in terms of its ability to resolve a conflict. In other words, if it is functionally at least in the active interrogation mode, if it is functionally identical to that of the ACAS. It has the advantage that it can communicate with the ground, but it is not essential to do so to resolve the conflict. Therefore the cost to the user is the thing that we are concerned about here. The cost to the user would be less for BCAS than ACAS. The cost to the public at large would be the same.

Mr. GOLDWATER. You are saying that BCAS is not dependent upon the ground?

Mr. WEDAN. That is right. BCAS can operate by an air-to-air type of communication. It can interrogate other aircraft and listen in. It is not dependent on the ground. It can take advantage of the fact that the ground is also providing interrogation of aircraft and listen into it, but it is not dependent on that in order to resolve a conflict.

Mr. COCHRAN. The main advantage, of course, is that as soon as you buy your BCAS box, you not only buy protection from other people who have bought the BCAS box, but you buy protection from everyone who has an altitude and coding transponder. So let us say you are an airline and you bought one, and then you would fly in the oceanic areas or overseas in areas where there is positive control or there is a control situation where such as the two aircraft that ran together not too long ago over Yugoslavia, both of those—if one of those had had a BCAS box on it and the other one had had the ICAO adopted transponder with altitude and coding, he would have gotten warned of it. The guy with the BCAS box would have had a warning whether the aircraft was BCAS equipped or not, as long as he had that big box. So the first day you buy, if you are the first guy to buy a ACAS box, you do not get protection from anybody.

Mr. GOLDWATER. But you are going to need that fairly sophisticated ground based equipment to interrogate the——

Mr. COCHRAN. No, sir. That is what I am saying, you do not have to have it. There is one mode of operation of the BCAS system that will perform as long as the two aircraft are either equipped with the BCAS or with a standard transponder. In other words, if you are flying over a country that—let's say you are over the Gulf of Mexico where we have no interrogators, you are out of the range of the interrogators. I am flying there with a BCAS box, and you have got your transponder with altitude and coding. I will have protection from you.

Mr. GOLDWATER. I see. Now your next generation is DABS and IPC? You are working on this right now?

Mr. COCHRAN. Yes, sir.

Mr. GOLDWATER. In fact you have an IPC set up?

Mr. COCHRAN. We have a test model; yes, sir, and we would like to have you come up and fly that. You know, you can sit in the airplanes, and you can fly that system and see what it does. It does provide a means of air traffic control information, and we had a film clip on it. I do not know whether you were in here when we had it or not, but we had a clip on that. We can show it to you later if you would like.

Mr. GOLDWATER. No; I am fairly familiar with it.

Mr. COCHRAN. All right, sir.

Mr. GOLDWATER. My concern is the cost. I keep hearing how people talk about costs. I have never heard the FAA come out and say how much they have spent on this or how much this is going to cost us. Do you have a breakdown on what has been spent for DABS, IPC and BCAS versus ACAS and what you are projecting out in the future.

Mr. WEDAN. I would like to speak to the cost of the IPC. The cost of the ground equipment, surveillance equipment is on the order of $500,000 to $600,000 per set. That would be a cost to the Government for each area that we want to put these in. Now it would replace the function of our present surveillance system. So, you add them into the system and replace what is already there as they phase out. The cost of the user is the other part of the question. If you as a user did not want to receive this message that comes from the ground, you are not obligated to put any equipment in there, but if you would like to avoid collisions then you would have what you have today perhaps, that is a transponder with altitude and coding, because the other aircraft then would be able to see you and avoid the conflict. If on the other hand you want double protection and you want to get the command as well as the other fellow, then the cost to you would be the transponder which is different and this display which you saw mounted on your instrument panel. The altitude and coder would be the same. The difference between the transponder that would be applied to this system as compared to what you would buy today would be on the order, in our cost estimating, of about $400 over and above what you pay today. That is mainly to provide you with a data communications link with the ground.

The other item would be the display, and I believe the display as I recall would be on the order of about $400 or $500, but that would be an additional cost to give you that new service. Nothing in this concept would represent a mandatory requirement. It is compatible, what I am saying is that the advanced system is compatible with today's existing system.

Mr. GOLDWATER. What you are saying is that it will replace today's existing system?

Mr. WEDAN. It can operate jointly with today's surveillance system.

Mr. COCHRAN. I think one thing we need to clear up just a little bit—the DABS, the Discrete Address Beacon System is a beacon system that is being developed to replace the Air Traffic Control Radar Beacon System which has some severe limitations—some problems associated with that, the garble problems, the problem of overinterrogation, and the problems of false replies and things of this nature which are plaguing us today in the air traffic control system, and they increase in their complexity and difficulty to deal with as you try to automate the system, and you try to deal with all of this extraneous information that comes in off the existing system. So there are some fairly significant deficiencies in the present Air Traffic Control Radar Beacon System that we are trying to solve with the Discrete Address Beacon System. The Discrete Address Beacon System is attempting to solve those problems at the same time it remains fully compatible with the airborne and ground systems of the aircraft. In other words, if you now have currently in your aircraft an Air Traffic Control Radar Beacon transponder and we go ahead and implement that interrogator at a certain site, your aircraft would never know the difference in that particular phase of its operation. Associated with the development of the Discrete Address Beacon System is the ability to address discretely every aircraft that it has under surveillance. It can interrogate that aircraft—and that aircraft alone—with a special message and receive back from that aircraft a special message. It will also interrogate generally those aircraft that do not have discrete capability, but it can deal individually with those, and therefore it does provide a basis for communications, data communications back to the aircraft.

One of the fallouts from the development of the Discrete Address Beacon System would be the ability to transmit message information such as the intermittent positive control back to the aircraft, and our development program has proceeded along parallel paths in this area. We feel like that from an air traffic control viewpont we must develop a Discrete Address Beacon System to replace the existing system in the future, and then since we do have that parallel capability or that ability to transmit messages back, we are looking at the intermittent positive control features to see if that feature does not provide benefit in the way of positive traffic control in the areas of surveillance.

Mr. Goldwater. How much money have we spent on these systems and how much are we projecting to spend before they are to the point of implementation?

Mr. Cochran. That is a good question, and we will answer that for the record. I do not think we have that right off the top of our head, but we can answer that for the record and we will answer it that way. We will also list the development costs and then the implementation cost of these systems.

Mr. Goldwater. That will be fine.

Mr. Cochran. We will make some estimates concerning the full implementation of the various systems in the fleet also.

Mr. Goldwater. Mr. Chairman, I have used up a lot of time. I have some other questions on wind shears and weight vortices.

Mr. Milford. We would at this point state that any member, including some who had conflicting engagements today may wish to submit questions, and that the questions and your answers to the questions would be incorporated into the record up until the time the record closes, if that would be agreeable to everyone?

Mr. Cochran. We would be glad to answer any questions that you have for the record. We will furnish any information that you would like to have.

Mr. MILFORD. I would like to get into another area that may or may not be completely within the jurisdiction of this committee, but I know that Mr. Goldwater and I both would have interest in it, if not in this committee another one.

We have talked a lot today about MLS, ILS, wind shear and what have you, and the various pieces of equipment on board and on the ground. One of these—I must point out also that we have a large segment of aviation that is unable to carry this equipment on board or otherwise, but fly a great deal under VFR conditions or marginal VFR conditions, and also have need for assistance in landing aids. What I am getting around to is I would like to know what the present status of FAA might be in the utilization of VASI?

Mr. COCHRAN. We have implemented quite a number of VASI's and we have in our fiscal 1977 and 1976 programs we had a large number of them in the implementation program. I do not have the information concerning them, but I will furnish the numbers that we are putting in, but there is a sizable implementation program in the VASI.

Mr. MILFORD. What is the approximate cost of these VASI installations? Do you happen to know right off a ballpark figure?

Mr. COCHRAN. They vary quite a bit.

Mr. MILFORD. For the record I have been told that there is a very reliable VASI system that costs as little as $500 for an installation and that I would like for you to submit the cost figures on these various systems, and what they can do.

Mr. COCHRAN. Well, of course, they have varying degrees of sophistication and the cost varies widely depending upon the site. They have to have power and they need some form of control over them. Some of them have varying intensities and so forth, so they need control. In many instances I think you will find that the cost of the installation and the cost of the control system, to deal with it out on the end of the runway may be as much or more than the cost of the VASI itself, which is a box and some well-directed lights, but there are some other things that go along with it, and depending upon the complexity of the system and the problem it seeks to deal with, but I will try to furnish for the record the approximate cost of the boxes and the installation costs.

[The document follows:]

The "$500 VASI" (Visual Approach Slope Indicator) as we know it, consists of three unlighted orange-colored boards mounted near the touchdown area at general aviation runways. The FAA does not have a position on this system as there are none authorized under the ADAP program. However, we do plan to evaluate this type of VASI as a part of our efforts geared to support the general aviation sector.

Through September 30, 1976, the FAA installed 254 VASI systems, most of which fall within the 2-box or 4-box class. Under our 1976 program, the FAA has let two contracts for a total of 304 systems at an average cost of $8,500 per system. These systems are scheduled for delivery from January through October of 1977 and for installation from February 1977 through February 1978. Our present plans for VASI in 1977 include a contract for 137 additional systems for delivery in the first quarter of 1978.

Although installation costs for each of the VASI systems differ depending upon local terrain conditions, estimated equipment and installation costs for some existing authorized systems would be:

Description	Equipment	Total cost (including installation)
Pomola [1] 6 ft unlighted	$390	$500
Pomola 8 ft unlighted	450	600
Pomola 6 ft lighted	750	1,500
Pomola 8 ft lighted	840	2,000
2 box Vasi	5,700	22,700
4 box Vasi	8,500	33,400

[1] (Pomola)—Poor man's optical landing aid.

Mr. MILFORD. Let me philosophize just a little bit right now since you started it.

Mr. COCHRAN. Alright, sir.

Mr. MILFORD. One of the criticisms that is often directed to FAA has to do with built-in prejudices. I do not mean to infer here a deliberate prejudice, but instead a very human type of prejudice that is brought on by continued use of familiar and comfortable concepts and habits. For example, we have an ATC system that is radar based primarily. We would naturally tend to make improvements and hold on to that radar concept. Our ATC system also works on a system of airways wherein controllers maintain spacing and direct pilots in their routing. In your testimony today you have discussed your Office of Engineering and Development. Within that office what steps are taken to weed out internal prejudice which could be a very human thing?

Mr. COCHRAN. Well, one of the things, of course—I cannot point to any specific group that deals with that particular problem, so I am not going to be able to say that we have two people or four people that deal with that, but in any organization or any group of people, one of the difficulties is managing change. I think all of us accept that. That is a problem of management. It is a problem of all elements of management. You people, your committee is certainly a part of the management of our program. I mean, you review it and you have critiques of it so you are part of the management of it, too. So you have to help us manage that change.

A part of our sort of reluctance to make change in a hurry in many instances is the fact that we have a large number of people both inside the Agency in the air traffic control business, and then we have a large number of people who are accustomed to dealing with that on the outside—the pilot and user groups. These people all have understandings and they have spent years learning to some extent how to play in this system. That is both formal training and then their experience in the system which is considerable. So they have these developed understandings and we of course are very reluctant to make sort of precipitous changes unless we can see a great deal of benefit to both them and ourselves because they need to develop and come up on a learning curve of how to deal with new systems and new equipment. So I think that you will find this in any system that is as large as our fleet is in this country and has as great a variety of players in the fleet. In other words, we have some very sophisticated air carrier and executive aircraft that have the best of equipments and tremendous training on the part of other people and down on the lower spectrum we have some very low cost aircraft with some fairly minimal equipment and pilots who may have a great deal of experience, but we also have a variety of equipments and systems, and we have tried to make that system as available to all of those people as it is possible to make it. In other words we have tried to make the cost of buying into the air traffic control system as low as is possible. We want to make the common denominator as small as is possible to make it and therefore we have to keep the system reasonably stable to cover that wide variety of people.

Now, having said that, you need to manage the change to take care of the conditions of tomorrow, because having said that you have a program or a plan to try to exclude as few people from the use of any airspace they would like to use. That is what you really want to do. You want to give a man access to as much airspace as is possible consistent with all of the other constraints on the system, safety, capacity and all these other things. Then you want to prepare for tomorrow. We are increasing the number of aircraft coming into the system. I think general aviation manufacturers are making 15,000 aircraft a year. We are selling maybe 4,000 to 5,000 of these overseas, but the rest of them are staying here in the United States. So there is an increase in the number of airplanes flying in the system. There is an increasing number of pilots in the system, and so you have got to prepare for tomorrow. So you cannot live with today's system totally. You have to develop something new to allow you to handle that additional traffic and demand on the system of the future. So there is a problem with doing that and I realize that. But part of that problem deals not only on reactionary influences inside of the FAA but to try to satisfy the varying user group pressures that we feel, and we attempt to do that in that our user groups, I think, have about as much access to us as any group of people, but they still have conflicting desires on almost any subject that you want to come up with. Now I may have confused the issue.

Mr. Milford. That was a very good answer, Jeff, although it was not the question I asked.

[Laughter.]

Mr. Albrecht. Let me try a paragraph. In a very practical, personal sense. We have a number of very senior, competent people who have some very strong ideas and a very high degree of personal integrity, and, believe me, they do not agree with each other. I think we do a fair job of policing ourselves, if you will, in the internal debates we have, which, coupled with our availability to the public and the fact that there are essentially no secrets within the FAA, I think tends to keep us very honest.

Mr. Milford. Keep in mind, I was not talking about a dishonest thing. The prejudice I am talking about is a very human thing. If for example we have worked for years within a radar environment we tend to perpetuate that, but maybe we should go to something like a NAVSTAR receiver for spacing and data links and this sort of thing.

Really my question is what steps are you taking to keep your groups working in an objective manner without becoming prejudiced to existing comfortable ways and where you would make a choice of trying to improve the radar system as to going to a totally different concept. I am taking into consideration what Jeff said, he is correct in what he is talking about.

Mr. GOLDWATER. If the gentleman would yield, I could give you a very good example of where this accusation has been made and that happens to be that, in air collision avoidance systems, the FAA is wedded to a ground-based system, and you talk to the pilots and they want to keep the command in the cockpit.

Mr. COCHRAN. I think that our wedding to that—right now we see that as the best means of providing separation.

Mr. GOLDWATER. You always have.

Mr. COCHRAN. Yes.

Mr. GOLDWATER. There has never been a deviation—one iota.

Mr. COCHRAN. Well, hopefully, we are basing that on some objective reason, and maybe not totally accepted by everyone, and I think this conference that we will have—I will use that as an example of one of the things that we do. We are having conferences, the listening sessions. I do not believe hardly any agencies have any more of those, with people coming in and talking, and getting attention of the top management. You brought a man in who is perhaps one of the—an outstanding person in being able to understand a fairly sophisticated and technical problem, and he is listening. He attends those things as much as is possible for one human to do it, and he listens to them. So I would say that one of the things we need to do to shorten my last answer up is to create high visibility. We need to continue to do that. We need to stay visible. We need to open up those things that we are doing to the public. To you and to anyone else that wants to see them.

Mr. MILFORD. Let me put another question, and maybe this will get to what I am trying to get to.

Do you think it is advisable that now or from time to time that it would be advisable to assemble a technically knowledgeable group outside of FAA that would do a top to bottom study of our present navigation and control systems using that sort of as a cross check on your own internal planning?

Mr. COCHRAN. Well, we have in fact just recently, had one large meeting and several submeetings, and impaneled a technical advisory committee consisting of 15 experts.

Mr. MILFORD. Outside of Government?

Mr. COCHRAN. Yes, sir, well, some of them are from Government.

Mr. MILFORD. Both?

Mr. COCHRAN. They are from inside and outside of government but they are chosen because of their technical expertise and not because of their association necessarily with a Government job. They represent a considerable body of technical understanding. We will furnish for the record that group. We have had several major task forces review the air traffic control system in the past. We had the Air Traffic Control Advisory Committee that was paneled back—and came up with the Upgraded Third Generation Air Traffic Control System. We did not invent the Upgraded Third Generation Air Traffic Control System. This advisory group that came from the outside assisted us with that and they came up with this.

Mr. MILFORD. Is that the technical advisory committee that is shown on the organizational chart that you presented earlier that you are talking about now?

Mr. COCHRAN. Yes, sir. Well, the one I just mentioned to you, the 15 experts, outside experts, is that that is shown on that chart.

Mr. MILFORD. Are these people paid?

Mr. COCHRAN. No, sir, they are not. I believe the outsiders may get a nominal fee for serving and travel expenses.

Mr. ALBRECHT. But, for example, three of the tasks they have taken on are to study FAA's programs in the collision avoidance systems. They represent a wide diversity of opinions.

Mr. MILFORD. Yes; this I am not sure gets to what I am talking about, because they are in effect critiquing something that you are bringing up as opposed to sitting down and giving original thought and being able to be paid enough to make a very detailed study.

Mr. ALBRECHT. This particular group does not start with our program. They take a look at other approaches that we could have made. They are broad enough so that if we have missed some direction, they are going to point it out. They have an overview of our R. & D. program task. They study the general program, if we are going in the right direction, what is its justification and why. The kind of talent involved in this group—it will be a very broad look.

Mr. MILFORD. I would like some more information on it, if you would?

Mr. COCHRAN. We will furnish you its charter and its membership and some little background on the membership.

Mr. MILFORD. Gentlemen, I imagine you all are about starved or given out. We may have additional meetings and as stated earlier we anticipate that some of us will be visiting rather extensively during November and December of this year at the various installations, projects and programs. We would continue our questioning then perhaps on a more informal basis, but there may be additional questions—you have got some more questions?

Mr. GOLDWATER. Yes.

Mr. MILFORD. We are going to have to evacuate here in 5 minutes.

Mr. GOLDWATER. I think we could run through these real quick.

The other day the FAA requested $70 million to upgrade some activity up at NAFEC. Have you ever examined the compatibility between what is being done at Langley under NASA and NAFEC?

Mr. COCHRAN. We have looked at the activity at Langley. We have some joint programs with NASA there. We have an understanding of the things that go on there and we also have an understanding of things we hope to accomplish at NAFEC over the next period of time. We feel like that because of the investment that we currently have at NAFEC which is considerable, and I am not talking about the buildings we intend to replace, but the facilities that we have there. We have a dedicated airport. We have some support facilities in the way of instrumentation for those things. Things of this nature. We have taken a look at it and it looks like the best thing for us to do and for NASA, too, for that matter because I think they have a pretty full range program at their base, is to have a separate facility.

Mr. ALBRECHT. One of the disadvantages of the previous studies plan out at Langley is that we need some fairly free and uncluttered airspace which we do have at Atlantic City and Langley is pretty crowded.

Mr. GOLDWATER. Has there ever been an actual study done of this?

Mr. SHEFTEL. There was a group that looked into this overall situation before NAFEC was established. They looked at all the candidate sites throughout the country and narrowed it down to a few and NAFEC was the one chosen, but it was based on criteria such as not being near noise sensitive areas and having freedom of airspace so we could experiment freely and such factors. It was a formal study.

Mr. GOLDWATER. Back in 1970–72 this subcommittee urged FAA to establish an office for quiet short-haul transportation. In 1975 this office was disestablished.

Do you feel that in light of what is happening today that you are not in need of this office or an area that constitutes short-haul transportation?

Mr. COCHRAN. I would say that it is being adequately covered with our coordination between ourselves and NASA and with the work that the Department is doing, the Department of Transportation is doing and the overall look at various modes of transportation between communities, and in our Office of Environment Quality. Maybe, Mr. Sheftel, would like to address this—since he used to be the Director of the office.

Mr. SHEFTEL. Just to make it very brief—the office is set up primarily to attempt to exploit VSTOL technology and to see what merit that has in the civil system. That was done quite thoroughly to see how it might help in the noise and capacity area to the extent that we identified even other problems in the system that were beyond what this technology might achieve. We went into such places as Midway in Chicago since it looked like a candidate for these types of aircraft. It is a smaller airport that might be a reliever for O'Hare, and we found that Midway might be quite an interesting airport without VTOL technology.

To make a long story short, it looked like this kind of a subject should be approached more than just from a short haul basis, so the office itself really was replaced by putting this function into the current policy office, which is looking more in a broad sense rather than just a short haul VTOL alone.

Mr. GOLDWATER. In the area of wind shear and wake vortices, it appears to me that your wake vortex effort has gotten away from any sophistication and you are just looking at these anemometers and interpolations through the computers.

Mr. WEDAN. That is right.

Mr. GOLDWATER. Do you feel that is a better way to go?

Mr. WEDAN. Yes, the answer to your question is yes, because we believe that an essential ingredient is to be able to get this equipment installed at as many airports as possible. This would require going for the lowest system that does the job. We believe that this system does provide that capability and that the added sophistication would not gain us anything functionally or performance-wise and would cost considerably more.

Mr. COCHRAN. Well, that is not to say we will not have to buy some sophisticated equipment to validate and we have done some of that. We have used some very sophisticated equipment to validate the accuracy of the indicators, the simple indicator. In other words we have done that simultaneously with the use of that. We have used some Dopplers and some rather sophisticated radar to check on the validity of the information that is being generated.

Mr. GOLDWATER. In the area of wind shear, it has been claimed that we have the capability to measure at incremental altitudes wind direction and speed. Now where are you doing most of this work? Are you doing most of this work in-house?

Mr. COCHRAN. Well, sir we have some help. We are using the wave propagation lab of NOAA as one of our helps and we also have some help from Stanford Research Institute and I think Douglas is helping us with some airborne problems in simulators, and we have the Transportation Systems Center at Cambridge. So we have a variety of approaches with a variety of contracts.

Mr. GOLDWATER. Just one last, I would be interested in your reaction to this. I have talked to one or two contractors that contract with government, DOD, NASA, a few in the area of aeronautics, and I have heard it claimed that they would not try to contract with the FAA if they were paid to do so, that the FAA is unreliable, that they take information that is developed and sequester it off to their own laboratories. That they are constantly changing their mind on things. There are requests for proposals that are constantly changing and updating, that it is very difficult in other words to work with the FAA from a contractor's standpoint. That is not a very good reputation to have I would say.

Mr. COCHRAN. I cannot speak to how general that reputation is. I do not know. I have heard that from some contractors. I have had some contact with them. I know of some other contractors that we have worked with over the years that have—and certainly I hope that any of them we have we have paid, so they should not work for us unless we do pay them and pay them adequately, and our philosophy of course is to get what we have contracted for and to get that under the terms of the contract. We have had a number of studies, the last several administrators have had studies made of the contracting process in the FAA. The Department of Transportation has reviewed that and has a review authority over it. There are some very well defined and drawn up regulations that relate to our contracting procedures. So I feel like that in general we try to obey those rules and regulations, and deal fairly with the contractors. And if we have not we will certainly attempt to do so.

Mr. GOLDWATER. I am going to try to pin this down, but I just think from your standpoint that that is not a very good reputation to have from the standpoint of the contracting community. It would sure seem to me that as Director of this whole operation that you would certainly be sensitive to that kind of accusation and perhaps explore where it is coming from or maybe why or if it is valid or not. I do not know whether it is or not. That is why I raised the question. I have just heard it from one or two.

Mr. ALBRECHT. I think that statement goes much too far comparing our practices with other similar government organizations. I think we should run it down.

Mr. GOLDWATER. I would hope you would. I just do not know how valid it is or how widespread it is. I have heard this.

Mr. COCHRAN. Well, from my own point of view I could say this that I have never had a contractor who has sought to see me that I did not talk with him. The door is open. If they have a complaint, you know I am a fairly small guy, so they can come in and complain and they do not need to fear very much. I will be glad to hear from some of them that would like to do this. I know that Dr. McLucas feels the same way. He has had an independent assessment made of our acquisition process and he is now reviewing that assessment.

Mr. GOLDWATER. Mr. Chairman, I have one last question.

Mr. Cochran, you are Acting Deputy Administrator?

Mr. COCHRAN. Yes, sir.

Mr. GOLDWATER. How long have you been Acting Deputy Administrator?

Mr. COCHRAN. I think since about the first of April of this year.

Mr. GOLDWATER. Now, do you have to be confirmed by the Senate?

Mr. COCHRAN. No, sir, I have not been nominated. My regular position or my position on record—I am the Associate Administrator for Engineering and Development. The Administrator asked me if I would help him out as the Acting Deputy Administrator until there was an appointed official put in that job.

Mr. GOLDWATER. So you do not anticipate that you will be appointed?

Mr. COCHRAN. Sir, I am a career civil servant and you can tell by the color of my hair that I have been there for some time. [Laughter.]

Mr. GOLDWATER. But there is no problem as far as, or not something pending to switch this from Acting to full fledged Administrator, is that right?

Mr. COCHRAN. I do not know of any effort of that sort.

Mr. GOLDWATER. So the Acting Deputy Administrator is the slot that you were asked to fill and as far as you know there is no one else being posed to be fully Deputy Administrator.

Mr. COCHRAN. I do not know whether there is or not.

Mr. GOLDWATER. I thought there was some problem.

Mr. COCHRAN. No, sir; I do not know of any problem.

Mr. GOLDWATER. Thank you very much, Mr. Chairman, for your patience.

Mr. MILFORD. Mr. Cochran, gentlemen, we appreciate very much your coming up and doubly appreciate your staying over past the noon hour, and additional questions may be forthcoming in the mail.

The subcommittee will stand adjourned until 10 o'clock tomorrow morning in this same room.

[Whereupon, the subcommittee was adjourned at 1:55 p.m.]

1978 FAA R. & D. AUTHORIZATION

WEDNESDAY, SEPTEMBER 22, 1976

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON AVIATION AND TRANSPORTATION R. & D.,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10 a.m., in room 2325, Rayburn House Office Building, Hon. Dale Milford, chairman, presiding.

Mr. MILFORD. The subcommittee will come to order.

Ladies and gentlemen, I apologize for the late start. Unexpectedly they called a morning session this morning, and to keep from being interrupted by a quorum call we decided to just start afterwards.

This morning the Subcommittee on Aviation and Transportation R. & D. will continue its annual review of FAA R. & D. programs.

Yesterday, the FAA outlined its ongoing programs and long range plans. Today we will be hearing evaluation of these programs and plans from expert witnesses outside the FAA.

Our first witness this morning will be Dr. Walter Jensen of the Air Transport Association of America.

Mr. Jensen, we have your prepared statement which will be accepted in full for the record, and you may proceed as you see fit. We appreciate your patience and appreciate your appearing before the committee.

STATEMENT OF WALTER A. JENSEN, VICE PRESIDENT, OPERATIONS AND ENGINEERING, AIR TRANSPORT ASSOCIATION OF AMERICA

Mr. JENSEN. Thank you, Mr. Chairman.

The prepared statement is intentionally very short and hits only the high spots, and I think therefore it might be well to just read it.

Mr. MILFORD. That is fine.

Mr. JENSEN. I am Walter A. Jensen, vice president of operations and engineering of the Air Transport Association. With me is Mr. Siegbert B. Poritzky, special assistant for systems and research. The Air Transport Association represents virtually all of the scheduled airlines of the United States.

The airlines have a deep and continuing interest in the FAA's research and development program because nearly all of the programs affect the safety and efficiency of airline operations. If the R. & D. is intelligently planned and conducted and successfully concluded and the results implemented, safety and efficiency will be improved. If, on the other hand, R. & D. is poorly conceived and is unsuccessful, not only will safety and efficiency suffer but valuable assets including user tax funds obtained from airline passengers will be wasted. The limited funds usually made available for FAA R. & D. programs must be wisely applied to those efforts which show the most promise of solving the most urgent problems.

With these thoughts in mind we testified before the committee on February 18 of this year. I have reviewed that testimony and find our comments are still valid and pertinent. I commend them to your attention; to save time I will not repeat them today. ATA also appeared before the Subcommittee on Transportation of the House Appropriations Committee on March 24 of this year. Attached to that testimony was a statement of "Airline Views on the FY 1977 FAA Research, Engineering and Development Program" portions of which are pertinent to today's hearing. For your information a summary of that paper is attached to this statement.

The February testimony and the attached summary just referred to provide our views on the entire FAA R. & D. program and our views on priorities within that program. For this hearing you have indicated a particular interest in five specific subjects. I will now address each of these.

The Microwave Landing System development has progressed to the point where there is an international standardization effort under way in the International Civil Aviation Organization. The airlines support orderly development and early international standardization of the signal format for a universal Microwave Landing System. We believe a number of users in the United States have an early need for Microwave Landing Systems and early technical standardization is needed if those users—primarily the military and general aviation—are to be served soon with the technically best system which can be achieved in an economically sound way.

Airlines have favored a single transition from the existing ILS Instrument Landing System to a new system, and we have, therefore, recommended that FAA avoid encouragement of, and minimize support for, any interim landing system, since installation of interim systems is likely to hamper both the necessary exploitation of ILS and the orderly development and transition to a new system.

Airlines believe that the existing ICAO standard ILS will be in wide use long past the current 1985 international protection date and should continue to be improved. FAA development activities to improve ILS should be increased over the minimal current level. We believe also that there will be a need for MLS and that the time for international standardization and development of a National Standard is now.

We believe that development and standardization of the new Microwave Landing System should occur concurrently with the development of the basic criteria under which the system will be used to achieve measurable operational benefits such as closely-spaced parallel runway operations, and more efficient arrival and departure paths for optimized runway usage.

System wide transition to any new landing system must be based on clearly demonstrable major superiority of the system from the standpoint of technical performance, flexibility, economics and stated operational benefits.

Much has been learned about Microwave Landing Systems in the years of their development, and it is clear that they offer important technical improvements over the existing ILS. We are aware that there is a risk that if international standardization cannot be achieved, a variety of other, less capable systems are standing in the wings vying for possible U.S. implementation. We believe that sufficient information is currently available for ICAO to arrive at a sensible MLS decision. It would be a great mistake for this technical achievement to be dissipated by lack of decision. We strongly encourage an early ICAO decision and the prompt adoption of international and national standards.

The Aeronautical Satellite program has not been one of the airlines' priority efforts. It has been a controversial program with initial opposition by the carriers because of the indications that cost of such a system would be high in comparison to the expected benefit.

Based on certain commitments by DOT/FAA in July of 1973 and subsequent modifications to the Aerosat program, the airlines withdrew their objection to the program in February of 1974. In withdrawing their objection the airlines were not supporting operational implementation of the satellite system and felt that money to be spent by the United States in the development program should be kept within strict limits. We understand that the program costs have risen, and we realize that this causes new difficulties.

We continue to concur fully with the views expressed by you, Mr. Chairman, in your testimony before the Subcommittee on Transportation of the Committee on Appropriations on March 24, "* * * that the FAA should not have to unilaterally shoulder the economic burden of such a (Aerosat) program * * *" and "* * * that there is no way that FAA can realistically fund the program in fiscal year 1978."

We have become aware that there are pressures on FAA to absorb, within its engineering and development budget, the costs of the Aerosat program. We understand that these costs are to be on the order of $25 million for fiscal year 1978. If the total research, engineering and development budget for 1978 is to remain at roughly the same level as this year—in the order of $70 to $75 million, there is no way to fund the Aerosat program within that budget without cancelling a number of other important R. & D. programs of higher priority. Our acquiescence to the Aerosat program from the beginning was on the assumption that the program would not be conducted in lieu of the essential research, engineering and development which is universally agreed to be needed.

We would have no choice but to strongly oppose the Aerosat program, if it is to be done at the expense of research, engineering and development programs which we feel are vastly more important than Aerosat.

The DABS/IPC programs in which you expressed committee interest are elements of the broader subject which FAA calls aircraft separation assurance. I will comment on them in that context.

Aircraft separation assurance is simply preventing aircraft from colliding. In our view the first emphasis in this regard should be on continuing the improvement of the Air Traffic Control system. Its reliability needs to be increased by minimizing the risk of ground system and human failures. The conflict alert program needs to be improved in en route areas and expanded into terminal areas. The follow-on program of conflict resolution is also important and needs to be completed. We believe safety would be enhanced by requiring the use of altitude encoded beacons in certain congested airspace where they currently are not required in all aircraft. While we expect pilots to be vigilant in avoiding VFR aircraft in VFR weather, see-and-be-seen should not be the primary method for separating airline aircraft from other aircraft; ATC separation should be the primary method.

One method of enhancing separation assurance is Intermittent Positive Control. It, together with the Discrete Address Beacon System which is necessary for IPC, have both been under extensive investigation by FAA for a number of years. We have been closely following the DABS/IPC work and have participated in some of it. We believe there is sufficient potential merits in DABS/IPC for us to encourage the FAA to pursue the developmental work to a prompt conclusion. The results should then permit a decision as to whether DABS/IPC would produce benefits commensurate with the cost.

Since IPC service would be limited for many years to airspace within the coverage of the ground based radar beacon system associated with terminal areas, consideration is also being given by FAA to independent airborne collision avoidance equipment. Based on information currently available, the active Beacon Collision Avoidance System, active BCAS, appears preferable over ACAS, such as the Minneapolis-Honeywell or the McDonnell Douglas collision avoidance systems, or passive BCAS and the development and evaluation of active BCAS is encouraged. Final answers on airborne collision avoidance equipment must await the completion of the active BCAS development and evaluation program.

The committee asked that we comment on airline views with respect to DOT and FAA long-range planning activities. The airlines are of course interested in Government plans over the long range in improving the Air Traffic Control system, because we need system improvement, and because the plans frequently involve large expenditures both of trust fund moneys and expenditures for new airborne systems. Yet we have not been greatly impressed with much of the work that has been done in long-range planning. We have seen efforts to use the clean sheet approach in which the planner is told to assume that there is no system now, and that in 15 or 20 years, it will be possible to establish the best of all possible systems. We believe, for example, that the recent work conducted by DOT, first called the Fourth Generation Air Traffic Control System, and later the Advanced Air Traffic Management System, produced only very minimal results at very high cost.

In other cases long-range planning has been based on extrapolations of requirements which may be either very optimistic or very pessimistic. In yet others the planner is authorized to make assumptions of technological progress which we know generate from a cloudy crystall ball.

We have serious reservations about all of these approaches. We tend to think instead that forecasts for the future must be grounded in the present. Those who are charged with making long-range plans must not only be fully aware of the system as it exists, but must also start with the assumption that changes will be evolutionary rather than revolutionary.

Perhaps most important, from our point of view, is that many of the efforts now underway are in reality long-term efforts. We cannot realistically expect major automation to come into the system in less than 10 to 15 years. We cannot expect to see full-scale implementation of the Discrete Address Beacon System, or Intermittent Positive Control, or the Microwave Landing System, or the Global Positioning Satellite System to come into being in a short time; yet the technology of some of these systems is currently known and quite well understood.

We believe that long-range work must start with realistically based planning of system evolution, utilizing techniques now available or on the horizon. It is necessary to involve the people who are expert in the system as it is today in such planning. This means that FAA should do the planning job. We are aware of the arguments that those who are working on day-to-day problems have difficulty looking beyond their noses, and to some degree this is true; yet in practical terms, and we think research and development programs need to be kept in practical bounds, the people who operate the system today and who are hampered by practical realities in thinking about the future are a necessary part of the future planning process.

Thus, we believe the long-range planning for the evolution of the FAA system must be done by FAA, using engineers and scientists well aware of the present and the upcoming technology, but also well aware of the practical limitations and operating realities.

Wind shear has been a problem to pilots landing aircraft since aviation began, and every airline has procedures and training processes to help pilots cope with wind shear. Recent landing accidents have properly focused attention on this problem, and the airlines strongly support FAA's R. & D. activities to learn more about wind shear; its detection, prediction and means to cope with it. We believe FAA is moving energetically and well on two fronts.

The first effort is to deal with the wind shear problem in the aircraft by examining means to provide better indications of impending wind shear and to develop better ways of coping with it either by procedures or by the use of additional instrumentation. The airlines are cooperating fully with FAA in this part of its work.

The second approach, equally important, is the development of better information for prediction and detection of actual wind shear. FAA, with other Government agencies, is working hard at the development of several ways of detecting wind shear on the approach path and communicating it to pilots. We strongly support these efforts, are cooperating with FAA where we can, and we urge that FAA be given the resources to move rapidly on this problem.

Wake vortices have caused the FAA to impose increased aircraft separation standards as a safety measure. They are applied all the time even though wake vortices are a hazard only a relatively small percentage of the time at many runways. These increased separation standards significantly reduce airport capacity and therefore result in fuel consuming delays.

The airlines have been closely monitoring the development of a Vortex Advisory System by FAA and the Transportation Systems Center. We think it has been a solidly based, well-managed FAA effort, and we look forward to early practical results. We are aware of FAA's intention to move rapidly to procure and implement Vortex Advisory Systems for the major airports as soon as system validation at O'Hare Airport is complete. We believe that implementation is now the major need in order to obtain relief from wake vortex separations any time they are not needed.

We believe FAA's R. & D. efforts should continue, with high priority, on the follow-on to the Wake Vortex Advisory System, that is to use terminal area automation to provide adaptive spacing advice to air traffic controllers. This is part of the FAA metering-and-spacing effort which has been very slow in coming, but must be pursued because of its expected high value.

We are aware of efforts by NASA to work on the reduction of the wake vortex as it is generated by the aircraft. This is a longer range effort than FAA's detection and avoidance activities, but we believe it is important and it should be pursued.

This concludes my prepared statement. Mr. Poritzky and I will respond to your questions or supply information for the record. Thank you.

Mr. MILFORD. Thank you very much, Mr. Jensen.

Let me get into an area with you. The FAA informed us yesterday that great economic benefits would accrue to the airlines through the use of Aerosat. However you state that the cost of the system would be high in comparison to expected benefits. Is there some sort of lack of communication between you and FAA on this particular subject?

Mr. JENSEN. No, not at all. Of all the subjects I can think of, I think there has probably been more extensive communication between ourselves and FAA on Aerosat than most anything else. It is not like a communication at all. It is the fact that there are some different basic views about the Aerosat program. They understand our views. We understand their views.

Mr. MILFORD. I should think ATA would be in a position to determine the economic benefits of the program since you would be the major user.

Mr. JENSEN. Well, part of the difference of opinion that I referred to earlier, Mr. Chairman, is whether or not the Aerosat program needs to be just a communications system or whether it needs to be a navigation and surveillance system as well. The airlines had the view that the primary need was for improved communications and that that ought to be the function of the Aerosat system. The airlines were not nearly as interested as FAA in the additional functions of navigation and surveillance. The additional functions have a great effect on the cost of the Aerosat system. It means more satellites need to be in flight in order to provide the surveillance and navigation functions and that is an example the difference in the cost aspects between ourselves and FAA.

Mr. MILFORD. What particular surveillance functions will Aerosat perform and what navigation functions are planned?

Mr. JENSEN. As planned there are enough satellites in the program, and remember this is an experimental program, to be able to do certain position determinations and then relay that information to the flights as a navigation function. By the same token the knowledge of position of the aircraft obtained by more than one satellite being involved permits the ground to be aware of the position of the aircraft thus providing a surveillance function.

Mr. MILFORD. My understanding is that Aerosat is a communications satellite. It has no navigational functions. Have I misunderstood this?

Mr. JENSEN. I think you understand what we would like it to be, but I think FAA has always felt that the experimental program should look at both the navigation and the surveillance functions as well as communications.

Mr. READ. Navigation is a secondary function though isn't it?

Mr. JENSEN. I think FAA would agree, Mr. Read, that the primary interest even on their part is communication, but they also associate the secondary interests of navigation and surveillance. Really that is a better question for them than it is for me because we do have this difference of opinion.

Mr. MILFORD. They will get the question, you can be sure.

[Laughter.]

It is my understanding that Aerosat is a communications system—and I will certainly seek clarification on that. I do not really see with the Navstar program coming up how we would be needing to get into a navigational vehicle, but I will clarify that with others.

The Aerosat has been a stop-and-go program for nearly a decade. In fact, it almost stopped several years ago when ATA strongly opposed an operational program. As you note, the airlines withdrew their objections in 1974 when Aerosat was changed to an experimental program. Now, if other R & D programs are to suffer, do you strongly oppose the program again? Can we realistically uncommit ourselves again? There seems to have been quite a bit of treaty work and other things going on.

Mr. JENSEN. It would be very difficult for the United States to change its view and discontinue participation in the Aerosat program. As you point out, a memorandum of understanding has been signed between the United States and the European countries. That memorandum of understanding does contain a clause that says that the signatories to it will participate to the extent that funds are made available for them to do it. I think the situation we are being confronted with now is that either the Aerosat program must be properly funded by the Congress or the program should not go ahead if it is not properly funded and if the only funding means that you have to discontinue other R. & D. activities that both FAA and ourselves are in agreement are more important.

Mr. MILFORD. Do you have any idea how your foreign counterparts, that is to say other air carriers and other commercial airline operators, feel about Aerosat?

Mr. JENSEN. I have not heard any recent pronouncements by them, Mr. Chairman, however, I was personally, intimately involved in the various negotiations on Aerosat with FAA and DOT, and the impression I had during those negotiations was that the foreign airlines that would be affected by Aerosat, primarily the North Atlantic operators, but to some extent the Pacific operators, were about as cool to the Aerosat program as the U.S. operators. However, some of those airlines, as you I am sure know, are pretty intimately connected with their governments in varying degrees and that makes it somewhat difficult for them to speak out their own airlines views separately from any views their government might have. That has impeded a clear understanding of exactly what some of the foreign airlines really feel about Aerosat. I think in summary though the impression we have had is there is about the same coolness to the Aerosat program internationally as there is domestically.

Mr. MILFORD. Let us go to MLS for just a moment.

Mr. JENSEN. May I just make one further comment about Aerosat before you leave it, Mr. Chairman?

Mr. MILFORD. Surely.

Mr. JENSEN. I think it ought to be clearly understood that the Aerosat program is a Government advocated program. It was not an airline pushed program, not an airline advocated program, and I say that because I think the Government has a difficult problem now to figure out what to do with it in terms of the financing of it. Certainly it would be difficult to discontinue the program now, however, there are certain financial commitments to be made, presently planned for November but could be deferred a little bit. So as difficult as it might be now, it will be more difficult later on to make any adjustment in the program if this financing matter cannot be solved. So it is a Government pushed effort. The airlines have not pushed it. It is a problem now for the Government to sort out just where is the money coming from in a way that will not harm other activities.

Mr. WYDLER. Mr. Chairman, will you yield to me?

It sounds to me like everybody is against this. Who is for it?

Mr. JENSEN. The FAA started out being for it first.

Mr. WYDLER. They have a governmental position so at least they are on the record for it, but they certainly are not enthusiastic about it. You say the U.S. airlines are not for it, they do not want it particularly. The international airlines do not want it. Who the heck wants it? I do know we have a treaty and that is a serious problem, but who is really enthusiastically for it and why?

Mr. JENSEN. I think the specific answer to your question, Mr. Wydler, is that elements of our Government are for it and elements of European governments are for it.

Mr. WYDLER. I get the impression that the elements in our Government are for it for the reason that we have treaty obligations. That is an understandable reason. Are there some that really think it is a great idea? I have not heard from them yet. I would like to know who they are.

Mr. JENSEN. I am trying to be as objective about it as I can, having been pretty closely associated with it. I think there is justification for saying that a proper satellite program will be useful some day in the future to provide better communications over oceanic areas for example. A lot of the debate is how to do that, how much to spend on it, who should do it and when. The FAA had views that it ought to be done soon, and it ought to be done in a fairly big way. We thought that it was not required quite as soon, and it did not really require quite the amount of experimentation that FAA thought. The Europeans had views that it ought to be a pretty big program, and they saw in it some value to their governments in terms of technology, and these are some of the things that were worked over the stormy past of this program.

Mr. WYDLER. You have not answered my question at all.

Mr. JENSEN. I will answer it again, Mr. Wydler. I think those who are in favor of it were governments.

Mr. WYDLER. Who are they?

Mr. JENSEN. The FAA. I understand the State Department is. I understand NASA has said they thought it was a good thing, and certainly the space activities of the European governments are also in favor of the program.

That is the best answer as far as I know it.

Mr. MILFORD. The key to it, I think, is more space types are interested in this program as opposed to the aeronautical types, who are using it.

Mr. JENSEN. I think that is an accurate statement, Mr. Chairman.

Mr. WYDLER. It just strikes me—I do not know what part of this program cost is launching the satellite and all this, but if we are going to spend quite a few billion dollars on this shuttle, we have plenty of opportunities to put something up there if we want to, so I am just curious, there is no rush, there is no great need for this and so on. Well, I am for meeting our treaty obligations. I think we can do that in a reasonable way depending on changes in circumstances, and certainly if we can do it in connection with another project, it makes sense to me. I have to be frank with you, I do not get the impression, talking to anybody, that there is any enthusiasm for this program. They feel an obligation to the program, but I have not found any enthusiasm for the program at least on the U.S. side from anybody, and I can understand the obligation, but now you tell us that the foreign airlines are not enthusiastic about the program. So I am just wondering who are we left with—a couple of government officials. Who are the enthusiasts?

Mr. JENSEN. I think you are right. We are talking about governments being the enthusiasts. As the chairman pointed out it appears from everything I have seen, it is more the space-interested people in government than it has been the aviation, aeronautical interests.

Mr. WYDLER. Thank you.

Mr. MILFORD. Mr. Poritzky, I understand that you are the chairman of the DOT/FAA MLS Advisory Committee. Could you please explain the makeup and general functions of that committee?

Mr. PORITZKY. Yes, sir.

Since the selection process for the Microwave Landing System began in 1967 in the Radio Technical Commission for Aeronautics, everyone involved has tried to maintain the process completely open, and to gather the best experts from across the world. When the program grew to the point of an FAA leadership effort, a multimillion dollar effort to examine the technology further and to develop systems for evaluation, FAA chose to retain that open process and selected an advisory committee, primarily made up of disinterested users. The committee is made up of technical and operational representatives from several aviation organizations—ALPA, AOPA, NBAA, airlines both domestic and international, representatives of the Defense Department, as well as Army, Navy, and Air Force, and three experts selected to represent the public interest.

The committee has offered specific advice and counsel to FAA sometimes requested, sometimes not wanted so much. FAA chose early, to its credit, to bare its soul, and they permitted themselves to be criticized, in some instances severely, on the way the program was being conducted. The committee was an observer on the selection process that has led to the current TRSB choice. Its function has been to be as candid and forthright as possible in helping FAA create a Microwave Landing System that would be internationally acceptable.

Mr. MILFORD. The FAA has been charged with being somewhat prejudiced toward the TRSB, in this selection process. Has your committee observed any such prejudice or do you feel that the selection was made in a technically competent way?

Mr. PORITZKY. Mr. Chairman, I speak for the committee only at my peril. I will offer my view, if I may, of what I believe to be the committee's view on this point.

We watched the selection process, the work that was done by the central assessment group in the fall and winter of 1974. The committee was aware of, and in fact participated in, the development of the process. Everyone involved was anxious for the technically right answer to come out. FAA at that time had spent large amounts on the development of both the Doppler, and what became the TRSB approach.

The committee was not asked to vote. It restricted itself to two things—First, to convince itself that the selection process FAA had used was a fair and objective one. The committee felt that indeed, when the process had been completed, it had been a fair and objective one.

After the selection was made in December 1974, the committee heard the reasons for FAA selection of TRSB. As you know, the discriminants between the two systems were small. Both systems were found to be of very high quality. Both were found to be quite acceptable as the U.S. proposal for international standardization.

The committee listened to the four or five discriminants which the central assessment group had found, and did not quarrel with their conclusions, recognizing however that the discriminants were small. FAA, having chosen its course would now, of course, be expected to be enthusiastic about it.

Mr. MILFORD. As a layman trying to evaluate technical arguments on Doppler and TRSB, if I were to make the statement, that what we really seem to be involved with are very technical engineers debating differences in microseconds when 5 minutes more or less would be quite fine in an operational sense, would I be very wrong in trying to evaluate Doppler and TRSB?

Mr. PORITZKY. I think you would be a bit wrong. I believe that both systems are very good. Many of the discriminant issues are much smaller than the protagonists would have us believe; yet I think there are some differences between the systems. They are small differences, and in the end I suspect the decision will have to be made by management people. Obviously the engineers on both sides of the ocean are looking for the last drop of performance. I think there are significant differences, but unfortunately they line up rather well for both—some for Doppler and some for TRSB.

Mr. MILFORD. We have a report that The Hague working group, in July, stated, "The potential for a single complete monitor design for

Doppler MLS should tend to facilitate standardization and reduce cost." Also, that the TRSB solution to the multipath problem "would appear to involve some increase in signal-to-noise ratio, and possibly might adversely affect accuracy."

Are these part of the discriminates that we are talking about? If not, what would be your comments on these two statements?

Mr. PORITZKY. The "single point monitor" question has been around for 2 years. It was a much overheated argument at the beginning, although. I sense it has kind of evaporated. The single point monitor argument makes the point that in the Doppler system one can place a monitor probe at the center line of the path and get total information of the performance of the system throughout its coverage. There is a variety of Doppler antennas, and most of the Doppler antennas can do this. The direction FAA is currently taking in the development of its antennas, phased arrays of various varieties also permits single point monitoring. The point is that nobody I know would ever consider using a single point monitor alone. In every instance monitoring is done both integrally within the system and externally somewhere in the far field. Thus, while there is a theoretical argument here, I do not think that the argument was ever important nor do I believe it is a real argument today.

Mr. MILFORD. In other words, it is not a significant factor?

Mr. PORITZKY. No, sir, I would say it is an insignificant factor which has a great deal of appeal to the layman.

Mr. MILFORD. How about the increased signal-to-noise ratio? Is that a significant factor?

Mr. PORITZKY. I do not identify that one readily. I think the evidence of how the systems performed in the tests is the best evidence available. Multipath is a phenomenon which changes the signal to noise ratio whether it is Doppler or TRSB. I cannot identify this as a problem.

Mr. MILFORD. What is the position of your committee concerning the relative cost performance aspects of Doppler and TRSB?

Mr. PORITZKY. The committee has listened at ghastly length to arguments about cost and performance.

Mr. WYDLER. I will assure you that both will cost a lot more than they say.

Mr. PORITZKY. Yes, sir, I was about to say that. I find it very difficult and I think the committee does—to believe cost estimates before actual implementation occurs. FAA, and the British, and the Germans, and the French have done cost studies with perfectly good intentions. The variables tend in my view—and I believe in the committee's view—to make these cost estimates always suspicious. There are no really fundamental differences. There are two small discriminants which are worth mentioning. The Doppler system proponents have made a case that the basic antenna for the Doppler system are cheaper than the basic antennas for the TRSB system. I suspect that is true; however, Doppler antennas have evolved in the past year or two and have gotten more complicated. I believe you saw the system at Bedford and then you saw the system at Cowes. The system at Cowes is a pretty formidable piece of machinery compared to the one at Bedford.

It is frequently forgotten that one should not look at the antennas alone, but must look at the total system. The Doppler requires two transmitters. The TRSB requires one. That is a cost offset. Thus on the ground side I think the cost differential argument is probably kind of a red herring. TRSB antennas will be built inexpensively as well as Doppler antennas.

There is, however, a point on the airborne side which raises a small flag. The Doppler system depends on quite sophisticated airborne processing; more sophisticated processing than TRSB. The Doppler airborne processing has been undergoing a rapid evolution, for the better I might say, over the past year. Because we know relatively little about the internal parts of the airborne Doppler processing we must put a cost question mark on that element.

Mr. MILFORD. I have been told that the proposed FAA solution to multipath coverage control is a dangerous technique. Would you comment on that?

Mr. PORITZKY. Yes, sir. I do not believe it is a dangerous technique at all. It is another area where the protagonists make very large issues out of small points. The Doppler system does not have within the capability for readily controlling the area of radiation, the sector coverage, whereas the TRSB does. Now users of MLS clearly prefer to have some uniformity in the way the coverage is provided. No one argues that point as far as I know. Yet MLS systems will not all be the same for all applications. In many instances limited coverage is quite acceptable because that will be the best one can afford to buy. It is quite safe if there is clear understanding by both the providers of the service and the users know what the coverage is.

FAA has taken the view, I believe, and I share that view, that while coverage control is not a desirable thing to do when you do not have to do it, there may be situations of multipath, particularly in military applications and possibly in some major airport applications where there are many structures at the airport around the approach path or the rollout path, for which coverage control may be a last resort. I think it will be needed in few places, if any, in the civil world. It is likely to be needed in the military. While the coverage control argument has been overblown, I believe the capability is a useful last resort to have in your pocket.

Mr. MILFORD. One of the controversies as I understand it between the two systems deals with a Lincoln Lab report concerning side-lobe multipath that was simulated on a computer. Do you think that an actual field testing of the British Doppler system by taking it to Los Angeles International which is one of the computer models, and setting it up could resolve this controversy or would it be meaningful to conduct such a test?

Mr. PORITZKY. I think it would be meaningful because it would demonstrate how this system behaves at Los Angeles International Airport. It is very hard to argue against a practical demonstration. I do not know that it would be meaningful in resolving the issue because one would need to go to a sizable number of places before one could gather conclusive evidence. Multipath measurements are extremely difficult, and are affected by all manner of extraneous effects. That really is the reason most of the people in the ICAO arena have said that while the multipath computations, the computer models, have limitations—they are probably the best way to normalize the various systems. The prospect seems to me high that unless one puts

MLS systems at a significant sample of bad locations, we will not end up with conclusive evidence.

Mr. MILFORD. In other words by going to one particular location you would not necessarily prove or disprove the theory of the side-lobe multipath?

Mr. PORITZKY. I think that is correct.

Mr. MILFORD. If the British could solve their theoretical multipath problem in the next few months, would you be in favor of supporting a majority ICAO decision on the MLS selection, not an overwhelming majority, but a simple majority?

Mr. PORITZKY. I believe first of all that it is important for there to be an ICAO decision. I think it would harm the carriers, it would harm everybody, for ICAO to fail in this first attempt of ICAO at reaching a decision on a system which does not already exist in implementation. I believe a large majority is essential for this reason. The ICAO All Weather Operations Panel recommendation is only the first step in going to a worldwide meeting to achieve standardization. There are not many countries right now who are panting to buy MLS. If the decision is a very small majority in either direction, I think there is a risk that the next step, the Air Navigation Commission consideration of whether a worldwide meeting is to be called, might be negative. A worldwide meeting, if held, would wonder why these high powered technical experts could not reach a decision with some degree of unanimity or at least a significant majority. Thus I believe an ICAO AWOP decision is important, and that the welfare of the MLS standardization in its next steps demands a significant majority.

Mr. MILFORD. I am going to ask you for a subjective opinion which you may or may not want to give. Do you really feel like we are going to get a significant decision out of the AWOP group?

Mr. PORITZKY. All I can say is I hope so, but I do not know how.

Mr. MILFORD. One of the things that disturbs me about the AWOP group is that I consistently hear reports that the decision is not being made on an objective basis, but actually it is getting into nationalism and even a little politics. This disturbs me. I have a strong feeling that this country is getting itself into a box. Our own national need is approaching the point to where we are going to have to resolve the MLS problem. We have got small community problems. We have a military problem. The frequency congestion we have with ILS in some of our communities is critical and we have a serious noise problem. A decision one way or the other is vital to this country's interest. I am very much in favor of resolving this in an international body. But if that body fails to resolve the question, I am beginning to think that we may have to move. That is why I pose the question would you be willing to accept a majority opinion of the AWOP group?

Mr. PORITZKY. Mr. Chairman, two points here. The advisory committee has debated this question and feels that FAA should do—the United States should do—whatever it can to achieve an international standard.

Mr. MILFORD. I am for that.

Mr. PORITZKY. I think we are all for that for many, many reasons. Failing it, or failing an early resolution, recognizing that there are needs that you have identified which I certainly agree with, the committee has felt that FAA should then go forward with provisional standard, on the assumption that if ICAO cannot reach a significant agreement, the next steps (the work in the Air Navigation Commission and the worldwide meeting) are not likely to take place for 5 years, 10 years, I do not know the number.

A provisional standard which has support from some other States, as would be likely in this case, is a second choice. It is a pretty far down second choice because the international standard is far more desirable. My feeling would be, and I think this would be the committee's feeling, that if a genuine, objective U.S. attempt to get an international agreement fails, the United States should proceed with a provisional standard for TRSB.

Mr. MILFORD. OK. Mr. Wydler?

Mr. WYDLER. Would it be possible to have both systems operating simultaneously without losing any efficiency on the part of the airline?

Mr. PORITZKY. Mr. Wydler, that has been proposed half jokingly and half seriously.

Mr. WYDLER. I am doing it with great seriousness. What would it mean as far as the aircraft itself were concerned? Would they have to have two different pickup systems or could there be one system?

Mr. PORITZKY. No, sir, there would have to be two. There is some commonality between the two systems, in fact, there is a lot of commonality between the two systems. There are differences however which are likely to make a substantial difference in cost in the airborne hardware. A solution by addition would solve the problem on the ground, even though the cost of the hardware would be somewhat higher if we had two systems. In the aircraft, and it becomes technical here, there are significant differences. Claims have been made that in this day and age it would mean just another microprocessor chip—a $5 difference—to have both TRSB and Doppler in the aircraft. I do not believe that is true. I think the cost would be substantial in airborne hardware. I would hate to put an estimate on it, but I would guess it would be between 15 and 20 percent. That is a large cost when spread over the rather large spectrum of users.

There is another disadvantage to it. These systems tend to evolve. If we have two systems going, I think the evolution would be less fast and probably less technically sound. So I think there is more than prejudice in saying that we should not let two systems to proliferate, because if there are two, Doppler and TRSB, the Germans, who have a system of their own, are going to say if there are already two why should there not be three. The game goes on from there and we have lost the tremendously important goal of being able to agree on one system.

Mr. WYDLER. You do not want to solve this by tossing a coin or something like that?

Mr. PORITZKY. I did not say that.

Mr. WYDLER. You make it sound very much to me like there is really not much difference between the two systems. You are making the judgments on almost esoteric points, that is what seems to come down in my mind. I have not heard a very good argument either way as I have sat and listened to all of this. You seem to bring it down to a lot of little, refined little engineering arguments and so on of one system or the other. One comes in with a little cost estimate and tries to prove that it will be a lot cheaper kind of thing. All of which does not seem to have much substance. There is no real great difference between the two systems.

Mr. PORITZKY. I think that is true. FAA yesterday talked at some length about the multipath problem that has been found in the Doppler. That is, of the several small issues, there are roughly half a dozen discriminant issues that are even worth talking about. The multipath issue is a significant one potentially. One question will be as Mr. Milford has said—does one believe the simulation? Or is it just not good enough to show the real situation. I believe that if the Doppler multipath problem turns out to be serious, we are then confronted with a situation where at certain large airports there may be a problem with Doppler. If it turns out to be serious—and it has to be looked at objectively—one cannot have the protagonists alone judge—then a real discriminant has been found. If the multipath issue turns out to be relatively minor or if someone finds something equivalent in TRSB, then I would say coin tossing is probably the cleverest way to go.

Mr. WYDLER. Let me ask you. I am a little bit confused about the history of this competition. This is my last question because I truthfully think we have heard enough about this. We have been kicking it around here for I do not know how many years. We might as well get on with something or other.

Was TRSB one of the original competitors? Was not this competition between Doppler and something else, and then they pulled in this TRSB at the last minute? My recollection is——

Mr. PORITZKY. That is not a simple question. The original competition began between something called FRSB, Frequency Reference Scanning Beam, and Doppler. Very early in the evaluation process the FRSB system turned out to have some sizable flaws. There was a period of dramatic exercise by the scanning beam proponents. The system changed. It did not change greatly, but it changed significantly—from using a frequency reference to a time reference.

A great deal has been made of that, changing horses in midstream. You invented one and now you are trying to sell another—that kind of argument. The differences were significant but not terribly great. Doppler was also changing while this was going on. It went from frequency division approach to a time division approach. This is a change, probably not quite as great, but almost so. The point I want to make is that both systems have evolved—both systems improved dramatically during that selection process. I think it was a good thing rather than a bad thing that these shifts were made.

Mr. WYDLER. Thank you, Mr. Chairman.

Mr. MILFORD. Just one final question.

If FAA establishes an interim standard microwave landing system pending on their adoption of MLS, would aircraft hardware used in the meantime be compatible between the two systems?

Mr. PORITZKY. I am sorry. I do not understand your question. Are you talking about the interim, or are you talking about the FAA interim microwave landing system, the ISMLS?

Mr. MILFORD. Yes; ISMLS.

Mr. PORITZKY. And the question was again?

Mr. MILFORD. In other words, suppose we elected to go on and wait for ICAO to make up its mind. Having pressing needs immediately, we try to fulfill those needs with ISMLS. Obviously a lot of airplane drivers are going to have to buy a lot of radio gear. Would they be able to use that radio gear or convert it at a reasonable cost to use TRSB or Doppler once it is finally adopted?

Mr. PORITZKY. No; that would be very difficult to do.

Mr. MILFORD. OK. Gentlemen, we appreciate—Excuse me.

Mr. JENSEN. May I make one closing comment, Mr. Chairman?

I heard your opening comments yesterday, and I would like to congratulate you and the committee on your view about the need for there to be good R. & D. and it to be adequately funded. I think that the point of view that you expressed is in line with the view that the committee came up with as a result of the look at the future of aviation where it is clear that we need to do those things necessary to keep the United States in the forefront of aviation, and I would like to congratulate you and the committee on that point of view that you have arrived at. I think it is very important.

Mr. MILFORD. Thank you very much. We think the outlook for aviation is an important thing for this country, and one area where I believe we have not focused proper attention on, and we hope that our work in that field will at least make people more aware of the importance of aeronautics to the country itself.

Gentlemen, thank you.

We have just had a vote bell. Before going to the next witness, the subcommittee will recess for 15 minutes.

[At which time the subcommittee was in a short recess.]

AFTER RECESS

Mr. MILFORD. The subcommittee will come to order.

The Chair now recognizes Mr. William J. Tull, President of Tull Aviation Corp.

Welcome to the committee, Mr. Tull. We have your formal statement and attachments. They will be accepted in full for the record at this point and you may proceed in any manner you care to.

STATEMENT OF WILLIAM J. TULL, PRESIDENT, TULL AVIATION CORP.

Mr. TULL. Thank you very much, Mr. Chairman.

It is a pleasure to be here today and add my thoughts to the others that have been presented to you. The Microwave Landing Systems have gained both national and international attention. In the process they have also become the center of a considerable amount of controversy. Because of this I believe a little bit of background is in order.

In the late 1940's the Instrument Landing System known as ILS was adopted as an international civil system for use at international airports throughout the world. The standards for this system first appeared in ICAO annex 10 dated June 1949 and became effective March 1, 1950. At that time the system was already in wide use because of its extensive use by the U.S. military forces during World

War II. Its adoption for civil use by the brand new Provisional International Civil Aviation Organization, PICAO, was relatively simple and straightforward. It should be noted that there were microwave landing systems undergoing tests at that point in time. The ILS, which had seen considerable operational use, was chosen with the full knowledge of the promised potential of these microwave systems. It was recommended at that time that microwave systems be developed for the future. It was the proper choice for the time.

In 1949, after much international debate, VOR was adopted by ICAO as the international standard for civil use for short-range navigation. The losing competing system was Decca, a British developed system. Both the U.S. VOR and the British Decca had seen a considerable amount of operational use before these debates and decisions took place. The VOR/Decca arguments have never really died. There still exists a great deal of bitterness over this decision.

In the early 1960's microwave landing systems were developed for military use. These systems were primarily aimed at providing a capability which could not be provided to the military with the ILS. For example, the Navy needed a system for use on board its aircraft carriers where ILS was of no use. The Air Force wanted a low-cost portable system which could be set up and in operation within 5 minutes, and so on. As a consequence of these developments each of the military services except the Army now have their own special microwave landing systems.

In the late 1960's a number of organizations saw the need for a future civil microwave system. As a consequence Special Committee 117 of the Radio Technical Commission for Aeronautics was formed. It was charged with establishing first the operational requirements and later the technical requirements for a new civil system. Mr. Poritzky who just spoke representing the Air Transport Association was appointed chairman of SC–117. The SC–117 techniques assessment team started its work February 4, 1969, and completed its work with a report dated September 1, 1969. The signal format development team started with the recommendations of this report and completed their work December 18, 1970. The Special Committee 117 has not been dissolved to this date, in case it would serve a further useful purpose.

The SC–117 approach to the problem of landing guidance was as the chairman sometimes iterated "with a clean sheet of paper". No thought was to be given to the past systems, but rather only to a new system to meet the requirements. Members of the committee pointed out that at some point in time recognition must be given to the fact that we were not really starting with a "clean sheet of paper".

Mr. Jensen's comments this morning on clean sheets of paper were very pertinent. At some point we must determine how we proceed from where we are to where we want to be. In fact, one major difference between the MLS program and the ILS is the fact that ILS preceded MLS. No significant landing aid preceded ILS. Because of this, ILS introduction was not bothered by prior international standards, but MLS is and will be. The situation is not unlike the introduction of the first black and white television, to be later followed by color television. There were screams when noncompatible color was first proposed. Fortunately, a decision was made to standardize on a color system which allowed existing black and white receivers to receive black and white versions of the new color broadcasts.

The International Civil Aviation Organization is currently deliberating upon its choice for a future MLS standard. They have received proposals from the United States, United Kingdom, Australia, France, and Germany. It would appear that only three different system types are currently receiving serious consideration—(1) the United States/Australian TRSB system, (2) the United Kingdom Doppler system, and (3) the German system based upon distance measuring techniques. In view of past history, it is not unreasonable to assume this process will take a considerable amount of time. SC-117 in the introduction to its final report volume II in January 1969 states, "It is estimated that initial operational availability of the complete new system (full capability) would occur in approximately 1975, and that the phasein period of the system would be likely to stretch from the 1973–75 period through at least 1980–85." There have been postponements and there will probably be others.

So far, neither ICAO or the United States has reached the point where serious consideration has been given to the implementation problems, or how do we get from here to there. Some attention has been given to the interim use of microwave systems.

The efforts of the U.S. research and development program on MLS has been directed to obtaining the information necessary to establish international standards for microwave landing systems. This is also true of other countries' programs. Once these standards are established production hardware can be designed to meet the yet to be established system implementation requirements. The production hardware may or may not resemble the present equipment being tested on the FAA R. & D. program. This depends, of course, first, on the outcome of the ICAO standardization efforts, and second, on the particular version of hardware (meeting that standard) which can best meet the future implementation needs. This should be the most cost effective version of the MLS equipment.

Most participants in the ICAO debates seem to agree that the process of—(1) agreeing on standards, and (2) obtaining international implementation agreements will not result in significant MLS implementation before 1985. Whatever this time period may be the United States is in excellent position to proceed in an orderly fashion towards adoption of sound international standards without taking undue risks of premature implementation. This position has been obtained by the adoption of an interim standard MLS or ISMLS.

The ISMLS is a system whose unique characteristics make it ideal for the transition from ILS to MLS. ISMLS can best be thought of as a microwave version of ILS. It extends the useful life of ILS until sound MLS decisions are made. The characteristics of ISMLS that make it ideal for the role are:

(1) It utilizes the existing ICAO standards in a way which allows the currently available ILS airborne equipment to be used as a part of the ISMLS airborne system. This results in a minimum change in the aircraft, and provides microwave capability to the user at low cost.

(2) The ISMLS microwave equipment added to an aircraft for ISMLS reception need not be thrown away when MLS standards are

finally adopted. An MLS processor, either TRSB or Doppler, added to the ISMLS receiver provides the user/owner with a complete MLS airborne system when he chooses.

(3) Future MLS airborne systems can, if desired, be provided with ISMLS capability thus allowing users the choice of landing at ILS, ISMLS, or MLS equipped airports for little more than the cost of MLS only.

In addition to all of the above, the ISMLS provides a unique and modern maintenance capability. Many of the factors that require visits by maintenance personnel to the ILS sites have been eliminated in ISMLS through the use of computer techniques and ordinary non-dedicated telephone lines. Future MLS and other systems are planned to make use of such systems in the future. ISMLS has been operating using these maintenance techniques since 1972.

I am sure that you are aware that the complete ISMLS was developed without the use of taxpayers' money. Having such an interim system allows the FAA to provide excellent service and save current facilities and equipment and operating and maintenance funds through the use of ISMLS wherever ILS is less cost effective. Such a move allows the United States to gain many of the major benefits of microwave systems while waiting for the international standardization process to take place. Since the ISMLS provides the capability of moving in the future to either the TRSB or Doppler standard it does not prejudge or jeopardize the delicate international negotiations currently in process.

From the FAA and user point of view it also avoids the possibility that it might be a throw away system. Obviously, if either a Doppler or TRSB system was implemented prior to final ICAO agreements the risk and the costs would be high in the event the competitive system became standard.

It would appear desirable to continue MLS R. & D. efforts in support of the international standardization process. When such standards exist, it would be time to start the design of production hardware to meet not only these standards, but the many other requirements demanded of operationally sound systems of high integrity, and low operating and maintenance cost. It is even possible that once the standards are established that American industry without the further expenditure of Government funds would make such equipment available.

I am sure you are aware that there has been high user interest in the subject of MLS, ISMLS, and ILS. Many of these views have been presented to this committee and other committees in the past.

Since the views of NASAO, AOPA, ALPA and NBAA differ considerably from those that have been expressed by ATA, I have with their permission attached hereto and made a part of this testimony copies of their position as expressed in joint letters from them to the FAA Administrator in January and February of this year.

I have also provided for your information four figures. The first simply lists the major factors that prevent the continued use of ILS into the indefinite future. The second lists the major gains to be realized through the use of MLS or ISMLS due to their elimination of the basic ILS limitations. The third repeats the information on equipment prices contained in my testimony of February 18, 1976, but adds and compares prices that have since been developed by the MITRE Corp. in their report of April 1976. I believe their prices to be optimistic but of approximately the correct ratio between MLS and ISMLS. The fourth chart is a repeat of the simple ISMLS/MLS diagram presented during the February 18 hearings.

This concludes my formal testimony and I will be happy to answer any questions that the subcommittee may have or provide any additional data that may be requested.

I wish to express my appreciation for the opportunity to express these views.

Mr. MILFORD. Thank you very much, Mr. Tull. I have not had an opportunity to study the attached charts that you have submitted here and so perhaps the answers to the questions I am going to ask may be lying right before me.

I want to be sure I understand what you are saying in your testimony. Page 5—the three characteristics of ISMLS that you list stated "utilizes the existing ICAO standards in a way which allows the currently available ILS airborne equipment to be used as a part of the ISMLS airborne system." What specifically are you talking about in the airborne systems there that can be used with ISMLS and ILS?

Mr. TULL. If you refer to the very last page on the testimony you will see a diagram. What I am specifically referring to is that the ILS receiver which is already onboard an aircraft is continued to be used when you have an ISMLS onboard your aircraft because the ILS is the data processor of the ISMLS system.

Mr. MILFORD. Well, now since the ILS receiver is VHF receiver how is it going to work on microwave?

Mr. TULL. OK. The converter which is basically that part that you add when ISMLS is——

Mr. MILFORD. Now wait—now you are adding something now.

Mr. TULL. That is right, sir.

Mr. MILFORD. You are modifying equipment.

Mr. TULL. That is correct. You are adding to the ILS.

Mr. MILFORD. So in the receiver itself then you are going to have to add a modification.

Mr. TULL. You add a modification to the receiver and you add a converter to the aircraft so that you end up with a complete ISMLS consisting of a modified receiver——

Mr. MILFORD. Would not the same thing apply if we were on regular MLS?

Mr. TULL. Regular MLS, again if you wish to refer to the figure here adds what I have shown as a dotted box off the bottom which is a processor which will process whatever kind of ICAO format is some day decided upon be it TRSB or Doppler. But it cannot use, by definition, the same signal format that ILS now has.

Mr. MILFORD. You are utilizing in effect a modification to the receiver which then feeds into the existing locator and glide slope indicator. Again, if you wanted to modify existing equipment wouldn't the same modification work for MLS, other than the signal difference?

Mr. TULL. No, because the ILS has been designed to utilize a 90- and a 150-cycle modulation on their transmitters and the basic ILS receiver decodes this into information which makes your fly left-fly right needles, et cetera, operate. The new ICAO standard, if it is the TRSB as described by FAA yesterday, will require a totally different system than that to do it.

Mr. MILFORD. What sort of costs are you looking at in modifying existing ILS onboard equipment for ISMLS?

Mr. TULL. At the present time the equipment that is being sold is listed for $2,155.

Mr. MILFORD. $2,155?

Mr. TULL. Right. That includes the complete system.

Mr. MILFORD. Well, I have had estimates submitted to me of onboard equipment for MLS costing less than that.

Mr. TULL. Well, if you will refer to one page back from the last you will see again all the prices except the extreme right hand side are the ones I submitted in February and you will see at the bottom some MLS prices and some ISMLS prices.

Mr. MILFORD. Do you think as a practical matter that an air carrier would convert existing equipment if they went to ISMLS——

Mr. TULL. I do not think an air carrier would use ISMLS at all.

Mr. MILFORD. So you are talking about general aviation?

Mr. TULL. Primarily general aviation and some——

Mr. MILFORD. Well, the manufacturers of that equipment have given me a considerably different price for the cost of an MLS onboard system.

Mr. TULL. I am not aware of those prices, but the FAA did commission MITRE to do such a study and I put the MITRE figures next to those on the complete right hand side. I believe the MITRE figures to be very optimistic.

They have both reduced the MLS figures and the ISMLS figures.

Mr. MILFORD. OK. Do you have any questions?

Mr. HINTON. There are a couple of questions I would like to either ask or have put into the record.

Mr. MILFORD. Since we have some members who are not here and since I would also like to study this a little bit more, would you be willing to let us correspond with you by mail on some additional questions? Both the questions and the answers would become a part of the record. There are some other members—I know Mr. Lloyd in particular has an interest in this field—they have other commitments this morning; therefore, we may have additional questions.

Mr. TULL. I would be pleased to answer those.

Mr. MILFORD. We certainly appreciate, Mr. Tull, your taking the time to appear before this committee and we appreciate your input in this hearing.

Mr. TULL. Thank you very much.

[The attachments to Mr. Tull's statement follow:]

NATIONAL ASSOCIATION OF STATE AVIATION OFFICIALS,
Washington, D.C., January 7, 1976.

Hon. JOHN L. MCLUCAS,
Administrator, Federal Aviation Administration,
Washington, D.C.

DEAR MR. MCLUCAS: Enclosed is a position paper endorsed by the Aircraft Owners and Pilots Association, Air Line Pilots Association, National Business Aircraft Association, and the National Association of State Aviation Officials.

Because airborne VHF-UHF ILS equipment will be required in aircraft for at least 20 years, and the standard international precision system format selection may not be resolved for years, we believe the enclosed position paper provides an immediate reasonable, rational and economical transition to precision microwave landing systems.

We respectfully request the Federal Aviation Administration to endorse this system and begin implementation now.

Sincerely,

J. B. Hartranft, Jr.,
President,
Aircraft Owners and Pilots Association.

J. J. O'Donnell,
President,
Air Line Pilots Association.

John H. Winant,
President,
National Business Aircraft Association.

John A. Nammack,
Executive Vice President,
National Association of State Aviation Officials.

Position Paper

The following organizations—Aircraft Owners and Pilots Association, Air Line Pilots Association, National Business Aircraft Association and National Association of State Aviation Officials—fully support the Federal Aviation Administration's position that landing systems of the future may utilize microwave technology. In public and visible support of this position, the above-named organizations have provided personnel and requirement inputs to the FAA in direct assistance to the development of such a microwave landing system (MLS) to insure, if it ultimately proves technically and economically feasible, that a usable system evolves.

While the diverse nature of our members' equipment and operational needs precludes unanimous agreement on support of the ultimate national MLS system now under early development, there exists today, by this position paper, complete agreement among the four organizations on the need for timely and positive support of the ISMLS program.

Our organizations are deeply concerned over the attitude of the FAA towards the relationship of the longer-range MLS program and the existing (badly named) interim MLS (ISMLS). Instead of utilizing the low-cost equipment already available, there are increasing signs that some FAA staff members view the implementation of the ISMLS as a "threat" to the long range MLS program.

The FAA-designated standard ISMLS was developed by private industry at a minimum cost to the federal government and provides a unique capability and usefulness for certain applications for a wide range of the aviation community. We believe that the FAA should encourage the use of ISMLS where its advantages are significantly apparent. At the minimum, the FAA should discontinue its present attitude of discouragement of ISMLS utilization. Where applicable, either Facilities and Equipment (F&E) or ADAP funds should be utilized for installation of the ISMLS.

We call attention of all concerned to the fact that the ISMLS is available now. Further, it is authorized to be used for public IFR service. Through the immediate implementation of the ISMLS the FAA, for suitability equipped aircraft, can:

(*a*) Provide reliable precision approach service at difficult sites.

(*b*) Provide service at additional locations and runways without resorting to the split channel (50 kHz) frequency plan.

(*c*) Reduce site preparation costs that would be associated with ILS.

(*d*) Make available needed precision approach capability now for commuter, general aviation, and local (regional) service by air carriers to small communities.

(*e*) Reduce the operations and maintenance costs associated with rain, snow and other environmental effects.

(*f*) Gain operational experience with a microwave system.

Our organizations share with FAA a primary concern for the enhancement of flight safety which can be achieved through the installation of precision approach equipment. We believe that this concern can most effectively be met by encouraging the installation and use of the ISMLS now approved and available. In addition to the several operational advantages it would provide to aircraft operators, it could also benefit communities by diminishing aircraft noise exposure to the same degree that any vertical guidance system will assist in reducing aircraft noise exposure. It would also benefit communities by bringing to them increased business and related economic advantages which result from the addition of precision approach capability to the community's airport.

AIRCRAFT OWNERS AND PILOTS ASSOCIATION,
Washington, D.C., February 9, 1976.

Hon. JOHN L. MCLUCAS,
Administrator, Federal Aviation Administration,
Washington, D.C.

DEAR DOCTOR MCLUCAS: The four organizations that met with you on February 5, appreciated greatly having the opportunity to discuss with you our mutual concerns over the progress and planning of the MLS program. In response to your request, this letter is provided to supplement the subjects discussed at our meeting.

I have been authorized by the other three organizations, namely, NBAA, NASAO and ALPA to sign this letter on their behalf. The content is a coordinated and joint effort of our four associations.

Having participated in the MLS development program over a span of many years we feel confident that the following statements reflect a level of user expertise that will provide valuable guidance for the development of a rational FAA policy regarding ISMLS.

The FAA has made the decision and existing U.S. policy is that the next generation instrument landing system will use microwave technology. This decision is a matter of fact. The effect of this decision can be immediately recognized without reference to either the signal format or the international terms of ultimate agreement. Any VHF ILS system that is installed or "modernized" from here on will eventually be replaced in some future time period by equipment generically described as MLS. This, we sincerely believe, is the key decision.

Since ILS system days are numbered, it would be grossly unwarranted to extend unnecessary sums of money (either Federal or State) just for the sake of installing an ILS system at a difficult geographic site. Excessive site modification or preparation costs cannot be justified in many instances either through traffic count or the available funds. We deplore the philosophy that cost is no object with regard to site preparation, land acquisition and maintenance costs. The MLS technology provides the obvious alternative.

The national decision to go MLS means that ultimately a replacement plan will be generated to phase out existing ILS in an orderly manner. To express it differently, more than 500 ILS will eventually be replaced over a period of decades. Similarly, any runway that would have either a "provisional or interim" MLS installation would be scheduled for conformance with the final international system format.

We are firm in our belief that the existing ISMLS equipment is, in fact, the proper candidate for the title "provisional" as expressed by the MLS Advisory Committee. Its use can, in no way, be construed as "unilateral" action by the U.S. or improper pressure on ICAO for a decision favorable to the U.S. In fact, the ability of the ISMLS to be modified easily to any agreed standard, is adequate demonstration of the U.S. sincerity and belief in the technical necessity to utilize microwave technology.

We see absolutely no difference in the orderly upgrading of "provisional" systems (ISMLS) than the necessary programming that will be required for the changeover from ILS to MLS. In the event that international agreement negotiations take an inordinantly longer time than might be desirable, the orderly installation of ISMLS could continue. Following agreement, plans for any necessary conversion could then be made without disruption.

The MLS Advisory Committee, in their letter of January 29, 1976, recognized the need for, and recommended implementation of, a "provisional standard" MLS "to meet unsatisfied domestic needs." In effect, they have now reached the same conclusion as the exponents of early implementation of ISMLS to fill the gap between the ILS program and the ultimate microwave landing system.

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It should be noted that each of the military services have in effect their own "provisional" microwave landing system. The civil users want equal treatment. This, then, would provide all users with the opportunity to avail themselves of microwave approach benefits while the international selection process is running what promises to be a lengthy course.

The FAA is continuing with an ILS program on the basis that there are no known siting or operational problems at any of the location sites that cannot be dealt with. However, FAA's own reports refute their claims about the minor impact of siting difficulties.

FAA Report ARD–730, dated October 9, 1974, titled "ILS Operational Restrictions," states that there are operational restrictions on more than 10 percent of the FAA-owned ILS. The Flight Standards Facility Summary, dated May 1, 1974, listed 57 of 460 FAA systems with operational restrictions caused by local siting or terrain conditions. It further indicated that all of these sites are candidates for MLS installations and that, as the ILS program goes forward, additional sites will have restrictions and should be considered candidates for MLS.

It is believed that a significant number of the locations remaining to be implemented with ILS are sites that have been bypassed previously in the ILS program because of siting difficulties. It makes no sense to continue to install ILS at such sites when the operational utility will be impaired and especially in view of the U.S. policy to go to the microwave concept.

The FAA approach system criteria ignores the precision approach needs of the sophisticated small airport with jet capabilities as spelled out in many State System Plans. The entrance requirement for ADAP funding of a precision approach system should be lower than the regular F&E criteria because of the shared cost by the local community in construction and the payment by the community of the total cost of maintenance.

Mr. Cochran told us at the meeting in your office on February 5 that there was no problem in providing frequencies for the expanding ILS program, with the possible exception of the Los Angeles and New York metropolitan areas. This was in the context of not resorting to split channels. Yet, the FAA's existing policy is to utilize split channels for ILS. Implementation of that policy has been deferred temporarily due to protests from the users who would have to convert to new split channel ILS avionics. FAA regional frequency people continue to press for use of the split channels for ILS, demonstrating that a frequency problem does exist. Use of ISMLS will provide the most economical solution to this problem when considering the eventual conversion to MLS.

Realization, that ILS and MLS systems will have to coexist for some period of time, lends support to a system such as ISMLS which provides the most economical approach to this dual capability.

Adoption of ISMLS as the "small community" or "provisional MLS" provides a system which satisfies existing user requirements, does not prejudge an ICAO decision and provides the capability for the most economical conversion to whatever MLS signal format is eventually adopted by ICAO.

Cordially,

J. B. Hartranft, Jr.,
President.

Figure 1

Major ILS Limitations

The major factors that prevent the continued use of ILS into the indefinite future are shown below.

(1) Lack of available channels

(2) Cost of site preparation

(3) Susceptibility to multipath problems: Interference from reflecting objects—terrain, snow, buildings, over-flying aircraft, ground traffic.

Other limitations cited

(1) Single approach path rather than multiple paths.

(2) Fails to satisfy military tactical requirements.

(3) Improved signal quality needed.

FIGURE 2

MAJOR GAINS THROUGH THE USE OF MLS OR ISMLS RATHER THAN ILS

The major gains to be realized through the use of MLS or ISMLS stem from elimination of the basic ILS limitations. These gains are shown below.

(1) Precision approaches available at less cost.
- (A) Reduction in site preparation cost.
- (B) Greater freedom from unwanted system shutdown due to environmental effects. (snow, etc.)
- (C) Use of improved maintenance techniques.

(2) Precision approaches will be available for locations previously not possible.
- (A) Lower cost.
- (B) Freedom from technical difficulties due to site problems.
- (C) Availability of additional channels.

(3) Precision approaches will be available with greater service reliability.
- (A) Freedom from weather effects.
- (B) Freedom from multipath effects.
- (C) Higher hardware reliability.
- (D) Use of improved maintenance techniques.

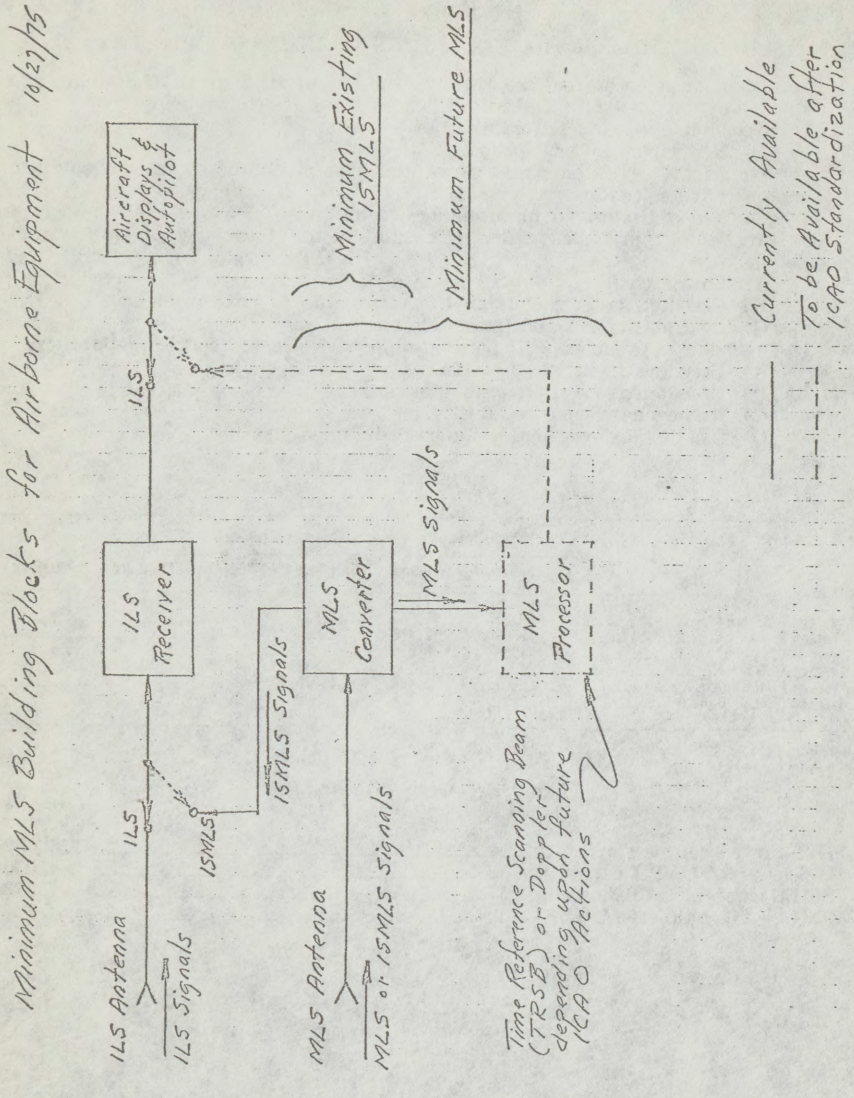
FIGURE 3

	1975 list prices [1]		Tull forecast prices [1]			
	Standard	Deluxe	Standard	Deluxe	Standard [2]	Deluxe [2]
Average DME price	$2,237	$5,086	$2,237	$5,086		
Average R-NAV price	2,095	7,416	2,095	7,416		
Average ILS price	1,882	4,050				
Average MLS price			1,882	4,050	$1,325	
Average ISMLS price		2,494	1,076	1,973	920	
Average ISMLS-20 price		1,425	900	1,599	800	

[1] From Feb. 18, 1976, hearings.
[2] From Mitre report.

(From February 18 hearings)

	Hardware price
MLS curved course capability	**$16,552**
MLS straight CAT I capability	**4,050**
ISMLS straight CAT I capability	**1,973**
ISMLS—20-channel straight CAT I	1,599



TULL AVIATION CORPORATION,
Armonk, N.Y., October 18, 1976.

Hon. DALE MILFORD,
Chairman, Subcommittee on Aviation and Transportation R. & D., Committee on Science and Technology, Rayburn House Office Building, Washington, D.C.

DEAR CONGRESSMAN MILFORD: Please find enclosed my response to the several questions which you asked in the attachment to your letter of October 12, 1976.

In closing my response to your questions, I would like to point out that we agree with you that an international standard for MLS, suitable for all users, must be agreed to at an early date. However, we do not see any requirement sufficiently pressing to make it necessary for the United States to move unilaterally on this issue in the absence of an ICAO decision. In fact we believe that such action would be extremely detrimental to all concerned.

The primary users interested in microwave capability now are those currently unable to obtain ILS service due to cost, technical difficulties or both. Generally these are third level carriers, commuters, air taxi operators, corporate operators, some helicopter operators, and some other general aviation users. All other users with the exception of the Army have either ILS or an interim military microwave system that provides adequate service until future international standards are available. The Army states that they have no requirements urgent enough to warrant the use of an interim system and plan to wait for a final MLS.

For many years we have been indicating that the process of arriving at an international agreement would be very time consuming and fraught with problems. It was anticipation of these problems that ISMLS was developed to provide a natural transition from our current ILS to the new MLS. The opposition to the use of ISMLS by some parts of the FAA has been extremely high. The users have been enthusiastically in support of its use.

The best approach to microwave landing system implementation and the least expensive to the taxpayer is through the use of the Interim Standard Microwave Landing System (ISMLS). This system is available now, has been approved by the FAA, is commissioned in two locations, and installations are complete in four additional locations soon to be commissioned. A seventh location is just beginning. It has taken four years to reach this status after availability of first production hardware installed at a customer's site in 1972. ISMLS development took place at private expense and at no cost to the taxpayer. The ISMLS was selected by the FAA to avoid proliferation of many system types while the ICAO decision making process took place.

Originally the opponents of ISMLS claimed that it was not technically possible to grow from ISMLS to MLS because no one knew what MLS would be. They now agree that this is possible but claim it is not economical. When this claim is investigated one finds that "it is not economical" is based on the assumption that FAA policy will curtail the widespread use of ISMLS. For the same usage of ISMLS as MLS they agree that the costs of ISMLS are 50% to 60% of those of the MLS.

At this time (and for the next 20 years) any aircraft operator wanting precision approach capability will need ILS on board his aircraft. This is true regardless of whether ISMLS or MLS is made available. In addition to ILS the operator will need either ISMLS or MLS airborne equipment in order to use one or the other new system. At this time a complete IMLS airborne system can be purchased for $2,155. This price is for high quality equipment similar to that used by air carriers. The price for less expensive general aviation equipment has been forecast by Mitre Corporation under contract with FAA. They forecast that a complete ISMLS can be purchased for $800 if the FAA does not restrain its use. We forecast a price of approximately $1,200 for the same system.

The previous price comparisons with which you have been supplied are for the electronic boxes only. The above prices are for complete systems. To change a complete ISMLS to an MLS airborne system approximately $1,000 needs to be added to the low cost ISMLS and approximately $2,500 to the high quality ISMLS. The resulting comparisons are:

	Standard		Deluxe	
	ISMLS	MLS	ISMLS	MLS
Electronics box	$900	$1,882	$1,600	$4,050
Antennas, etc., to complete system	300	168	330	200
Subtotal, system price	1,200	2,050	1,930	4,250
MLS add-on	1,000		2,500	
Total, ISMLS/MLS system	2,200	2,050	4,430	4,250

Mitre has estimated both the standard type ISMLS and MLS at lower values than we have. They have not estimated the price for Deluxe equipment.

There is no doubt that ISMLS can be added to and become an MLS for a reasonable expenditure. In fact, if one considers the effect of inflation between the time of the ISMLS purchase and the later add-on purchase the cost to the user for a full MLS would be less than waiting to purchase MLS only at a later date.

I trust this letter will be incorporated in the hearing record together with my responses to your questions. If you need any additional information, or if I can be of further assistance, please feel free to call upon me.

Sincerely,

WILLIAM J. TULL, *President*.

Attachment.

ANSWERS TO QUESTIONS FROM THE SUBCOMMITTEE ON AVIATION AND TRANSPORTATION R. & D.

Question 1. What is your interpretation of the Mitre Report analysis of MLS and ISMLS costs as relied upon by FAA?

Answer. Tull Aviation differs with several of the detailed Mitre numbers. However, without taking exception to any Mitre numbers the following conclusions can be drawn:

1. ISMLS is inherently less expensive to the user than MLS.
2. Present FAA policy will prevent the large scale production of ISMLS and keep the cost to the user high and approximately equal to that for the MLS when it is produced in quantity.
3. If FAA policy were to encourage ISMLS use and quantity production was realized the cost to the user would be approximately $800 for ISMLS versus approximately $1,325 for MLS.
4. Since ISMLS uses ILS as part of its airborne system, when ILS is retired in 20 or 30 years, the cost of ISMLS to the user would rise to be approximately equal to that of MLS.
5. ISMLS can be added to and become an MLS. If seven years time lapse takes place between the purchase of ISMLS and the subsequent purchase of an MLS addition, the total cost to the user is the same as for an MLS purchased at the later date.
6. An integrated ISMLS/MLS system can be provided when and if desired at a cost premium of 24 percent.

If Tull Aviation numbers were used rather than the Mitre numbers it would take only one or two years (not seven) between ISMLS purchase and the MLS add-on purchase to make the cost to the user less than to buy a complete MLS at the later date. In addition, Tull Aviation numbers would indicate an integrated MLS/ISMLS at a premium of less than ten percent, not 24 percent.

Question 2. Please describe your view of the pressures which may exist for preventing or stimulating early replacement of ILS with MLS.

Answer. The pressures that are most frequently cited as the reasons for implementation of a provisional MLS prior to an ICAO decision are:

1. Eliminate the possibility of ISMLS proliferation.
2. Military need.

I fail to see any real motivation to implement a provisional MLS. The U.S. has already adopted an interim standard which satisfies all known civil interim requirements. It has the unique capability of being able to grow and become either a Doppler or TRSB system when the ICAO decision has been made in an orderly manner. This system can be used to supplement ILS where the cost to implement ILS is excessive. The many time consuming regulatory actions required to make this possible have been completed. It would be a grievous error to expose the users to a second "interim" or "provisional TRSB system" as some have suggested.

Military motivation is a more complex and different matter. Because of their special needs the military services with the exception of the Army, have already adopted microwave systems to suit their unique requirements. When ICAO decisions have been made and the military need a next generation system they in all probability will design their systems to use this signal format. Military systems being what they are, I would be surprised if they were limited to ICAO capability only.

The Army not having a special system of its own, and at present waiting for an ICAO decision before moving forward with a new system, presents a different problem. The urgency of the Army need certainly impacts their decision. The options open to them appear to be:

1. Wait for an ICAO decision and then develop hardware to meet their special requirements utilizing the ICAO signal format.
2. Adopt one of the microwave systems used by another military service as an Army system.

3. Design an Army system utilizing the ISMLS signal format.

4. Design an Army system utilizing the U.S. proposed TRSB signal format.

It would apear desirable to choose option 1 or 2 above. The least desirable would be option 4 because of the expense and risk of obsolescence it involves.

Question 3. What pressures exist in your view for early implementation of ISMLS?

Answer. The pressure for the use of ISMLS is primarily to provide MLS benefits now for those users that need service prior to ICAO decisions, without compromising the ICAO decisions. Some of these are:

1. Eliminate the necessity of expending large sums unnecessarily on ILS site preparation where ISMLS is more cost beneficial.

2. Provide service at additional runways without resorting to the split channel (50 KHz) frequency plan.

3. Provide service in locations where it is technically very difficult or impossible to provide ILS service.

4. Provide a service for private and non-federal sponsors that they can afford—both from an initial investment and an operating and maintenance point of view.

5. Make available needed precision approach capability now for commuters, helicopter operators, general aviation, and local service to small communities.

Question 4. What disbenefits may occur in the United States or other country by going ahead with an MLS standard in advance of ICAO agreement?

Answer. There is no rational reason to go forward—however, if we did adopt TRSB as a national standard without international agreement;

1. All countries outside the U.S. would accuse the U.S. of negotiating in bad faith.

2. They could very well adopt any standard but ours out of spite.

3. The major U.S. trunk and international carriers would not implement for use of the national standard until an international pattern was established.

4. The major U.S. trunk carriers are clearly on record as not needing or wanting MLS for 10–15 years—if then.

5. The only potential users are the commuters, air carriers servicing small communities, some helicopters, corporates and general aviation. (They are on record in favor of ISMLS to provide needed service without the problems of international standards.)

6. We would face the same problem we had in 1951 when DME was adopted, and then 381 were installed only to be removed when we changed in February 1959 to DME–T or VOR–TAC as an international standard.

Question 5. Do you see pressing reason(s) for MLS implementation in advance of ICAO agreement?

Answer. I can't think of any rational reason that is not answered by the use of ISMLS. All moves in such a direction seem to me to result in disbenefits.

Question 6. What limitations of ILS necessitate MLS implementation?

Answer. The major factors that prevent the continued use of ILS into the indefinite future and can be overcome through the use of MLS or IMLS are:

(1) Lack of available channels.

(2) Cost of site preparation.

(3) Susceptibility to multipath problems: (Interference from reflecting objects—terrain, snow, buildings, over-flying aircraft, ground traffic.)

Other limitations which are frequently cited are:

(1) Single approach path rather than multiple paths.

(2) Fails to satisfy military tactical requirements.

(3) Improved signal quality needed.

Each of these is more debatable. For example, some argue that multiple approach paths are neither needed or desirable, and if they are needed they can be accomplished today through the use of R–NAV equipment.

Question 7. What are the major gains to be realized through implementation of either MLS or ISMLS?

Answer. The major gains to be realized through the use of MLS or ISMLS stem from elimination of the basic ILS limitations. These gains are:

(1) Precision approaches available at less cost:

(*a*) Reduction in site preparation cost

(*b*) Greater freedom from unwanted system shutdown due to environmental effects (snow, etc.)

(*c*) Use of improved maintenance techniques

(2) Precision approaches will be available from locations previously not possible.
(*a*) Lower cost.
(*b*) Freedom from technical difficulties due to site problems.
(*c*) Availability of additional channels.
(3) Precision approaches will be available with greater service reliability.
(*a*) Freedom from weather effects.
(*b*) Freedom from multipath effects.
(*c*) Higher hardware reliability.
(*d*) Use of improved maintenance techniques.

Question 8. Can you provide a comparison of both ground and airborne hardware for MLS (both TRSB and Doppler) and ISMLS with ILS (both air carrier, military and G.A.)?

Answer. Our work has concentrated on the CAT I or small community situation, therefore, I can only answer for systems of that type. This is, of course, where we believe the greatest need exists. In production quantities of approximately 100/year and after a few years production, we would expect small community MLS to sell F.O.B. the manufacturer's plant for approximately $75,000 and ISMLS for approximately $50,000. In small quantities I would expect small community MLS to be approximately $150,000 and ISMLS $100,000. I would not expect significant differences between TRSB and Doppler small community ground hardware prices. Perhaps if anything, the Doppler might cost slightly less than TRSB.

In the long range our list price estimates for ILS, ISMLS, and MLS electronic boxes are:

	Standard	Deluxe	Arinc
ILS	$1,882	$4,050	$7,963
MLS	1,882	4,050	7,963
ISMLS-100	1,076	1,973	3,877
ISMLS-20	900	1,599	3,142

These prices are based upon the assumption that MLS prices will be equal to ILS prices, which may be optimistic. I have no estimates for military systems. Arinc equipment is of course air carrier equipment. ISMLS–100 is one hundred channel ISMLS, and ISMLS–20 is 20 channel equipment. Twenty can grow to 100 and 100 to MLS of course.

Question 9. Where did the proposal to introduce an interim or provisional TRSB originate? Do you give it any support or hope for adoption?

Answer. I first heard the proposal to introduce a provisional TRSB from Mr. Poritzky in his capacity as chairman of the MLS Advisory Committee. I do not know if it originated with him or someone within the FAA.

The ISMLS was adopted presumably to reduce the possibility that many different types of interim systems would be used and thus "proliferate". Presumably ISMLS by its selection would make available one system which could be used without concern for proliferation. The proposal to introduce a "provisional" TRSB MLS prior to ICAO standardization is of course in itself an attempt to further proliferate.

Albeit fortuitous the ISMLS which was adopted, and which has now gone through the time consuming process of obtaining the many regulatory approvals, provides the service most immediately needed, and has the unique characteristic of being able to grow into not only the "TRSB MLS" but also the "Doppler MLS".

In addition to the above, it also provides the small community customer with the required service at the lowest cost. This is true both for the ground equipment and the airborne equipment. In effect it extends the natural life of ILS and provides for great savings of dollars by the elimination of site preparation costs at those airports where ILS is very difficult to install.

It would appear that the real concern is that some MLS advocates are afraid that MLS will not be able to compete with ISMLS. Because of this fear they would rather expend large sums on continued ILS installations into difficult and expensive sites, not realizing that when MLS is eventually ready it will have lost its major cost benefit due to such action. We should not, and probably will not, replace ILS that has been installed between now and the time MLS is available. It should only be replaced at the end of its natural life, unless MLS provides "real" benefits which warrant its earlier installation.

Contrariwise ISMLS installed *now*, provides benefits *now*, and does not require the site preparation dollars be expended. In addition ISMLS reduces the O&M costs *now* because it uses the maintenance techniques that MLS proposes to use—but ISMLS uses these techniques now and has been since 1972. MLS proposes to use such techniques but for budget reasons has not yet started a program to this end.

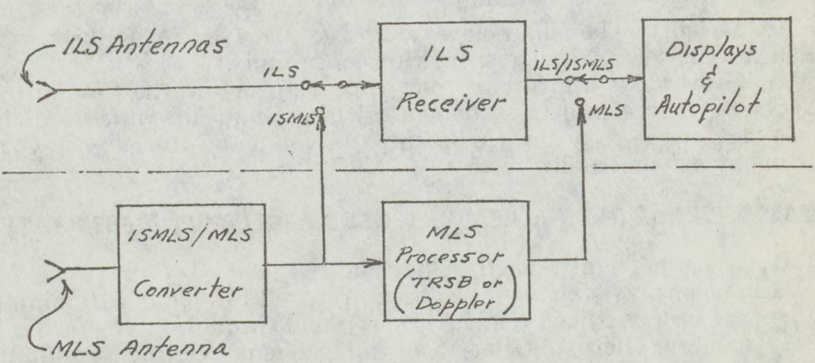
This may sound like I am against MLS—I am not! I am concerned about premature implementation of a system which may be rushed into production to fight off an imaginary ghost (ISMLS proliferation). I believe that dollars will be saved, better service will be provided, and a better MLS will result through the use of ISMLS *now*. If ISMLS is never replaced in the small communities because MLS as presently conceived cannot compete, the right decision was made. If MLS does eventually replace ISMLS—great—it will be because it was able to compete and provide either a better service for the same funds, or the same service for less funds.

Question 10. How would ISMLS grow into either TRSB or Doppler MLS? What are the relative costs?

Answer. This question can best be answered by the use of a simple drawing. The drawing has been oversimplified to make it easy to understand. The costs that are shown do, however, include all items whether shown on the drawing or not.

In the figure shown below the top portion represents a complete ILS airborne system, while the bottom portion represents an MLS without distance or curved approach computer capability.

An ISMLS airborne system is nothing more than the MLS converter the output of which is switched into the ILS receiver. An ISMLS user saves money by not buying the MLS processor. An ISMLS user can become an MLS user at anytime by buying the missing MLS processor.



Any of these systems ILS, ISLMS or MLS provide only straight-in approaches. The MLS airborne equipment, (when used with a new and additional Distance Measuring Equipment (DME) and a computer) can provide curved approaches, when used with an MLS ground station which provides a wide region of linear performance. ISMLS provides the least expensive microwave system performance.

ISMLS ground stations transmit ILS type signals at microwave, which after conversion to VHF by the converter are processed by the ILS receiver. MLS ground stations do not transmit ILS type signals therefore the ILS receiver cannot process the signals. MLS ground stations are proposed to transmit either Doppler or TRSB signals which after conversion to VHF by the converter can be processed by either a Doppler or TRSB MLS processor. Which processor is used depends upon a future ICAO decision.

The approximate prices for the ISMLS and MLS are tabulated below:

	ISMLS	MLS processor add-on	Total ISMLS/MLS	Total MLS only
Box prices:				
Standard	$900	$1,000	$1,900	$1,882
Deluxe	1,600	2,500	4,100	4,050
System prices:				
Standard	1,200	1,000	2,200	2,050
Deluxe	1,930	2,500	4,430	4,250

Question 11. Are you aware of a transponder based ILA combined with a Synchro-DABS which was reported upon by the Naval Weapons Center at China Lake in TN 3955–1–75 dated October, 1975? If so, please comment on the capability of this system vis a vis the others under consideration.

Answer. The China Lake system is basically a simplified ILS operating at L-Band using the transponder as a receiver in the aircraft.

The system is operating in a frequency band which is not available for this type of service. If it were changed to the proper frequency it would become just one more C-Band development. Its chief current advantage is its use of the airborne transponder receiver.

The chief disadvantages of the system relative to ISMLS or MLS are:

1. It provides no multipath protection.
2. It provides inadequate coverage area.
3. Its data rate is far too low.
4. Its aircraft capacity is very limited (particularly if the data rate was increased).
5. It would have poor system integrity and be subject to mutual interference.

In general I would say it represents too little too late. It is very similar to a C-Band system Honeywell sold in the early '60's and has since been abandoned.

Mr. MILFORD. The Chair now recognizes Mr. Glen A. Gilbert with Glen A. Gilbert & Associates, aviation consultants.

Mr. Gilbert, we appreciate your appearing before the Committee. We have your complete statement with attachments which will be accepted for the record at this point, and you may proceed with your testimony as you see fit.

STATEMENT OF GLEN A. GILBERT, GLEN A. GILBERT & ASSOCIATES

Mr. GILBERT. Thank you, Mr. Chairman.

Inasmuch as my statement has been prepared for about a 10-minute delivery, I propose that I read it right straight through.

My name is Glen A. Gilbert, an independent aviation consultant for over 25 years, specializing in programs for increasing air transportation safety and efficiency, including such areas as aircraft operations, air navigation, airport design, air traffic control system engineering, and many related facets in the field of research and development.

The first observation I would like to make with respect to the R. & D. programs of the Federal Aviation Administration is that current funding is at too low a level. The R. & D. appropriation for fiscal year 1977 represents about 3.5 percent of the FAA's total budget authorization. In private enterprise, on the other hand, many of the most progressive companies dedicate around 10 percent of their earnings to R. & D. If this formula were to be applied to the FAA, its annual R. & D. fundings should be in the order of $200 million, or about three times the amount authorized for fiscal year 1977.

Because of such relatively low-level funding, the FAA is constrained in the extent to which it can carry out significantly R. & D. programing for new system concepts. The net result is that the FAA's fiscal year 1977 R. & D. program largely involves continuation of work on previously initiated programs, much of which could be considered as band-aiding old projects. Furthermore, an examination of the FAA's 10-year plan, 1977–86, reveals that the 1977 R. & D. funding levels and program contents are projected to continue virtually unchanged for the next decade. If the Congress permits this situation to continue unchanged, I visualize that the future progress and development of our national aviation system will be in grave jeopardy.

In the light of the foregoing observations, I would like to address myself within the context of these hearings to two basic areas: establishing priorities for R. & D. programs, and determining construction of R. & D. programs.

Obviously, any R. & D. funding must have a ceiling, although, as I have just mentioned, I think that the current FAA's R. & D. ceiling is entirely too low. Once established, however, how best to assign program priorities within authorized R. & D. funding is a critical task. In the FAA's fiscal year 1977 R. & D. budget, out of the total of $74.350 million, about 72 percent is assigned to air traffic control, and 21 percent to navigation, the remaining 7 percent being split between aviation weather and aviation medicine.

Thus, an FAA R. & D. program priority assessment basically involves air traffic control and the interrelated field of navigation. Within these two fields are a number of subprograms which have been assessed priorities, in effect, by virtue of funding allocations made by the FAA within the total authorized R. & D. ceiling.

It is inescapable that an R. & D. project, if successful, should lead to meeting an operational requirement; otherwise it is an exercise in futility. Or, conversely, that an operational requirement should dictate the need for an R. & D. project. In the final analysis, an R. & D. program, with its consequentially presumed implementation program, should be preceded by: (a) an identification of system user requirements and support; (b) a life cycle costing (LCC) analysis of the final project; and (c) a cost/benefit analysis of the final product.

In my opinion, many of the FAA's R. & D. programs and priorities are not particularly responsive to the criteria just briefly outlined.

For example, the beacon (DABS/IPC) subprogram will use about 15 percent of the FAA's total R. & D. fiscal year 1977 funding. Yet, I have not seen any hard facts as to the LCC or cost/benefits of this program if and when implemented.

"Automation", in one form or another, accounts for around 30 percent of the total FAA fiscal year 1977 R. & D. budget. There is no doubt but what some form of automated data processing capability is needed in the ATC system to reduce controller workload as this system is presently conceived, that is, man intensive and ground centralized. But this approach also tends to be more restrictive and inflexible in its capability to handle mass air traffic density, being tailored essentially to the control of airline conventional takeoff and landing CTOL aircraft at a relatively small number of CTOL airports.

Another subprogram which I would like to touch on in the context of the foregoing comments is the FAA's MLS R. & D. effort. In the past 5 years, it appears that about $90 million R. & D. funds have been spent by the FAA on this project, without any clear idea of what the LCC and cost/benefits would be if and when the system were to be implemented. In addition, the program has been carried on so far in the face of no international commitment on standards, without which there can be no logical basis for the United States to proceed unilaterally with its MLS program in my mind. Perhaps an international agreement should have come first and then joint international funding could have been insisted upon if, indeed, there was a consensus internationally that a microwave instrument landing system was in fact needed. In fiscal year 1977, the MLS will account for around 20 percent of the FAA's total R. & D. budget.

A final R. & D. project I should like to comment on in passing is the Aerosat subprogram, which accounts for about 8 percent of the FAA's fiscal year 1977 R. & D. budget. While commendable international cooperation has been achieved in this instance, the program is experimental in nature and begs such questions as are there better ways to go; for example, a combined navigation/communication satellite system? If the Aerosat concept were to be implemented, what would be total system costs and benefits of Aerosat in comparison with other candidate concepts; for example, use of commercially operated satellites in the field of aeronautical communications?

The four programs I have just identified absorb about three-fourths of the FAA's total fiscal year 1977 R. & D. budget. It is obvious, therefore, that virtually no room is left to examine new, innovative R. & D. programs in the FAA for fiscal year 1977. And assuming that the fiscal year 1978 R. & D. effort basically will be just more of the same thing, we are faced with the serious question I raised in the earlier part of this statement to the effect that unless we pursue positive, innovative and operationally responsive and cost/beneficial R. & D. programing in the FAA, we surely are facing dangerous prospects for the future of our Nation's air transportation system.

Mr. Chairman, at this point I would like to express my views briefly on what the FAA should be doing in the field of R. & D. that it is not doing; and what the FAA is doing that it should not be doing. These are my opinions. There may be others who disagree.

In the first category, I consider that there is a need for an in-depth analysis of ways and means to more effectively distribute air traffic management as between the controller and the pilot, and thus help unload the present man-intensive ground based ATC system. Considerable work along these lines has been accomplished by MIT in the form of using an airborne air traffic situation display (ATSD). The FAA has been apprised of this program, but so far has not included any project of this type of any significance in its R. & D. planning. Many presentations have been made in this area—the area I am talking about is distributing management of the ATC system between pilot and controller—including studies and papers by myself and representatives of such organizations as the Air Line Pilots Association. I would be pleased to make such material available to staff, if so desired.

Mr. Milford. I would at this point welcome it and say that such material would appear in the record at this point.

Mr. Gilbert. Mr. Chairman, I will certainly do that right away.

[The document follows:]

Supplemental Statement by Glen A. Gilbert

With regard to the general subject of "distributed management" in the Air Traffic Control System, it is important to avoid semantics which may tend to obscure or confuse its inherent meaning. Consequently, simple definitions of "distributed" and "centralized" are useful reference terms. Webster says that distribute means "to divide among several or many; to deal; allot". The same source defines centralize to mean "to bring to a central point; to bring into one system, or under one control".

In applying these definitions to ATC System engineering, an extreme in either direction certainly would not be desirable. As a comparison, a 100% *centralized* management system of our automobile traffic, in which every individual automobile would be directed (hand carried) by a policeman would be completely unmanageable. Yet, this is pretty much how our ATC System is designed today. On the other hand, 100% *distributed* management would not be feasible, any more than it would be in our automobile traffic system by letting every motorist do what he felt like doing without regard to such constraints as stop-go lights, speed limits (both maximum and minimum) and one way traffic.

Thus, it is considered that the question to be addressed should be the *extent* to which air traffic control functions (management/responsibility) could be distributed most beneficially, as between the controller and the pilot. Putting it another way, perhaps the clearest description of the subject area to be dealt with in this context is *optimization of ATC aircraft separation responsibility and air-ground workload distribution.*

This approach involves greater delegation to the pilot for separation and spacing functions and better airspace/airport utilization by means of airborne equipment which will provide new pilot/controller tools in the ATC System. The controller thus becomes primarily concerned with data collection and flow control, assisted by ground computer complexes. A *mix* of automation and the human element is combined with suitable interfaces. The new pilot/controller tools would include widespread implementation by the FAA and system users of such developments as airborne area navigation equipment, data link air-ground-air communications, airborne displays of traffic control information and instructions, proximity measurement (station keeping) and collision warning instrumentation. The pilot/controller interface for carrying out these and other related functions could be by means of a suitably designed cathode ray tube—CRT—Airborne Traffic Situation Display (ATSD) system.

Using an ATSD, the pilot can assess a given traffic situation and maneuver his aircraft accordingly. Or, in cooperation or coordination with the controller, the pilot may carry out directly—by reference to the ATSD—certain functions to "unload" the ground ATC System, and at the same time increase airspace/airport capacity. These include:

Station-keeping, which involves flying within specified close proximity to other aircraft.

In-trail spacing at optimum distances from other aircraft departing, en route, and landing.

Passing (going around) aircraft being overtaken.

Avoiding crossing traffic.

The ATSD also may incorporate other pilot-interpreted information such as ground proximity warning and landing/takeoff area positioning.

For more in-depth information on the general subject of "distributed management", a bibliography of useful references is attached.

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(Prepared by Glen A. Gilbert, Glen A. Gilbert & Associates)

Mr. GILBERT. In my statement before this distinguished subcommittee last May on the future of aviation, which with your permission, Mr. Chairman, I would appreciate being considered as supplementary testimony to my statement of today, I outlined a number of areas where new R. & D. efforts are indicated, especially with respect to the use of new technology air vehicles and the need for increasing ATC system capacity in order to be capable of handling needed future mass air transportation. It should be noted that in the FAA's 10-year plan for 1977–86, the word "helicopter" is mentioned once and the word "rotorcraft" once; "VTOL" is not mentioned at all. This is symptomatic of the FAA's almost total preoccupation in its R. & D. planning with CTOL (conventional takeoff and landing) aircraft and CTOL airports.

In the field of navigation, there is a big gap in the consideration of two important aspects: Area navigation, or RNAV as it is usually referred to, and satellites. In attachment A to this statement I have included a letter to the FAA from the Helicopter Association of America dated January 15, 1976, recommending an extension of previous FAA R. & D. efforts in this area. Action along these lines is not contemplated in FAA's fiscal year 1977 R. & D. programing.

With regard to the use of satellites for navigation. Attachment B to this statement contains a statement I made on June 24, 1976, for the Telecommunications and Transportation Special Group of the Department of Transportation regarding the potential civil aviation use of the DOD NAVSTAR GPS—Global Positioning System—for civil aviation. This calls for R. & D. action to be carried out by the FAA, but the FAA's 10-year plan does not reflect any consideration of this important potential for civil aviation of the future. The same system can provide the means for ATC surveillance through air-ground datalink position transmissions, and collision avoidance capability through air-to-air data-link positioning exchange.

On the other pont—what the FAA is doing that it should not be doing—I think that too much R. & D. money is being allocated to the MLS program as indicated earlier. In this connection, I am enclosing as attachment C a letter dated May 18, 1976, from the Helicopter Association of America to Dr. John McLucas, FAA Administrator, expressing the helicopter industry's views on the FAA MLS program. In essence, this portion of our Nation's aviation industry concludes that it cannot at this time unequivocally support the FAA's SMLS—Standard Microwave Landing System—program.

Some final, summary, thoughts—FAA needs a more aggressive approach to R. & D. programs based on what is good for the overall system and ultimately the flying public—not just special preconceived interests.

FAA does not conduct pure research or advanced development, as almost all its R. & D. is system development and implementation oriented. More emphasis should be placed on R. & D. activity in advanced research and development cooperative programs with such other governmental entities as NASA and DOD.

There needs to be consistency in FAA R. & D. programs in order to produce meaningful and cost/beneficial results. Programs are initiated and then cutoff; and then reinstated—result is increased costs, and reduced productivity. Example—the RNAV R. & D. program—plans were developed by an FAA/industry RNAV Task Force 5 years ago; the R. & D. was carried out, but now there appears to be little carryover to system implementation.

Large system implementation efforts consume very large percentage of resources—for example, Aerosat MLS, DABS/IPC. This destroys R. & D. program consistency and fundamental R. & D. in functional areas; and creates a reactionary mode where the only projects that are adequately funded are part of large previously committed programs.

FAA must take the leadership role in planning for current and future navigation systems in a cost/beneficial and forward-looking manner.

Current FAA internal organization tends to detract from effective efforts between R. & D. and operating services, and tends to inhibit smooth transition between R. & D. efforts and system implementation.

The logistics/legal/procurement system that now exists is so cumbersome that it is very difficult for both contractors and FAA personnel to be responsive to R. & D. programs and FAA requirements. For example, 2 years is common from inception to contract award for an R. & D. project, and 6–8 months just for a simple contract modification to update needs of the program.

Mr. Chairman, the foregoing statement is intended to be constructive in the furtherance of continued and expanded development of our Nation's vital air transportation system. I thank you and the members of this subcommittee for giving me the opportunity to make this presentation.

Thank you, sir.

Mr. MILFORD. Thank you, Mr. Gilbert.

For the record, Mr. Gilbert, what is Glen A. Gilbert and Associates?

Mr. GILBERT. An aviation consulting group, consisting of a series of independent aviation consultants and consulting organizations which we put together for joint pooling efforts as required, for both private and Government contracts. Individual consulting work is handled by individual consultants. For example I individually act as a consultant to the Helicopter Association of America and individually as a consultant to Bell Helicopter Co. Together in our combine we develop contracts with the Government on studies in the R. & D. field as well as with private companies.

Mr. MILFORD. How many employees would you employ permanently?

Mr. GILBERT. In the total combine of the associated companies? Approximately 250.

Mr. MILFORD. 250 employees?

Mr. GILBERT. About that, yes, sir.

Mr. MILFORD. What is your technical background, Mr. Gilbert?

Mr. GILBERT. Well, if I had a biographical résumé here, I would submit it for the record if you want it.

Mr. MILFORD. I would be glad to accept it for the record.

Mr. GILBERT. All right, why don't we do that. I hate to talk about all these years that I have been in the aviation business.

[The background on Mr. Gilbert follows:]

BIOGRAPHICAL RÉSUMÉ—GLEN A. GILBERT

With over forty years of experience in aviation, Mr. Gilbert has an extensive background involving airline operations, Government, United Nations and private aviation consulting. A principal organizer and founder of the U.S. Air Traffic Control Service, Gilbert became its first Director when this activity was inaugurated by the Federal Government in 1936 following prior airline development in which he played a significant role. He also played a key role in the creation of the International Civil Aviation Organization (1944) and in the subsequent development of international air traffic control standards and procedures, as well as in multilateral agreements on aeronautical facilities and services. Mr. Gilbert continued as Director of the Air Traffic Control Service until 1947 when he was named as Special Assistant to the Administrator of Civil Aeronautics for the development of U.S. air policy in the post-war years. During the next five years he was appointed by the President or the Secretary of State to represent the United States at numerous international aviation conferences throughout the world as delegate or head of delegation. After 15 years of service, receiving the Government's Distinguished Service Medal, Gilbert was appointed Senior Aviation Advisor in the United Nations' Technical Assistance Program. In this post he prepared aviation development studies for underdeveloped and developing countries on a worldwide basis. During this time he received a "Commendation" from the President of El Salvador, C. A. for his work.

He organized and directed a U.N. sponsored International Civil Aviation Training Center in Mexico serving all of Latin America and covering all major aspects of air transportation technical careers. In 1957 he established Glen A. Gilbert & Associates, specializing in aviation studies, analyses and evaluations. An active pilot since the mid-1930's, with multi-engine and instrument ratings, Gilbert has devoted major attenton to programs for increasing air transportation safety and efficiency, covering such areas as aircraft operations (CTOL, STOL, VTOL), related research and development, air traffic control, navigation and communications system engineering, with emphasis on improving the utilization and capacity of airspace and airports. He has served, and continues to serve, in many government/industry advisory and coordinating activities. Mr. Gilbert is the author of the world's first comprehensive book on Air Traffic Control (Ziff-Davis, 1945), as well as numerous articles and papers on various aspects of aviation. He is the author of a current book "Air Traffic Control: The Uncrowded Sky", published by the Smithsonian Institution Press and featured in the new National Air and Space Museum. He holds Member grade in American Institute of Aeronautics and Astronautics, Aviation/Space Writers Association, Institute of Electrical and Electronic Engineers, Institute of Navigation, Society of Automotive Engineers, Membership or affiliation in aviation organizations includes Aircraft Owners & Pilots Association (charter member), Aero Club of Washington, Airport Operators Council International, Air Traffic Control Association, American Helicopter Society, Canadian Air Traffic Controllers Association, Experimental Aircraft Association, Greater Miami Aviation Association, Helicopter Association of America, International Federation of Air Traffic Controllers Associations, International Omega Association, National Pilots Association, National Aviation Club, National Association of State Aviation Officials, National Aeronautics Association, National Business Aircraft Association, Professional Air Traffic Controllers Organization. He received his B.A. degree from the University of Wisconsin, and is listed in "Who's Who in Aviation"; "Leaders in American Science"; "Men of Achievement (Int'l)"; "Who's Who in the South and Southwest". He received the "Outstanding Floridian in National Aviation" award from the Greater Miami Aviation Association in 1972, and was elected to the OX–5 Aviation Pioneers "Hall of Fame" in 1975.

Mr. MILFORD. Do you have an engineering background?

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Mr. GILBERT. No; I have a straightforward Bachelor of Arts background as far as formal education is concerned. I have been a licensed active pilot with multiengine, single-engine and instrument ratings since 1938. I was an original founder of the U.S. Air Traffic Control Service and headed it for its first 10 years. Five years after that, representing the United States in postwar international aviation development. Six years in the United Nations as senior aviation advisor in their technical assistance program and since 1957 have headed my independent aviation consulting work.

Mr. MILFORD. Your remarks about future funding for FAA, I personally very much agree with. We have tried in our recent report on the "Outlook for Aviation" have tried to bring this to light in a dramatic way not only FAA funding but also NASA's. As a matter of fact we will probably bear down more heavily on NASA than we would FAA since they are a technology development agency.

You made a statement, "In addition the program has been carried on so far in the face of no international commitments on standards", we are talking about MLS here, "without which there can be no logical basis for the United States to proceed unilaterally with its MLS program."

You are in an area that I have strong personal concerns about. The information that I have received indicates that there are very serious problems with frequency congestions in ILS in certain of our metropolitan areas. We have a crying need for the small community systems where it would be too expensive to install ILS. Our military has stated that they are faced with an immediate decision on this matter. In fact the Army helicopter program is the very one that is really up against the wall. If you are familiar with Bell Helicopter, I think you would be familiar with that program.

Mr. GILBERT. Sure.

Mr. MILFORD. The noise situation that we have in many of our major airports could be alleviated by the features available in MLS that are not available in ILS. All of these together seem to impress upon me that there is a strong need for us to move with MLS either unilaterally or with international cooperation. I have always emphasized that I would prefer it be within international cooperation. But you seem to be taking a position opposite to that.

Mr. GILBERT. I would like to comment on your question in two broad areas. First of all, Mr. Chairman, I think that having been one of the originators of the International Civil Aviation Organization back in 1944 when the international convention was first called to create an international civil aviation organization, and spending a number of years with it, and then subsequently also being in the area of getting international agreements for facilities and establishment of equipment in the post-war era, and then going through the time when we were having within our own country disagreement as to whether we would have a VOR system for navigation or a TACAN system, we had to make a compromise. We sort of dragged in those days a lot of people internationally along with us. Today, I do not think that can be done. I just do not really see myself, and having flown all over the world as a pilot, I really do not like the idea of having to have more than one common system for navigation.

Mr. MILFORD. I do not either. I am in total agreement. But suppose you get into a situation where the international group seemingly cannot make a decision, then what do you do?

Mr. GILBERT. May I just make an observation on that which is my second point. I am a member of and I represent the Helicopter Association of America, on RTCA SC–125 which is on the subject of so-called "standard" MLS implementation.

I think it is generally considered and agreed by the members of that group that, with respect to "standard" MLS implementation, it is considered that full system operation probably could not be achieved before close to or around the year 2000. That is the target: 25 years from now. In the next 25 years I see a lot of technology coming up. I see our satellites providing us with a precision navigation aid to almost any point on the surface without having to anchor necessarily an electronic piece of gear at that particular point. I can see a greater use of airborne self-contained navigation systems. I am running some very simpe experiments now with a very simple mapping radar with two helicopter companies, and we are getting the equivalent of category I minimums by having a rather simple area navigation system to go to a target point and then using the mapping radar for a final approach. That is using pretty crude equipment, so I guess what I am saying is that if we are talking about an MLS program the operational implementation era is some 25 years from now, I think we should take a hard look at some other things at this point before we commit to something like FAA's proposed MLS.

Mr. MILFORD. Are you in a position to show me where we could alleviate the problems which I have outlined here? These are pressing now, not 20 years from now.

Mr. GILBERT. Well, ILS is not all that bad especially if——

Mr. MILFORD. I did not say it was bad at all. I am saying that ILS cannot solve the problems that I have outlined. The Army cannot put an ILS system in the field.

Mr. GILBERT. That is true. However, the so-called interim standard MLS, "ISMLS," has a lot of merit, and in attachment C of my statement here you will find a letter that the HAA sent to Dr. McLucas which says that although the helicopter industry cannot support unequivocally the FAA MLS program, that is, the standard MLS program, they do feel there is a role for an interim MLS and especially the interim standard MLS if it is packaged in a single unit.

Mr. MILFORD. Is the interim standard MLS capable of flying curved approaches that would perform a noise abatement program in some of our key cities?

Mr. GILBERT. You can do a curved approach on an ILS or interim MLS, you can do a two segment approach on either system for noise abatement. We can do any kind of a curved approach that you want, if the aircraft has the sufficient flexibility and maneuverability.

Mr. MILFORD. It fixes you in space at any given time?

Mr. GILBERT. Oh, yes, especially if you have continuous distance measurement from your touchdown zone, like FAA is putting DME's colocated with ILS today. There is no problem at all in flying an RNAV or DME arc kind of approach to intercept the localizer final approach path at a desired point. You can pick distance out that you want to intercept—3 miles, 5 miles.

I do not think any fixed wing airline pilot wants anything less—the ATA people can certainly speak on this point. But in some of the two segment approach noise abatement work that I went through with American Airlines, for example, a couple of years ago in a 727–200, the general feeling of pilots flying high performance transport aircraft is that they want to have a stabilized approach for at least the last 3 miles and preferably the last 5 miles before touchdown. There is no great problem in intercepting the ILS, or ISMLS, at 3 to 5 miles coming in on curved approaches. That is basically what all the ILS intercepts are today anyway.[1]

Mr. MILFORD. We have had a vote bell, Mr. Gilbert, and I am sorry that we cannot continue our questions, but would you be willing to accept questions from other members and myself by mail and have the questions and your answers incorporated in the record.

We appreciate very much your taking the time to appear before this committee. Your testimony is very enlightening and it will be gone over very carefully.

Mr. GILBERT. I would be very happy to answer any further questions I can, sir.

Mr. MILFORD. Thank you very much.

The subcommittee will stand adjourned at the call of the Chair.

[The attachments to Mr. Gilbert's statement follow:]

ATTACHMENT "A"

HELICOPTER ASSOCIATION OF AMERICA,
Washington, D.C., January 15, 1976.

Mr. RAYMOND G. BELANGER,
Director, Air Traffic Service, AAT–1,
Federal Aviation Administration,
Washington, D.C.

DEAR MR. BELANGER: We appreciate very much your kind invitation to attend the area navigation (RNAV) briefing which was held by the FAA on December 18, 1975. The HAA was represented at this briefing by Mr. Glen A. Gilbert, who also represents the HAA in other areas of FAA activities.

Additionally, I wish to acknowledge with thanks the various RNAV documents transmitted to Mr. Gilbert in preparation for this briefing by Mr. Robert W. Wedan under letters dated October 24 and November 25, 1975.

At the conclusion of the briefing, Mr. Gilbert raised the point that nowhere in the FAA's RNAV study so far has the application of RNAV to helicopters been considered. While RNAV may not be critical to fixed wing aircraft operations at this time, we do feel that it will become more critical to that class of traffic in the sense of designing and adhering to route structures which will facilitate segregation of fixed wing and helicopter traffic. Furthermore, the use of RNAV for IFR helicopter operations is a critical problem now, and will become more so as IFR helicopter operations increase.

By 1980 we expect that there will be about 5,000 helicopters of U.S. registry equipped for and actively engaged in IFR operations. These operations will take place in the field of energy development off-shore in the Gulf of Mexico, off the Atlantic and Pacific Coasts, and in Alaska/Canada. In addition, the use of IFR helicopters in corporate/executive applications will be greatly increasing, including flights in high density traffic environments. We also visualize the

[1] Other alleged problems raised by proponents of the FAA's SMLS program include: (1) ILS siting. These problems where encountered can be solved by ISMLS as well as by MLS. (2) ILS frequency congestion. The FAA has inaugurated 50 kHz channel spacing for the ILS VHF localizer where frequency congestion exists (actually only at a few major hubs). If the operators use 50 kHz channel localizer receivers, which most are transitioning to, ILS frequency congestion becomes no problem. (3) ILS accuracy. The British have been successfully using the ILS for some time to perform category III "hands-off" landings with their autoland system.

development of more and more city-center to city-center and city-center to conventional airport IFR helicopter operations. RNAV is a *must* for the successful conduct of all of the foregoing IFR helicopter services.

Other types of VTOL's are now under active development. These include Bell's XV15 (commercial model 301) tilt rotor vehicle which will operate in the helicopter mode up to about 110 knots and transition to the airplane for cruise speeds of around 300 knots. Compound helicopters with increased speed and range also are under development. Many of these new design helicopter/VTOL's will be capable of carrying upwards of 50 passengers.

The unique characteristics of the helicopters/VTOL's put a new dimension on RNAV applications and interface with the ATC system. These include capability to fly at relatively low speeds, to hover and touchdown, ability to accelerate or decelerate rapidly, perform steep ascent/descent gradients, and land/takeoff on small areas (heliports or helipads) which may be on the surface or elevated, such as on building roofs.

As a consequence of the foregoing considerations and in the light of the fact that FAA RNAV studies to date have not covered helicopter applications, the HAA strongly recommends that the FAA immediately expand its current work in the RNAV field to cover the following general subjects with respect to IFR helicopter/VTOL operations:

1. Perform a navigation support study with respect to various applicable systems, including but not limited to TACAN RNAV, airborne weather/mapping radar, NDB/ADF, Omega, Loran C, VOR/DME, satellite systems (e.g., Navstar), INS, hybrid VLF, conventional ILS, ISMLS and SMLS.

2. Evaluate criteria (present and proposed future) for the development of RNAV instrument approaches (IAP's) with respect to each candidate navigation system, including minimums, multi-segment approaches for obstruction clearance and noise abatement, credits for combined systems (e.g. TACAN RNAV with ISMLS. Similarly cover missed approach procedures.)

3. Determine RNAV system error; including flight technical error (FTE), route widths, holding patterns, and other elements comprising total RNAV system error relative to each candidate navigation system.

4. Develop criteria for low altitude RNAV discrete route structuring in terminal areas, en route and for transition.

5. Perform a cost benefit analysis of each RNAV system considered, including a life cycle cost (LCC) analysis.

6. Prepare conclusions and final recommendations.

I trust that the foregoing proposal will meet with the FAA's approval and that it will be commenced at an early date, as the results will be extremely important to the helicopter industry with respect to further navigation planning, as well as in providing a basis for the FAA to move ahead rapidly with the provision of the appropriate implementing facilities and procedures. If we can be of assistance to the FAA in carrying out this program, we will be most pleased to cooperate in any way as may be appropriate.

Yours sincerely,

ROBERT A. RICHARDSON,
Executive Director.

ATTACHMENT "B"

STATEMENT BY GLEN A. GILBERT ON BEHALF OF HELICOPTER ASSOCIATION OF AMERICA

The increasing use of civil IFR helicopter operations has focused sharp attention on the deficiencies of the present VOR/DME navigation system. These basically are the lack of precision navigation guidance (route widths up to eight nautical miles), line-of-sight limitations and unavailability of stations offshore and in remote areas.

Furthermore, the present national navigation system permits "precision" instrument approaches only where an ILS (future MLS) or Par (precision approach radar) system is installed. There are about 13,000 aircraft landing facilities in the United States and its possessions, including nearly 1,500 heliports, yet precision instrument approach facilities are available for fewer than 350 approaches to conventional airports, and none for heliports.

While the limitations of our conventional navigation system are expressed above in the context of helicopter operations, they apply equally to all classes of fixed-wing CTOL (conventional take off and landing) and STOL (short take off and landing) aircraft. These limitations become even more pronounced, however, when considering the growing need for precision approaches to virtually an infinite number of landing/takeoff areas for IFR-capable helicopters and other VTOLs (vertical takeoff and landing vehicles) now being developed. For example, approaches to city center heliports, to discrete helipads at conventional airports, to constantly changing locations for servicing of pipelines, to thousands of offshore oil rigs, to unpredictable locations for emergency rescue, etc.

CURRENT SYSTEMS AND CONCEPTS

Principal features of current basic air navigation and positioning systems are summarized within the ten following categories:

Inertial navigational system (INS): Operational range—unlimited; operational altitude—unlimited; accuracy—decreases at a rate of 1 NM per hour of operations.

Doppler Navigation System: Operational range—unlimited; operational altitude—unlimited; accuracy—degrades at a rate of 0.5 NM per hour along track, and at two percent of distance traveled across track.

OMEGA: Operational range—unlimited; operational altitude—unlimited; accuracy—approximately 2.0 NM (affected by solar eruptions).

VLF Communication Signals: Operational range—unlimited; operational altitude—unlimited; accuracy—approximately 1.5 NM (affected by solar eruptions).

Loran-C: Operational range—Each transmitter has a groundwave range of 1000 NM; signals from three ground stations must be available for navigation. Stations are located about 800 NM apart, and geometric limitations are imposed by the relative locations of stations to each other. Operational altitude—unlimited. Accuracy—approximately 0.4 NM.

VOR: Operational range—The operational range and altitude for VOR use are interrelated because of the radio horizon (line-of-sight) effect. For example, at a range of 200 NM from a VOR station the minimum altitude at which a signal can be used is about 26,000 feet. Operational altitude—At 800 feet, for example, the VOR signal is useful at a range of about 35 NM. Accuracy—Bearing accuracy is ± 3.5 degrees (95 percent probability) relative to the desired course center line. Thus, when 66 NM from the VOR station, position error is ±4 NM.

TACAN: Operational range—unlimited by the radio horizon (same as VOR); operational altitude—same as VOR; accuracy—range accuracy is ±0.5 NM, or three percent of the slant range, whichever is greater; bearing accuracy is same as VOR.

DME: Operational range—Limited by the radio horizon. DME is limited in the same manner as VOR and TACAN. Operational altitude—limited by the radio horizon. Accuracy—distance measurement specified for DME is ± 0.5 NM (95 percent probability), or three percent of the slant range, whichever is greater.

NDB/ADF: Operational range—Limited, depending on power output of nondirectional beacon and atmospheric conditions. Operational altitude—unlimited, subject to atmospheric conditions. Accuracy—yields azimuth only; no range information. Azimuth accuracy can vary greatly down to unusable, depending on atmospheric conditions.

Mapping Weather Radar: Operational range—Limited for navigation purposes in the order of 15 NM. Operational altitude—under 5,000 feet for navigation purposes. Accuracy—in the order of 0.1 NM, when used with an appropriate ground transponder installed at particular locations for navigation purposes.

SYSTEM REQUIREMENTS

The ideal navigation and positioning concept would be one which would have all of the following capabilities in an integrated system:

1. Highly accurate airborne area navigation (RNAV) accuracy so that airway/route widths could be no greater than 0.5 NM.
2. Sufficiently accurate approach and landing guidance by the airborne RNAV system so that "precision" instrument approaches (i.e. equivalent to CAT I and preferably CAT II) could be made to any pilot-selected point on the surface without the need to have an electronic landing aid at that location.
3. Ability to function without line-of-sight (radio horizon) limitations.
4. Vertical velocity measurement accuracy in the order of 0.1 feet/second; horizontal velocity measurement in the order of 0.1 knot.

5. Three-dimensional (lateral, longitudinal, vertical) 3–D navigational guidance sufficiently accurate to eliminate the need to rely on any form of barometric or radio altimetry.

6. Four-dimensional (4–D) guidance adding time referenced navigational capability to 3–D guidance with time stability accuracy in the order of 10^{13}.

7. Imperviousness to atmospheric conditions for noninterrupted operations.

8. Non-saturable capacity.

9. Service availability to all classes of airspace users on a worldwide basis.

10. Be cost-effective based on life cycle cost analyses, with system design such that it can have various levels of sophistication and thus will be affordable to all classes of airspace users.

BENEFITS

Assuming the successful implementation of a navigation and positioning system meeting the requirements outlined above, numerous benefits can be visualized along the following broad lines:

More efficient use of the airspace.

More efficient use of CTOL and STOL airports.

Greater flexibility in the availability of landing/takeoff areas for helicopters/VTOL's.

Increased safety.

Increased efficiency in the air traffic control system.

Savings to the government (i.e. to the Federal Aviation Administration in the context of this statement) as a result of decommissioning facilities now in use (e.g. VOR/DME) and eliminating or reducing the need for new facilities being planned (e.g. MLS).

Savings to the airspace users as a result of eliminating the need for certain airborne avionics equipment (e.g. VOR/DME; ADF).

COST/BENEFITS ANALYSIS

Four broad assumptions are made in the light of the foregoing dissertation:

1. That the desired navigation and positioning requirements can be met most effectively by a satellite based system.

2. That the satellite based system most likely to achieve these requirements in a realistic time frame is the DOD NAVSTAR Global Positioning System.

3. That the DOD under any circumstances would not deny use of nor degrade accuracy of the GPS for civil aviation.

4. That charges would not be levied against civil aviation for use of the GPS.

Thus, in order to determine the degree to which such a system would be used from the standpoint of civil aviation, a cost/benefits analysis would appear to be needed as the first step. As a prior condition for such an analysis, however, a life cycle costing (LCC) analysis of the GPS would be essential. The civil aviation LCC analysis would use as a base line the DODLCC for military use.

Once this phase has been completed, an analytical study should be initiated covering relevant aspects of civil aviation use of GPS including:

1. Development of GPS implementation and integration program plans.

2. Technical and operational system analysis.

3. Economic Benefit and Payoff analysis.

4. Specification of minimum acceptable GPS airborne equipment characteristics.

5. Generation of a low cost GPS hardware specification.

6. Development of detailed ground system phase out plan acceptable to government and industry.

7. Test plan development.

8. Performance of test plan.

9. Analysis of test results.

10. Test evaluation and conclusions.

ATTACHMENT "C"

HELICOPTER ASSOCIATION OF AMERICA,
Washington, D.C., May 18, 1976.

Hon. JOHN L. MCLUCAS,
Administrator, Federal Aviation Administration,
Washington, D.C.

DEAR DR. MCLUCAS: We have been informed that the FAA's Office of Systems Engineering Management is conducting an in-house cost/benefit analysis of the so-called Standard Microwave Landing System (SMLS). In conducting this analysis, we understand that the FAA is contacting potential user organizations as to their views on this question. This letter responds, therefore, to informal contacts we have had on this matter recently with several OSEM personnel.

First of all, I should like to mention that we have gone on record with RTCA Special Committee 125 "MLS Implementation" with respect to our views on desired MLS performance characteristics for helicopters (VTOL's). (See RTCA Paper No. 46–76/SC 125–48, Attachment 10.). This paper, however, deals only with broad technical points and does not address itself to whether or not the helicopter industry feels that the SMLS is cost beneficial.

With respect to this question, I should like to express the following relevant considerations:

1. Looking ahead ten (10) years or so (time frame for possible SMLS implementation), we visualize well over 5,000 helicopter/VTOL's in this country which will have instrument flying (IFR) capability.

2. To attain the maximum benefits to our national air transportation systems which these vehicles can provide, instrument approach capability is needed to serve hundreds of designated heliports (VTOLports), or "helipads", in business/executive operations, city-center service, intra-urban commuter service, on conventional fixed wing airports, in remote areas and on off-shore platforms. In addition, for emergency and other purposes, instrument approach capability for helicopters/VTOL's will ultimately be needed at virtually an infinite number of locations on the surface.

3. Thus, in principle, we do not feel that instrument approach capability for helicopters/VTOL's should require that an electronic aid must be anchored at each location where an instrument approach is to be made.

4. In support of the above concept, the HAA representative on the TERPS Advisory Committee (Mr. Glen A. Gilbert) has introduced a broadened definition of "precision approach procedure" to delete the present concept that such a procedure requires electronic guidance from the surface, which currently can be met only by ILS (at about 350 ILS equipped airports today) or PAR (hardly any for civil operations). Instead, we have urged that the definition be changed to permit precision approach procedures to be based on any combination of airborne, ground or satellite based systems which give equivalent (or better) azimuth and elevation guidance for approach and landing.

5. As a consequence of the above rationale, the HAA is extremely interested in the potential of the DOD NAVSTAR GPS program, and we are participating in meetings now underway to explore potential civil use of this system. It is interesting to note that the time frames proposed for SMLS implementation and that planned for GPS almost exactly coincide. In fact, if GPS implementation proceeds as now programmed, it would probably be ahead of any significantly achievable SMLS implementation.

6. Further, with respect to Point 4. above, we are looking very seriously at the potential for using airborne weather/mapping radar as a precision approach aid. Two of our member operators (Petroleum Helicopters, Inc. and Air Logistics) are evaluating two different systems now in off-the-shelf production. On June 30th and July 1st, the HAA IFR Committee will be conducting a two-day seminar to look at this and many other aspects of IFR helicopter operations (invitations to the FAA to participate will be forthcoming shortly).

7. By the foregoing, we do not wish to imply that a precision ground electronic approach aid may not be useful, or, in fact, essential for helicopter/VTOL instrument approaches in some instances. However, because of ability to readily reduce speed during an approach, we can accomplish a precision approach procedure with far less sophisticated ground equipment than a high-performance fixed wing aircraft. For example, we can use a standard Category I ILS to Category II minimums (100 ft. DH and 1200 ft. RVR). However, neither the ILS nor the SMLS configured for conventional fixed wing aircraft meet our requirements (again, refer to RTCA Position Paper mentioned earlier.).

8. In this respect, we feel that some of the "interim" MLS systems might economically meet our requirements for precision approach capability on a near term and on a selected basis. We have looked at the so-called "Interim Standard MLS (ISMLS)," and are aware of your statement of April 6, 1976, "Agency-wide Policy Relating to the Microwave Landing System Program." After the seminar referred to in Item 6. above, we may send you a proposal for some sort of ISMLS (or other "interim" MLS) implementation program for some of our IFR helicopter projects.

In the light of the foregoing considerations, I will conclude this letter by addressing more specifically the question "Is SMLS going to be cost beneficial?"

At this point, we have not seen any Life Cycle Costing (LCC) analysis of the SMLS, which seems to us to be a requisite before a Cost/Benefit Analysis can be made. Further, a Cost/Benefit Analysis of the SMLS needs to be made against certain logical candidate substitutes. Obviously, the ILS is the first indicated candidate. But, there are others: such as NAVSTAR GPS, self-contained airborne systems (e.g. radar), combination systems (e.g. INS with differential Omega update), and of course one or more versions of "interim" MLS. These are but a few candidate instrument approach concepts that come to mind which must be considered in making any meaningful cost benefit analysis of the SMLS.

In view of the foregoing brief outline of our views, the HAA cannot at this time, without further substantiating life cycle costing and cost benefit data, lend its unequivocal support of the FAA's SMLS program.

With kind regards.

Yours sincerely,

ROBERT A. RICHARDSON,
Executive Director.

PETROLEUM HELICOPTERS INC.,
Lafayette, La., May 25, 1976.

MR. ROBERT RICHARDSON,
Executive Director, Helicopter Association of America,
Washington, D.C.

DEAR BOB: My compliments on your letter dated May 18, 1976 to Dr. McLucas concerning the HAA's position on microwave landing systems.

I feel that you have correctly summarized the importance of keeping the IFR helicopter independent of additional ground navigation aids that would restrict the number of landing areas.

It is important that we continue to develop methods to provide the flexibility of making an instrument approach to unprepared locations. It is also most important to get the FAA thinking that way to realize the real potential of the IFR helicopter.

Very truly yours,

STANLEY R. CLAY,
Vice President, Chief Pilot.

[Whereupon, the subcommittee was adjourned at 12:50 p.m.]

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