COLLISION AVOIDANCE AND PILOT WARNING INDICATOR SYSTEMS

HEARINGS

BEFORE THE

SUBCOMMITTEE ON AVIATION

OF THE

COMMITTEE ON COMMERCE

UNITED STATES SENATE

NINETY-SECOND CONGRESS

SECOND SESSION

ON

S. 2264

TO AMEND SECTION 601 OF THE FEDERAL AVIATION ACT OF 1958 TO REQUIRE THE INSTALLATION OF COLLISION AVOIDANCE AND PILOT WARNING INDICATOR SYSTEMS ON CERTAIN AIRCRAFT, AND FOR OTHER PURPOSES

DECEMBER 1, 1971, AND FEBRUARY 29, 1972

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COLLISION AVOIDANCE AND PILOT WARNING INDICATOR SYSTEMS

WEDNESDAY, DECEMBER 1, 1971

U.S. Senate,
Committee on Commerce,
Subcommittee on Aviation,
Washington, D.C.

The subcommittee met at 10 a.m. in room 5110, New Senate Office Building, Hon. Howard W. Cannon (chairman of the subcommittee) presiding.

Present: Senators Cannon, Moss, Pearson, Baker, and Stevens.

OPENING STATEMENT BY SENATOR CANNON

Senator Cannon. The hearings will come to order.

Today's hearing begins a subcommittee inquiry into the subject of midair collision avoidance, and a study of Government and industry efforts to reduce the risk of such occurrences in the future.

More particularly, we are interested in hearing testimony on legislation introduced by the distinguished Senator from Utah, S. 2264, which would require the development and universal installation of a collision avoidance system within the next 5 years.

In recent months the subcommittee has become concerned with what appears to be an increasing danger to the flying public from midair collisions. Just this summer more than 55 persons lost their lives in a collision between a commercial airliner and a Marine Corps fighter plane near Los Angeles, Calif.

In the past several months there have been two other instances in which airliners and small planes collided, in both cases narrowly averting major catastrophes.

With the great increase in aviation activity of all kinds, military, commercial, and private, comes the increasing risk that our air traffic control will not be prepared to adequately separate the expanding aviation fleet.

The committee is interested in hearing from Government and industry about developments, both in the field of air traffic control and in avionics, which may promise a greater degree of separation and safety in the future.

We are particulary anxious to ascertain whether the Government itself is moving forward with sufficient speed and urgency to attempt to find better methods and systems for separating aircraft.

Staff member assigned to these hearings: Robert E. Ginther.

(The bill and agency comments follow:)

92D CONGRESS
1ST SESSION

S. 2264

IN THE SENATE OF THE UNITED STATES

JULY 12, 1971

Mr. Moss introduced the following bill; which was read twice and referred to the Committee on Commerce

A BILL

To amend section 601 of the Federal Aviation Act of 1958 to require the installation of collision avoidance and pilot warning indicator systems on certain aircraft, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That section 601 of the Federal Aviation Act of 1958 (49 U.S.C. 1421) is amended by adding at the end thereof the following new subsection:

"COLLISION AVOIDANCE AND PILOT WARNING INDICATOR SYSTEMS

"(e) Not later than January 1, 1973, minimum standards pursuant to this section shall include requirements that—

"(1) a collision avoidance system shall be installed on any aircraft having a maximum certificated takeoff weight of 12,500 pounds or more; and

"(2) a pilot warning indicator system shall be installed on any aircraft having a maximum certificated takeoff weight of less than 12,500 pounds."

SEC. 2. The Administrator of the Federal Aviation Agency is authorized and directed to require, not later than January 1, 1975, that a collision avoidance system or pilot warning indicator system shall be installed on public aircraft as defined in section 101 (30) of the Federal Aviation Act of 1958.

DEPARTMENT OF THE AIR FORCE,
Washington, January 25, 1972.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce, U.S. Senate

DEAR MR. CHAIRMAN: Reference is made to your request for the views of the Department of Defense with respect to S. 2264, 92d Congress, a bill "To amend section 601 of the Federal Aviation Act of 1958 to require the installation of collision avoidance and pilot warning indicator systems on certain aircraft and for other purposes." The Department of the Air Force has been assigned the responsibility for expressing the views of the Department of Defense.

The purpose of this bill is to reduce midair collision hazards. The bill is applicable to both civil and public aircraft. The bill would amend the Act to provide that, not later than January 1, 1973, the minimum standards established for civil aircraft pursuant to 49 U.S.C. §1421 (a) include requirements for collision avoidance systems and pilot warning indicators.

The more sophisticated and costly collision avoidance system requirement would be mandatory for aircraft having a maximum certificated takeoff weight of 12,500 pounds or more. The more limited and less costly pilot warning indicator system would be mandatory for aircraft having a maximum certificated weight of less than 12,500 pounds.

Section 2 of the bill directs the Administrator of the Federal Aviation Administration to require the installation of a collision avoidance system or a pilot warning indicator system by January 1, 1975 on public aircraft. This would include all U.S. military aircraft, a number in excess of 20,000 such aircraft.

There are a number of technical problem areas that require resolution prior to acheving a capability to comply with S. 2264. The state-of-art of technology is only now beginning to produce collision avoidance systems that satisfy some of the requirements that have been defined. Total solutions have not been achieved. The collision avoidance systems that have been developed have received limited flight testing and have depended on computer simulations for a great part of the test data that has been accumulated. The Deputy Administrator, Federal Aviation Administration, Department of Transportation, stated before the Subcommittee on Government Activities of the House Committee on Government Operations on August 3, 1971, that: "We can report good progress toward a CAS for voluntary airline use. We have as yet however, far too little experience and too many unanswered questions to be able to predict if or when such a system should become a requirement."

In the case of collision avoidance systems, there are several techniques presently being advocated, such as the time frequency and airborne interrogator/transponders. These techniques are not compatible. A decision will eventually have to be made at the national level as to which of the several techniques should be adopted as the standard. It is essential that all facets of aviation employ compatible equipment, since the collision hazard exists between all aircraft.

The same problem of compatibility exists in the relationship between collision avoidance systems and pilot warning indicator systems. In this latter area, certain development efforts are currently being directed toward infrared detection systems using optical type sensors. There needs, however, to be additional technical and operational evaluation of those possible systems and of the interoperation between CAS and PWI in order to provide protection between aircraft equipped with the separate systems.

During the course of testimony before the House Government Activities Subcommittee of the Committee on Government Operations on August 3, 1971, representatives from various manufacturers of the competing collision avoidance systems were questioned on the availability of equipments in the event implementation was made mandatory. The earliest estimate given was 16 months from the time of decision between the competing systems. With respect to installation of the system in airline aircraft, the earliest estimate was July 1973. Both estimates are optimistic and assume immediate decisions. In view of the uncertainties outlined in the preceding paragraphs, such a decision is not expected in the immediate future. The mandatory date indicated in S. 2264 is not attainable.

There are in excess of 130,000 general aviation aircraft and implementation of a new generation of avionics in these aircraft by 1975 does not appear attainable. If any collision avoidance system is to be effective, it must be installed in the majority of civil airline, general aviation, and military aircraft.

The budgetary impact of the criteria in S. 2264 is critical to DOD. As an example, the majority of DOD aircraft would require installation of a collision avoidance system. Assuming an average equipment cost of $25,000 per system, DOD would spend $500,000,000 for procurement of systems. On the basis of past experience, installation costs would double the procurement costs resulting in a total DOD program of approximately $1 billion. A program as costly as this should not be undertaken before there is full assurance that the available technology will do all that is claimed of it and that there is no other way of performing the same objectives at much less cost.

The Department of Defense supports the objectives of S. 2264 to promote collision avoidance. However, we do not support S. 2264, since it would not be feasible to select a system, to complete development, and to comply with the provisions of the bill in the time frame specified.

This report has been coordinated within the Department of Defense in accordance with procedures prescribed by the Secretary of Defense.

The Office of Management and Budget advises that, from the standpoint of the Administration's program, there is no objection to the presentation of this report for the consideration of the committee.

Sincerely,

PHILIP N. WHITTAKER,
Assistant Secretary of the Air Force
(Installations and Logistics).

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
Washington, D.C., March 8, 1972.

Hon. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate,
Washington, D.C.

DEAR MR. CHAIRMAN: This is in further reply to your request for the comments of the National Aeronautics and Space Administration on the bill S. 2264, "To amend section 601 of the Federal Aviation Act of 1958 to require the installation of collision avoidance and pilot warning indicator systems on certain aircraft, and for other purposes."

S. 2264 would amend 49 U.S.C. 1421, which is entitled "Safety Regulations of Civil Aeronautics," by adding a new subsection (e) at the end thereof. It would require civil aircraft to be equipped with collision avoidance and pilot warning systems by January 1, 1973. The Administrator of the FAA would be authorized and directed to require that all public aircraft be equipped with the above systems by January 1, 1975.

It is noted that the proposed amendment should be designated as subsection (d) rather than (e).

While it is the apparent intent of section (1) of the bill to regulate only "civil aircraft," this intent should be expressly stated. Further, it is not clear whether "civil aircraft of the United States" as defined by 49 U.S.C. 1301 (15) would be covered under section (1). This may be significant since NASA aircraft are treated as "civil aircraft of the United States" as well as "public aircraft."

The inclusion of "civil aircraft of the United States" in the bill's coverage would raise the question of whether NASA aircraft were subject to the January 1, 1973 deadline for civil aircraft or January 1, 1975 deadline for public aircraft.

It should be noted that the proposed NASA space shuttle and all launch vehicles now in use are purely experimental in nature with flight paths and schedules that make collision with other vehicles unlikely. In any event, as a general matter, such vehicles would not fall within the definition of the term "aircraft" contained in 49 U.S.C. 1301(5). Thus, if S. 2264 is enacted, we would interpret it as having no application to such vehicles, even during the limited period during which some of them may navigate or fly in air.

As to the major policy considerations relating to whether S. 2264 should be enacted, the National Aeronautics and Space Administration defers to the Department of Transportation.

As a matter of interest, it is noted that NASA has for several years been involved in research and development on collision avoidance and pilot warning equipment. An optical technique for providing pilot warning was developed at the Electronics Research Center (ERC), and was later tested there under NASA sponsorship after ERC was transferred to the Department of Transportation. Although the report on this technique will not be available until March 1972, preliminary information indicates that warning ranges averaging 1.8 miles were achieved.

NASA has also developed and tested microwave pilot warning equipment at Langley Research Center. While the equipment worked satisfactorily, the estimated cost of providing it appeared to be too great for use by general aviation. It has since been redesigned and additional flight tests will be run in 1972.

Langley Research Center (LRC) has recently contracted for a study of the cost of several versions of the Air Transport Association's Collision Avoidance Equipment with a view to reducing its cost. LRC has also conducted tests to determine the ability of a pilot to visually detect the presence of another aircraft when he is given various cues as to its position.

The Office of Management and Budget has advised that, from the standpoint of the Administration's program, there is no objection to the submission of this report to the Congress.

Sincerely,

H. DALE GRUBB,
Assistant Administrator for Legislative Affairs.

Senator CANNON. Our witnesses will include the Department of Transportation, the National Transportation Safety Board, and the Department of Defense, in addition to a number of witnesses from the private sector.

Today's hearing will be limited to private witnesses. It will be followed by a hearing next week, at which time we will hear from the Government.

Our first witness this morning is the Honorable Frank E. Moss, Senator from Utah, the author of the bill under consideration.

Senator Moss, we are happy to have you testify.

STATEMENT OF HON. FRANK E. MOSS, U.S. SENATOR FROM UTAH

Senator MOSS. Thank you, Mr. Chairman. I appreciate the opportunity to appear, and also I appreciate your setting this hearing at a time when the pressures on the Senate floor are so great. It indicates the urgency of the problem and I believe that these hearings and the record will go far to determine what can be done with this very difficult problem.

Hopefully, the testimony today and those which will be delivered next week will provide an accurate development status report on aircraft collision avoidance systems, the merits of the bill before us, and any other legislation that may be suitable. Of course, I recognize, and we all do, that no bill is inviolate when it is introduced. It is a basis for the discussion, and out of it may come some variation of the original text. But the problem to which we address ourselves here is one that cries for solution.

It is of the utmost urgency that Government and the aviation industry undertake additional positive action to protect the lives of air travelers against the dangers of air collisions. Speaking at the March 26, 1971, Midwestern Aviation Conference, Federal Aviation Administrator John Shaffer noted the increasing congestion of our national air space by predicting that in the next 10 years there will be a "growth in the number of airline aircraft from 2,580 to 3,640" and an "expansion in the general aviation fleet from 134,000 to 232,000." The primary method adopted by the FAA of separating this increasing air traffic and avoiding in-flight collisions is the air traffic control system.

As far back as June 1958, President Eisenhower submitted a message to Congress recommending utmost priority be given to preventing midair collisions. He stated:

> Recent midair collisions of aircraft, occasioning the tragic loss of human life, have instituted the need for a system of air traffic management which will prevent them, within the limits of human ingenuity.

Nevertheless, between 1958 and 1970 there occurred three midair collisions between air carriers, 14 between air carriers and general aviation planes, four between air carriers and military airplanes, and 35 between general aviation and military aircraft. The total fatalities in reported midair collisions through 1970 numbered 966. Moreover, in a National Transportation Safety Board study released in March 1971, it is projected that assuming air collisions and fatality rates will continue at past levels, we will witness 335 collisions resulting in 792 deaths in the decade from 1968 to 1978.

The tragic collision of June near Los Angeles between an Air West jetliner and a Marine F–4 Phantom Jet provides a sorrowful example of a midair collision that should outrage the consciences of all Americans as 49 lives were needlessly lost.

In conjunction with this tragic air collision, I am aghast that the National Transportation Safety Board's recommendation issued November 9, 1971, urging the FAA to take the following action:

> Coordinate with the Department of Defense, and, in areas where a large intermix of civil and military traffic exists, develop a program to insure that appropriate graphical depictions of airspace utilization and typical flow patterns are prominently displayed at all airports and operational bases for the benefit of all airspace users.

There is no recommendation here requiring installation of a collision avoidance system that could have prevented the collision; rather, the FAA is urged merely to set up a precautionary program of flow pattern displays.

The installation of pilot warning instruments for all aircraft represents a deficiency in Federal efforts to improve air safety. How many lives must be lost before systems are mandatorily required to serve as backup protection for air traffic control?

S. 2264 proposes to correct this deficiency by requiring the mandatory installation of a collision avoidance system on all aircraft over 12,500 pounds or a pilot warning instrument on all aircraft under this weight limitation by 1975. A collision avoidance system under the bill is an all-weather system which can detect all aircraft which represent a potential collision threat to the CAS-equipped aircraft, automatically evaluate the degree of threat, and, if necessary, indicate to the pilot a safe evasion maneuver.

A major purpose of this hearing today is to determine their present availability and to inquire into the development status of these systems. Collision avoidance represents a deceptive and complicated technical field in which there are no easy solutions. Numerous companies have devoted considerable time and money since 1958 in an effort to advance and flight test their air separation concepts. Of course, much money has been spent in this area.

Some people have objected to the requirements of S. 2264, on the basis of cost and the limited time required for implementation. A collision avoidance system or a pilot warning must be sufficiently low in cost so as not to impose an unreasonable economic burden on air carriers and other aircraft owners and operators. I am most anxious that the cost element be examined closely today. The expense of a collision avoidance system, however, can be easily justified when compared to the human and dollar costs of a midair collision.

In March of this year, the *Washington Star* reports on a recent collision indicating that negotiations were taking place "for damage claims of some $70 million. Moreover, a December 16, 1960, collision involving two airliners produced payments of more than $29 million." Based on qualified estimates, a midair collision between two jumbo jets would cost the airlines between $180–$190 million, which is also the approximate cost of equipping the entire air carrier fleet with collision avoidance systems.

The underlying premise of my bill is that because the FAA has the regulatory function regarding air safety, it should undertake, therefore, to evaluate closely and set standards for a national system of collision avoidance. To minimize the danger of air collisions, it is essential that all common air space users be encompassed in one national cooperative system. This requires the establishment of national standards and requires the FAA to evaluate competing systems to determine if they qualify.

To date, the FAA has demonstrated a remarkable ability to avoid positive action in the face of continued strong demands from the public and aviation industry for accelerated efforts to solve the midair collision problem. In the past 13 years, despite the pressing nature of the problem, the FAA has funded collision avoidance and pilot warning efforts only $4.4 million. In-house and contracted research and development has been remarkably small in comparison to the total FAA R. & D. effort.

In a statement presented to the House Government Activities Subcommittee, on August 6, 1971, with regard to the FAA's "moderate interest" in developing collision avoidance systems, the Aircraft Owners and Pilots Association, representing over 160,000 general aviation members, stated—and I quote:

> . . . we can only surmise that the FAA fears development of CAS/PWI in anticipation of the possibility that such a development might make some aspects of the ground based control system unnecessary. It is significant to note that the FAA, the ATA, and the manufacturers of time/frequency equipment all have asserted and emphasized that CAS/PWI must only be considered as a backup or supplement to the existing and future groundbased control system sustained by the FAA for the separation of air traffic.
>
> The doubts and questions raised by the FAA regarding operational problems appear insubstantial and inconsequential to us. The greatest potential impact on the Air Traffic Control system is that CAS/PWI would make it safer for all.

I strongly urge, therefore, that the FAA immediately clarify its acceptance of a national CAS/PWI system and publish guidance documents for the manufacturer and user industries. If there are questions which remain unanswered before standards can be set and a collision avoidance system endorsed, I urge the FAA to bring out these questions in their testimony before this subcommittee.

In the House hearings of August 3, with regard to aircraft collision avoidance systems, Kenneth Smith, Deputy Administrator of the FAA, stated as follows:

> By the end of calendar year 1971, we believe we will have the answer to enough questions to be able to recommend change to the CAS or to the air traffic control system—or to both—which will allow safe utilization of an airborne collision avoidance system in conjunction with ATC.

This is the end of the calendar year 1971. Is it now possible for the FAA to make these recommendations?

In House hearings, the FAA also promised to proceed with the procurement of the first ground stations, a study of ground station location, and support for development of a low-cost system. The ground station proposal request was to be issued within 60 days. What is the current status of these efforts? The FAA has the duty and responsibility to move forward now with resolve and determination to evaluate and set standards for collision avoidance.

I apologize for the rather lengthy introductory statement. Even though I skip read I ask permission that the entire statement go in.

Senator CANNON. Your entire statement will be made a part of the record.

(The statement follows:)

STATEMENT OF HON. FRANK E. MOSS, U.S. SENATOR FROM UTAH

Mr. Chairman, As a member of the Senate Aviation Subcommittee and author of Senate bill 2264, I appreciate the opportunity of appearing this morning to discuss the pressing problem of keeping airplanes apart in our increasingly crowded skies.

This committee is to be commended for its outstanding and diligent efforts to promote air safety and especially for convening hearings to explore ways of minimizing the dangers of air collisions. Hopefully, the testimony to be delivered today and on December 10 will provide an accurate status report on aircraft collision avoidance system development as well as a detailed examination of the merits of my bill amending Section 601 of the Federal Aviation Act of 1958 to require the installation of collision avoidance systems and pilot warning instruments on all aircraft.

It is of the utmost urgency that government and the aviation industry undertake additional positive action to protect the lives of air travelers against the dangers of air collisions. Speaking at the March 26, 1971, Midwestern Aviation Conference, Federal Aviation Administrator, John Shaffer, noted the increasing congestion of our national air space by predicting that in the next 10 years there will be a "growth in the number of airline aircraft from 2,580 to 3,640" and an "expansion in the general aviation fleet from 134,000 to 232,000." The primary method adopted by the FAA of separating this increasing air traffic and avoiding in-flight collisions is the air traffic control system.

Air travelers and the aviation industry have long recognized the need for a collision avoidance system to supplement the capability of the nation's already over burdened air traffic control system in assuring aircraft separation. A primary reason for this recognition is the alarming fact that approximately 80 percent of all aircraft flying in this country is of the small general aviation category, flying under visual flight rules, outside the control of radar and air controllers on the ground.

In June 1958, President Eisenhower submitted a message to Congress recommending utmost priority be given to preventing mid-air collisions. He stated:

"Recent mid-air collisions of aircraft, occasioning the tragic loss of human life, have instituted the need for a system of air traffic management which will prevent them, within the limits of human ingenuity."

Nevertheless, between 1958 and 1970 there occurred three mid-air collisions between air carriers, 14 between air carriers and general aviation planes, 4 between air carriers and military airplanes and 35 between general aviation and military aircraft. The total fatalities in reported mid-air collisions through 1970 numbered 966. Moreover, in a National Transportation Safety Board study released in March 1971, it is projected that assuming air collisions and fatality rates will continue at past levels, we will witness 335 collisions resulting in 792 deaths in the decade from 1968 to 1978.

In 1971, there have been numerous mid-air collisions involving air carriers including collisions between a B–707 and a Cessna 150, a military F–4 and a DC–9, and a B–707 and Cessna 150, in the United States; a B–727 and a DC–8 in Australia; and a B–727 and a military F–86 in Japan. The loss of life has been horrendous.

The tragic collision June 6 near Los Angeles between an Air West jetliner and a Marine F–4 Phantom Jet provides a sorrowful example of a mid-air collision that should outrage the consciences of all Americans. 49 lives were needlessly lost. Thirteen of these were residents of the State of Utah—among them some of most promising young business and professional men. The sorrow and loss felt by their families and friends throughout the State cannot be calculated.

Just recently I received a letter from Mrs. Wallace Pyke of Salt Lake City, stating, "I want to express my appreciation to you for introducing the bill calling for special avoidance systems to safeguard against mid air collisions. My husband, Wally, his two cousins, and six more of his good friends, were killed last June in the mid-air collision between Air West and the Phantom Jet. If measures such as you propose had been in effect, these fine men would be with their families today."

In conjunction with this tragic air collision, I am aghast at the National Transportation Safety Board recommendation issued November 9, 1971, urging the FAA to take the following action:

"Coordinate with the Department of Defense, and, in areas where a large intermix of civil and military traffic exists, develop a program to insure that appropriate graphical depictions of airspace utilization and typical flow patterns are prominently displayed at all airports and operational bases for the benefit of all airspace users."

There is no recommendation here requiring installation of a collection avoidance system that could have prevented the collision, rather the FAA is urged merely to set up a precautionary program of flow pattern displays.

The glaring absence of regulations requiring an effective collision avoidance system or pilot warning instrument for all aircraft represents a major deficiency in Federal efforts to improve air safety. How many lives must be lost before systems are mandatorily required to serve as back-up protection for air traffic control.

S. 2264 proposes to correct this deficiency by requiring the mandatory installation of a collision avoidance system on all aircraft over 12,500 pounds or a pilot warning instrument on all aircraft under this weight limitation by 1975. A collision avoidance system under the bill is an all-weather system which can detect all aircraft which represent a potential collison threat to the CAS-equipped aircraft, automatically evaluate the degree of threat, and, if necessary, indicate to the pilot a safe evasion maneuver.

A pilot warning instrument under the bill is a device intended to be utilized to assist the pilot in visually detecting other aircraft that may offer a potential threat of collision. After visual sighting, the pilot utilizing PWI must evaluate the situation and intitate any necessary evasive action.

A major purpose of this hearing today is to determine their present availability and to inquire into the development status of these systems. Collision avoidance represents a deceptive and complicated technical field in which there are no easy solutions. Numerous companies have devoted considerable time and money since 1958 in an effort to advance and flight-test their air separation concepts. Many have failed.

At the present time, the front-runner CAS is based upon a time-frequency concept, jointly fostered by the Air Transport Association, Bendix, McDonnell Douglas, and the team of Sierra Research—Wilcox Electric. These firms have collectively invested some $10 million in 16 years of developing and successfully flight-testing anti-collision hardware. The system has been recently installed on a United Airlines 727 commuter aircraft which began regular flights between Los Angeles and San Francisco on November 23. In addition, the system has been ordered by Piedmont Airlines and exists in flight hardware form for general aviation.

Among the other CAS alternatives about which we shall learn more today are some based on variations of the interrogator response technology. The Secant system developed by RCA, for example, proposes to measure relative bearing to other aircraft by direction finding techniques to enable the system to employ a horizontal escape maneuver.

Some have objected to the requirements of S. 2264, on the basis of cost and the limited time required for implementation. A CAS or PWI must be sufficiently low in cost so as not to impose an unreasonable economic burden on air carriers and other aircraft owners and operators. I am most anxious that the cost element be examined closely today. The expense of a collision avoidance system, however, can be easily justified when compared to the human and dollar costs of a mid-air collision.

The March 3, 1971 *Washington Star* reports on a recent collision indicating that negotiations were taking place "for damage claims of some $70,000,000. Moreover, a December 16, 1960 collision involving two airliners produced payments of more than $29 million." Based on qualified estimates, a mid-air collision between two jumbo jets would cost the airlines between $180–$190 million, which is also the approximate cost of equipping the entire air carrier fleet with collision avoidance systems.

With regard to the time required by the bill for installation, I too, realize the 1975 date may prove unrealistic. But there is great urgency in getting a collision avoidance system into the airlines and as soon thereafter as possible into general aviation aircraft. To delay in the hope of no collisions is unconscionable. We must begin implementation by proceeding promptly with the technology now available.

These hearings also are intended to examine what remains to be done in order to achieve prompt CAS/PWI installations and widespread use throughout the aviation field. They are not held, however, to render a judgment from among competing systems.

The underlying premise of my bill is that because the FAA has the regulatory function regarding air safety, it should undertake, therefore, to evaluate closely and set standards for a national system of collision avoidance. To minimize the danger of air collisions, it is essential that all common air space users be encompassed in one national cooperative system. This requires the establishment of national standards and requires the FAA to evaluate competing systems to determine if they qualify.

To date, the FAA has demonstrated a remarkable ability to avoid positive action in the face of continued strong demands from the public and aviation industry for accelerated efforts to solve the mid-air collision problem. In the past 13 years, despite the pressing nature of the problem, the FAA has funded CAS/PWI efforts only $4.4 million. Inhouse and contracted research and development has been remarkably small in comparison to the total FAA R and D effort.

In a statement presented to the House Government Activities Subcommittee, on August 6, 1971, with regard to the FAA's "moderate interest" in developing collision avoidance systems, the Aircraft Owners and Pilots Association, representing over 160,000 general aviation members, stated:

". . . we can only surmise that the FAA fears development of CAS/PWI in anticipation of the possibility that such a development might make some aspects of the ground based control system unnecessary. It is significant to note that the FAA, the ATA, and the manufacturers of time/frequency equipment all have asserted and emphasized that CAS/PWI must only be considered as a backup or suplement to the existing and future ground-based control system sustained by the FAA for the separation of air traffic.

"The doubts and questions raised by the FAA regarding operational problems appear insubstantial and inconsequential to us. The greater potential impact on the Air Traffic Control system is that CAS/PWI would make it safer for all."

I strongly urge, therefore, that the FAA immediately clarify its acceptance of a national CAS/PWI system and publish guidance documents for the manufacturer and user industries. If there are questions which remain unanswered before standards can be set and a collision avoidance system endorsed, I urge the FAA to bring out these questions in their testimony before this Subcommittee.

In the House hearings of August 3, with regard to aircraft collision avoidance systems, Kenneth Smith, Deputy Administrator of the FAA, stated as follows:

"By the end of calendar year 1971, we believe we will have the answer to enough questions to be able to recommend change to the CAS or to the air traffic control system—or to both—which will allow safe utilization of an airborne collision avoidance system in conjunction with ATC."

This is the end of the calendar year. Is it now possible for the FAA to make these recommendations.

In the same House hearings, the FAA also promised to proceed with the procurement of the first ground stations, a study of ground station location, and support for development of a low cost system. The ground station proposal request was to be issued within sixty days. What is the current status of these efforts? The FAA has the duty and responsibility to move forward now with resolve and determination to evaluate and set standards for collision avoidance.

Mr. Chairman, these hearings have great urgency. We have the ability to act and the means to enforce our laws. It is of utmost importance that we now move to require the aviation industry to take firmer steps to protect the lives of America's air passengers. The favorable consideration of S. 2264 will require all responsible parties to adopt collision avoidance systems to improve air safety.

Senator CANNON. We certainly shall try to get some of the necessary answers from FAA and others as these hearings proceed.

You did quote the AOPA's testimony before the House Government Activities Subcommittee and while I don't always agree with ALPA, I don't always agree with AOPA. I think that statement is unwarranted and I think goes beyond proper interest in trying to solve a very serious problem. I can't believe that any agency of Government would try to take action deliberately to protect its own bureaucracy at the expense of American lives whether in the aviation industry or any other industry. So I am a litle surprised that that statement comes from a reportedly responsible organization such as AOPA.

Any questions, Senator Baker?

Senator BAKER. No, Mr. Chairman.

I arrived late from another meeting. I apologize to the committee and especially to Mr. Moss for having missed part of his statement and I will read it with great care.

Senator CANNON. Senator Eagleton is with us and desires to introduce one of the witnesses who will be before us later today.

STATEMENT OF HON. THOMAS F. EAGLETON, U.S. SENATOR FROM MISSOURI

Senator EAGLETON. Thank you, Mr. Chairman, and I will be as brief as possible.

I appreciate the indulgence of the committee in permitting me to introduce witness No. 6, Anatole Browde, who will appear in regular order, but thank you for introducing me at this time.

May I say how I appreciate the subcommittee interest in these hearings. Just this year's record alone demonstrates all too vividly the serious problem of collisions between aircraft and between aircraft and fixed obstacles. And the seriousness of this risk is magnified by the introduction of wide-body aircraft capable of transporting hundreds—rather than tens—of passengers.

Aircraft collisions have, of course, long been a matter of serious concern to aviation and to the manufacturers of aircraft and equipment.

The witness I will introduce to you will describe McDonnell Douglas' work over the past 10 years on its Eros II time frequency collision avoidance system. That system was placed in operational use in 1966 by McDonnell Douglas and has been extensively tested and refined, with the encouragement and involvement of representatives of the Air Transport Association, the FAA, the DOD, and other Government agencies.

It is a tested, tried, ready-to-go collision avoidance system that offers us the means for coming to grips with the midair collision problem and the problem of collision with ground obstacles.

It also offers an additional bonus: its capacity to supplement and increase the margin of safety in our overtaxed air traffic control system.

Mr. Chairman, I was very interested in hearing the testimony of Senator Moss. I know of his personal interest in increasing safety of air travel, and I commend you for scheduling these hearings. I hope that these hearings will prompt the FAA to make a decision before the year is out identifying the time-frequency collision avoidance system as the national standard for the United States.

Such a decision would both enable the International Civil Aviation Organization to begin the actions that are required to make time-frequency CAS the international standard for collision avoidance protection, and permit Government agencies and domestic aircraft manufacturers and equipment suppliers to focus their efforts toward applying this tested and proved technology.

Again, Mr. Chairman, I appreciate the opportunity to appear before the subcommittee and to introduce you to Mr. Anatole Browde, vice president, communication, navigation, identification systems programs, McDonnell Douglas Electronics Co., McDonnell Douglas Corp., parenthetically S.t Louis, Mo.

Mr. Browde is thoroughly conversant with the time-frequency collision avoidance system concept in general, and the McDonnell Douglas Eros II time-frequency collision avoidance system in particular.

It is a pleasure to introduce Mr. Browde, and I know the committee will give him its full attention.

Senator CANNON. Thank you. We are happy to have your fine recommendations.

I assumed he was from Missouri from the start. I took a wild guess.

Our first witness is Wayne Shear, program manager, collision avoidance systems, Bendix Avionics Division, accompanied by Mr. Young.

Before we start, we are likely to be interrupted by rollcalls all during the day, so I am going to request that insofar as possible the witnesses try to summarize, and to testify in the neighborhood of 10 minutes.

That will not be as firm as the House 3-minute rule, but I hope all will summarize in 10 minutes' time and submit the full testimony for the record. It will be transcribed in full in the record.

So you may now proceed.

STATEMENT OF L. B. YOUNG, VICE PRESIDENT, BENDIX CORP.; ACCOMPANIED BY WAYNE SHEAR, PROGRAM MANAGER

Mr. YOUNG. Thank you, Mr. Chairman. I am Mr. Young and I will try to comply with your request. I would like to summarize some of the basic issues and present our recommendations relative to them.

I will start with the premise that we should provide the greatest protection for the greatest number of people, and then work my way down through the system to the situation of the private pilot in uncontrolled airspace.

As I understand, statistics indicate that of some 12,000 airports, about 550 are served by airlines, and of these, 60 handle better than 85 percent of all passengers.

Outside of these major terminal areas, most of the commercial traffic, as well as high-performance military and business aircraft, operate above 10,000 feet.

Accordingly, for the ultimate safety of the majority, there is no question in our minds that an adequate collision avoidance system could and should be mandatory backup to the primary systems for all aircraft using high-density terminals and airspace above 10,000 feet.

Now, the investment in aircraft using this airspace runs anywhere upward of $50,000 to perhaps many millions of dollars, so we can see

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no significant financial burden in assigning the proper level of CAS equipment to the various types of aircraft sharing that airspace.

Now, what should a collision avoidance system give us? Looking at the problem in a broad sense, I could say that any two aircraft at the same altitude and not flying on parallel paths are theoretically destined to collide sometime.

I think the question is, "When will they collide?" If only seconds remain, an evasive maneuver is obviously necessary, most likely an altitude change. What we are looking for, then, is a collision avoidance system that will give us the critical time-to-impact and altitude information needed to generate an evasive maneuver if and when that becomes necessary.

Next, does such a system exist today? Our opinion is that time-frequency CAS has been proven feasible and should be designated as the common national system.

Specifically, we are recommending that time-frequency CAS in its complete and most sophisticated form should be mandatory for all high-performance military aircraft and airliners.

In its general-aviation form, it should also be mandatory for commuters, charter operators, business jets, and other general-aviation aircraft desiring to share the airspace I have just described.

Further research and system evaluations appear unnecessary and would only postpone the date when we can have this additional measure of safety.

In just a moment, Mr. Shear will summarize the status and capabilities of time-frequency CAS.

I would like to continue to discuss the situation that may exist away from the very high-density terminal areas, and below 10,000 feet. This is where there is much controversy as to whether CAS should be mandatory what flight rules should apply, and the merits of various pilot-warning indicators.

I think we should keep in mind that much of this remaining airspace is also covered by the primary surveillance system, which is being upgraded according to the national aviational system plan.

However, we feel there may be an inherent weakness in that the primary system depends mainly on beacon—or transponder—tracking, and conditions may continue to prevail under which aircraft sharing the same airspace will not have transponders.

Also, even those that will have transponders may lack the capability of automatic altitude reporting. In flying through broken weather, I am frequently advised, "Traffic at 2 o'clock, 3 miles, altitude unknown." Sometimes I see them; sometimes I don't. Sometimes they are at a very different altitude, which is no threat; sometimes they whiz by rather close.

However, we believe this is a situation that could be improved without CAS being mandatory.

The FAA has already proposed that altitude reporting transponders become mandatory for all aircraft in positive-controlled airspace. I suggest if we continue to permit mixed VFR and IFR traffic, which we should do, such transponder equipment should be mandatory for all who share that airspace, particularly that above 1,200 feet (AGL) and in the vicinity of an airport having approved instrument approach.

When the ground system is upgraded, the controller would have a much better capability to advise the IFR pilot of other uncontrolled traffic so he can change course or altitude as necessary.

This may be an adequate measure of safety in most instances. The cost would be modest. The general aviation radio, transponder, and encoding altimeter are comparable in price and well within the means of those who fly today.

However, a problem could exist around an uncontrolled airport with an approved instrument approach but whose traffic pattern is below the coverage of the primary system.

For example, under present rules, local traffic could be approaching or circling the field at, say, 700 feet, just below the cloud cover, at the same time that a pilot cleared for an instrument approach might descend through those clouds right into their midst, neither aware of the other.

I suspect some of you have shared this experience with me, which is rather real and frightening. What could be done?

First, it would help if all fields with approved instrument approaches and/or flight schools had mandatory Unicom radio facilities during normal hours when local traffic is heaviest, and all aircraft were required to have at least some minimal capability for two-way radio communications with such Unicom facilities. This could make it possible and mandatory for all concerned to be constantly aware of the traffic situation.

Second, the flight rules could be revised from a collision avoidance viewpoint to establish standard traffic patterns and cloud clearances within a certain radius of such airports to provide a safer margin for visual avoidance.

We might also ask if CAS or pilot warning indicators could help in the situation I have just described. With respect to general aviation CAS, technically it should work above some minimum altitude out of multipath problems, and providing it is within the synchronizing range of a ground station.

However, since it may not always be feasible to meet these conditions, I would not recommend that CAS be absolutely mandatory.

PWI, like CAS, appears to require a cooperative concept to be effective. Depending on the type of PWI, it usually requires that other aircraft have a compatible light source or radio beacon.

Unless I was sure that all other aircraft would have such compatible equipment, I might hesitate to voluntarily invest in a PWI.

On the other hand, if ATC transponders activated by the primary system were mandatory, then I would be more interested in a PWI which worked cooperatively with them. Such a PWI should also provide the pilot with useful information, such as approximate bearing and altitude of other aircraft.

This type of equipment is within the present state of the art, and I would recommend its development be encouraged for use on a voluntary basis.

In brief, our five recommendations are as follows:

One, accelerate implementation of ARTS III as the primary system with serious consideration being given to making compatible automatic altitude reporting transponders mandatory for all aircraft, as well as two-way radio communications.

Two, to designate and implement time/frequency CAS as the common national backup system with consideration being given to the necessity of its being mandatory in appropriate form only for certain classes of aircraft, and/or only for operations in certain high-density terminal areas and above some prescribed altitude, say, 10,000 feet.

Three, to revise the flight rules from a collision avoidance viewpoint in recognition that there will always be some areas and situations where neither the primary system nor CAS backup can be effective, but much can be done through regulation alone to minimize the collision hazard.

Four, develop voluntary PWI which is compatible with ATC transponders, and provide useful information to the pilot.

Five, place sole responsibility in the FAA for the overall collision avoidance system design, including the selection of techniques, equipment, and appropriate flight regulations on a reasonable but expeditious time schedule.

Thank you, Mr. Chairman.

Mr. Shear will add a few remarks on time/frequency CAS.

Senator CANNON. That is a fine statement.

Do you have any cost estimates as to some of these recommendations you have made?

Mr. YOUNG. The price of radios, transponders, and encoding altimeters are in the area of $500 to $1,000, depending on which brand the individual chooses to select. General aviation PWI might be in the same ballpark. General aviation CAS might cost about $2,500 depending on production volume. Airline CAS will cost more like $50,000 per system.

Senator CANNON. Mr. Shear.

Mr. SHEAR. Mr. Chairman, I am Wayne Shear, program manager for collision avoidance systems, Bendix Corp.

In 1967, the Air Transport Association sponsored a collision avoidance technical working group to examine the avoidance problem in the light of newly available technologies.

Technical personnel from the FAA, the military services, the airlines, and the avionics industry critically examined all recognized air-to-air data exchanging techniques and concluded that a new technology, time-frequency, offered the best solution for a technically feasible collision avoidance system.

The ATA technical working group, after lengthy deliberations, produced a description of a collision avoidance system that accommodated the densities and velocities of the future as well as provisions for "minimum" compatible systems to accommodate the general-aviation user.

Three avionics manufacturers, including Bendix, developed compatible systems to the Air Transport Association's specification. These systems were extensively flight tested by the Martin Marietta Corp. from June to November 1969.

On March 20, 1970, the Air Transport Association issued a report stating the tests had been successful, and that they had demonstrated the time-frequency method would provide pilots with warnings to prevent collisions, and the system had the power to accommodate all users of the airspace for the foreseeable future.

That is, the time-frequency collision avoidance technique is the only tested concept that would appear to provide the degree of protection required for the full spectrum of performance of civil and military aircraft.

Bendix, like McDonnell Douglas, and the potential users of this equipment, know that any ultimate system concept must also include a low-cost version of CAS to be compatible with the general aviation market.

Bendix, as a major supplier to the general aviation industry, has, in addition to the airline equipment, developed designs for a companion time-frequency system for the general aviation market.

We at Bendix feel the following specific actions are desired to further the implementation of aircraft collision avoidance systems:

One, recognizing the requirements and responsibilities of the FAA, we hope that the FAA will clarify its acceptance of the time-frequency CAS concept and publish guidance documents for the manufacturing and user industries.

Two, recognizing significant problems in the simultaneous usage of CAS and PWI, it is suggested that this area be examined by the FAA in depth relative to the overall system.

Three, FAA ground station RFP's, siting studies, procurement, and implementation should be expedited to encourage widespread utilization of airborne CAS. In similar programs in the past—the air traffic control beacon, distance measuring equipment—the FAA has supported the development of low-cost general aviation equipment. Such a program for a fully compatible general aviation time-frequency CAS could also be helpful, in this instance, to accelerate its availability and lower the initial cost.

Four, the FCC should take action to permit permanent licensing of the time-frequency CAS in the 1,600-MHz band on the frequencies identified for CAS by the U.S. position to the World Administrative Radio Conference.

Five, in April of 1972, the Seventh Annual Air Navigation Conference of the International Civil Aviation Organization will be held. CAS is scheduled for the agenda. The United States should develop a strong position in favor of the time-frequency system to assure worldwide adoption.

Six, we hope the FAA and DOD will enter into a joint civil-military program for collision avoidance as they often have in the past for other programs, so that all users of the airspace can share in this measure of extra protection.

In conclusioin, it must be emphasized that the aviation industry has been diligently searching for an answer to this problem for nearly 20 years.

The system that has become known as as the ATA time-frequency CAS was not invented per se by the technical working group in 1967–68. It represented, rather, a recognition of prior experience, starting with Dr. Morrel's mathematics and including the extensive time-frequency experience of McDonnell with their EROS 1 system.

New technology permitted the feasible implementation of these demonstrated principles in a package of acceptable size, cost, and reliability. This system has been extensively flight tested and found to be acceptable.

Recognizing the multiyear development cycle of an industry program, conception, flight evaluation, specification writing with industry coordination, and, finally, hardware development and production, any change in direction at this point would add a minimum of 4 years to the availability of this vital safety device.

Mr. Chairman, we appreciate having this opportunity to express our views on CAS, and we hope that we have contributed information that will assist the committee in their deliberations. Thank you.

Senator CANNON. Thank you very much for those fine statements.

Senator BAKER. Thank you. I have no questions except one or two that I think you have inferentially covered.

I would like to go back to the statement you made about potential for collisions in uncontrolled airspace and uncontrolled airports where there is a published approach plate.

You mention Unicom and that is part of the solution since, as I understand it, Unicom is a volunteer operation. Do you imply that there should be some sort of modified controlled airspace requirement in this connection?

Mr. YOUNG. Our suggestion is that all aircraft have a two-way radio communication capability and that be mandatory and that the managers of the airports who have a responsibility be responsible for operating a Unicom system at least during the high traffic hours, if not on a 24-hour basis and that the flight regulations be modified, from the collision avoidance viewpoint so as to not permit IFR traffic to be in the midst of VFR traffic—both legal—but the rules be modified to specify cloud clearances, minimum ceilings and some diameter around uncontrolled airports which have approved approaches.

Senator BAKER. I am not sure I understand. Do you propose that some modified controlled airspace requirement accompany your suggestion about the use of the Unicom system in now uncontrolled airports?

Mr. YOUNG. Yes. Unicom should be mandatory.

Senator BAKER. And the communications technique should be mandatory, that is for tower operations?

Mr. YOUNG. Yes, on a Unicom basis.

Senator BAKER. Right.

Senator CANNON. Senator Moss.

Senator MOSS. Do you have an opinion as to a ceiling price for a collision avoidance system for general aviation use?

Mr. YOUNG. I would try to expand on Senator Cannon's earlier question, that all these are in the same ball park of $500 to $1,000.

Now, if you are talking general aviation CAS, the figure is anywhere at $25,000 to $150,000, which has been talked about in previous hearings and again depends on the magnitude and volume of production runs involved in any one time by any one company, sir.

Senator MOSS. Do you think if CAS became mandatory and therefore volume production started that the price would be decreased for general aviation aircraft?

Mr. YOUNG. I think we have been in an era where radio equipment has dropped from $2,000 down to $500 and I think we will also—the spirit of competition plus volume production will bring the prices down, sir.

Senator MOSS. Can a bearing measurement be added to that time frequency system that you were discussing?

Mr. SHEAR. Yes, it could be.

Senator Moss. It could be. Thank you, Mr. Chairman.

Senator CANNON. Senator Stevens.

Senator STEVENS. Do you know whether the insurance rates on liability for general aviation vary according to the radio equipment?

Mr. YOUNG. Some insurance carriers offer premiums, for example, a discount of 5 percent on carrying a transponder or a pilot who voluntarily takes so much additional training in the year. I think it is up to the individual carrier.

Senator STEVENS. Thank you.

Senator CANNON. Thank you very much, gentlemen, for your testimony. It will be helpful to us.

(The statements follow:)

STATEMENT OF L. B. YOUNG, VICE PRESIDENT, THE BENDIX CORP.

Mr. Chairman: The Bendix Corporation welcomes the opportunity to comment on Senate Bill S2264, requiring the installation of Collision Avoidance Systems on aircraft.

For over thirty years, The Bendix Corporation has been a major supplier to the aviation and aerospace industries. Products designed and manufactured by Bendix are found in virtually every airliner in the free world. We have, in addition, a complete avionics product line for general-aviation aircraft. Bendix communications and navigation systems are also used on United States and foreign military aircraft. This has provided us with extensive experience and a detailed awareness of the requirements of safe flight.

With your permission, I would like to discuss some of the basic issues related to collision avoidance, and present our recommendations relative to them. I will start with the premise that we should provide the greatest protection for the greatest number of people, and then work my way down through the system to the situation of the student pilot in uncontrolled airspace. The statistics indicate that of some 12,000 airports, about 550 are served by airlines and of these 60 handle better than 85% of all passengers. Outside the terminal areas, most of the commercial passenger traffic, as well as high-performance military and business aircraft, operate above, say, 10,000 feet. Accordingly, for the ultimate safety of the majority, there is no question in our minds that an adequate collision avoidance system could and should be a mandatory backup to the primary system for all aircraft using major terminals and airspace above, say, 10,000 feet. Since the investment in such aircraft runs anywhere from upwards of $50,000 to many millions of dollars, we can see no significant financial burden in assigning the proper level of CAS equipment to the various types of aircraft sharing this airspace.

Now, what should this collision avoidance system give us? Looking at the problem in a broad sense, I can say that any two aircraft at the same altitude and not flying on parallel paths are theoretically destined to collide sometime, even if they must fly halfway around the world to do so. The critical question is, "When will they collide?" If only seconds remain, an evasive maneuver is required, most likely an altitude change. What we are looking for, then, is a collision avoidance system that can give us the critical "time-to-impact" and altitude information needed to generate an evasive maneuver command if and when that becomes necessary.

The next question is, does such a system exist today? Our opinion is that Time/Frequency CAS has been proven feasible, and should be designated as the common system. Specifically, we are recommending that Time/Frequency CAS in its complete and most sophisticated form should be mandatory for all military aircraft and airlines. In its general-aviation form, it should also be mandatory for commuters, charter operators, business jets, and other general-aviation aircraft desiring to share the airspace I have just described. Further research and system evaluations appear unnecessary, and would only postpone the date when we can have this additional measure of safety. In just a moment, our Program Manager, Mr. Shear, will describe the status and capabilities of Time/Frequency CAS in more detail. I would like to continue, if I may, to examine the situation that may exist away from the very high-density terminals and below, say, 10,000 feet. This is where there is much controversy as to whether CAS shoud be mandatory, what flight rules should apply, and the merits of various pilot-warning indicators.

First, we should keep in mind that much of this remaining airspace is covered by the primary surveillance system, which is being upgraded according to the National Aviation System Plan. However, we feel there may be an inherent weakness in that the primary system depends mainly on beacon (or transponder) tracking, and conditions may continue to prevail under which aircraft sharing the same airspace will not have transponders. Also, even those that will have transponders may lack the capability of automatic altitude reporting. By way of example, flying IFR through broken weather at, say, 8,000 feet, I am frequently advised by the radar controller of "traffic at 2 o'clock, three miles, altitude unknown". Sometimes I see them; sometimes I don't. Sometimes they are at a very different altitude which is no threat; sometimes they whiz by rather close. This is a situation which could be improved without CAS being mandatory for all aircraft.

The FAA has already proposed that altitude reporting transponders become mandatory for all aircraft in positive-controlled airspace. I would suggest that if we continue to permit mixed VFR and IFR traffic, which we should do, such equipment should perhaps be mandatory for all who share that airspace, particularly that above, say, 1200 feet (AGL) and in the vicinity of an airport having approved instrument approach. When the ground system is upgraded to be compatible with this concept, a controller would have a better capability to advise the IFR pilot of other uncontrolled traffic so he can change course or altitude if necessary. This may be an adequate measure of safety in most instances. The cost would be modest. The general-aviation radio, transponder, and encoding altimeter are comparable in price and well within the means of those who fly today.

However, a dangerous situation could still exist around an uncontrolled airport with an approved instrument approach but whose traffic pattern is below the coverage of the primary system. For example, under present rules, local traffic could be approaching or circling the field at, say, 700 feet just below the cloud cover, at the same time that a pilot cleared for an instrument approach might descend through those clouds right into their midst, neither aware of the other. From personal experience I can say this is a real and frightening situation. What can be done about it? First, it would help if all fields with approved instrument approaches and/or flight schools had mandatory Unicom radio facilities at least during normal hours when local traffic is heaviest, and all aircraft were required to have at least some minimal capability for two-way radio communications. This could make it possible and mandatory for all concerned to be constantly aware of the traffic situation. Second, the flight rules could be revised from a collision avoidance viewpoint to establish standard traffic patterns and cloud clearances within a certain radius of such airports to provide a safer margin for visual avoidance.

We might also ask if CAS or pilot warning indicators could help in the situations I have just described. With respect to general-aviation CAS, technically it should work above some minimum altitude out of multipath problems, and providing it is within the synchronizing range of a ground station. However, since it may not be feasible to always meet these conditions, I would not recommend making CAS mandatory.

PWI, like CAS, appears to require a cooperative concept to be effective. Depending on the type of PWI, it usually requires that other aircraft have a compatible light source or radio beacon. Unless I was sure that all other aircraft would have such compatible equipment, I might hesitate to voluntarily invest on a PWI. On the other hand, if ATC transponders activated by the primary system were mandatory, then I would be more interested in a PWI which worked cooperatively with them. Such a PWI should also provide the pilot with useful information, such as approximate bearing and altitude of other aircraft. This type of equipment is within the present state of the art, and I would recommend its development be encouraged for use on a voluntary basis.

In summary then, our recommendations are as follows:

1. Accelerate implementation of ARTS III as the primary system with serious consideration being given to making compatible automatic altitude reporting transponders mandatory for all aircraft, as well as two-way radio communications.

2. Designate and implement Time/Frequency CAS as the common national backup system with consideration being given to the necessity of its being mandatory in appropriate form only for certain classes of aircraft, and/or only

for operations in certain high-density terminal areas and above some prescribed altitude, say 10,000 feet.

3. Revise the flight rules from a collision avoidance viewpoint in recognition that there will always be some areas and situations where neither the primary system nor CAS backup can be effective, but much can be done through regulation alone to minimize the collision hazard.

4. Develop voluntary PWI which is compatible with ATC transponders, and provide useful information to the pilot.

5. Place sole responsibility in the Federal Aviation Administration for the overall collision avoidance system design, including the selection of techniques, equipment and appropriate flight regulations on a reasonable but expeditious time schedule.

Thank you, Mr. Chairman, for this opportunity to express our thoughts on the overall system and environment. Mr. Shear will now comment on Time/Frequency CAS in more detail.

STATEMENT OF WAYNE SHEAR, PROGRAM MANAGER FOR COLLISION AVOIDANCE SYSTEMS, THE BENDIX CORP.

The problems of aircraft collision avoidance are not new to Bendix. In 1955, in one of the earliest mathematical treatises on the aircraft collision avoidance problem, Dr. J. S. Morrel, now retired from Bendix, defined the problem and suggested means by which electronic collision avoidance equipment could be developed.

Dr. Morrel determined the problem would best be solved by measuring the range and rate of change of range of approaching aircraft. The technique is now known as TAU and is presently employed in the Air Transport Association's Time/Frequency Collision Avoidance System.

Another industry accepted theory of Dr. Morrel's is the necessity for a directed maneuver, as provided by the collision avoidance system, for high-performance aircraft. His analysis also indicated that a simplified PWI (Proximity Warning Indicator) concept would be inadequate for high-performance aircraft and high-density traffic.

In 1967, the Air Transport Association sponsored a Collision Avoidance Technical Working Group to examine the avoidance problem in the light of newly available technologies. Technical personnel from the Federal Aviation Agency, the military services, the airlines, and the avionics industry critically examined all recognized air-to-air data exchanging techniques and concluded that a new technology, Time/Frequency, offered the best solution for a technically feasible Collision Avoidance System. Time/Frequency, a technique in which an accurate frequency source permits accurate time measurements, provided a means of one-way ranging and instantaneous relative velocity measurement, required for the aforementioned "Tau" solution. Time/Frequency, in addition, was the only technique offering the capacity for several decades of growth.

The Technical Working Group, in lengthy deliberations, produced a description of a Collision Avoidance System that accommodated the densities and velocities of the future as well as provisions for "minimum" compatible systems to accommodate the general-aviation user.

Three avionics manufacturers, including Bendix, developed compatible systems to the Air Transport Association's specification. These systems were extensively flight-tested by the Martin Marietta Corporation from June to November 1969.

On March 20, 1970, the Air Transport Association issued a report stating the tests had been successful, and that they had demonstrated the Time/Frequency method would provide pilots with warning and flight commands to prevent collisions, and that the system as then conceived had the capacity to accommodate all users of the airspace for the foreseeable future. That is, the Time/Frequency collision avoidance technique is the only tested concept that would appear to provide the degree of protection required for the full spectrum of performance of civil and military aircraft.

The airline industry standards group, Aeronautical Radio, Incorporated, has approved and published a detailed equipment description, ARINC Characteristic 587, of the Air Transport Association's Collision Avoidance System. The Bendix equipment designed to this specification is called the IMAGE system (an acronym for Intruder Monitoring and Guidance Equipment). Needless to say, the detailed specification guarantees compatibility among the equipments from the several manufacturers.

Bendix, like McDonnell Douglas and the potential airline users of this equipment, know that any ultimate system concept must also include a low-cost version of CAS to be compatible with the general-aviation market.

Bendix, as a major supplier to the general-aviation industry, has, in addition to the airline equipment, developed designs for a companion Time/Frequency system for the general-aviation market.

It is important to note that the airlines, in the interest of being compatible with the general-aviation user, are willing to carry the burden of providing the precision time standards needed by the general-aviation pilot to synchronize his system. When the general-aviation aircraft is in the vicinity of an airliner, and this can be up to ninety miles away, his system will be timed automatically by the master system carried on the airliner. Thus, the complexity and cost of general-aviation equipment can be minimized. Additionally, the FAA can install ground stations to provide this synchronization.

We at Bendix feel the following specific actions are required to expeditiously further the implementation of aircraft collision avoidance systems:

1. Recognizing the requirements and responsibilities of the FAA in controlling the airspace within the United States, we hope that the FAA will clarify its acceptance of the Time/Frequency CAS concept, and publish guidance documents for the manufacturing and user industries.

2. Recognizing significant problems in the simultaneous usage of CAS and PWI, it is suggested that this area be examined by the FAA in depth relative to the overall system.

3. FAA ground station RFP's (requests for proposals), siting studies, procurement and implementation should be expedited to encourage widespread utilization of airborne CAS. In similar programs in the past (Air Transport Control Beacon, Distance Measuring Equipment), the FAA has supported the development of low-cost general-aviation equipment. Such a program for a fully compatible general-aviation Time/Frequency CAS could also be helpful, in this instance, to accelerate its availability and lower the initial cost.

4. The FCC should take action to permit permanent licensing of the Time/Frequency CAS in the 1600 MHz band on the frequencies identified for CAS by the United States position to the World Administrative Radio Conference.

5. In April of 1972, the Seventh Annual Air Navigation Conference of the International Civil Aviation Organization will be held. CAS is scheduled for the agenda. The United States should develop a strong position in favor of the Time/Frequency System to assure worldwide adoption.

6. We hope the FAA and DOD will enter into a joint civil-military program for collision avoidance as they often have in the past for other programs, so that all users of the airspace can share in this measure of extra protection.

In conclusion, it must be emphasized that the aviation industry has been diligently searching for a solution to the collision problem for nearly two decades. The system that has become known as the ATA Time/Frequency CAS was not invented per se by the Technical Working Group in 1967, '68. It represented, rather, a recognition of prior experience, starting with Dr. Morrel's mathematics and including the extensive Time/Frequency experience of McDonnell with their EROS 1 system. New technology permitted the feasible implementation of these demonstrated principles in a package of acceptable size, cost, and reliability. This system has been extensively flight-tested and found to be acceptable.

Recognizing the multiyear development cycle of an industry program, conception, flight evaluation, specification writing with industry coordination, and finally hardware development and production, any change in direction at this point would add a minimum of four years to the availability of this vital safety device.

Mr. Chairman, we appreciate having this opportunity to express our views on CAS, and we hope that we have contributed information that will assist the Committee in their deliberations.

Thank you.

Senator CANNON. Next is Glen Gilbert, Glen Gilbert Aviation Consultants.

STATEMENT OF GLEN A. GILBERT, GLEN A. GILBERT ASSOCIATES, AVIATION CONSULTANTS, WASHINGTON, D.C.

Mr. GILBERT. Thank you, Mr. Chairman.

Mr. Chairman, my name is Glen A. Gilbert, principal of Glen A. Gilbert Associates, an aviation consultant for 20 years and active pilot for over 30 years.

I appreciate the honor of being given the opportunity of making a statement before this distinguished committee. I would like to say that my statement will not deal with specific "black boxes" but rather with the application of a relatively new concept "area navigation," or RNAV as it is referred to, and its potential role in contributing to a reduction of the midair collision hazard.

Area navigation basically means that a pilot, civil and military alike, has the capability of flying on predetermined routings through the airspace by means of an airborne computer designed to use inputs from existing ground navigation stations or self-contained navigation systems such as those using inertial sensors.

There are a number of companies now manufacturing or starting to manufacture area navigation airborne equipment in various stages of sophistication and price, ranging from modestly priced systems for general aviation aircraft up into the large airline jet aircraft, as well as for military aircraft.

As a consultant for one of these manufacturers, Butler National Corp., during the past several years I have performed or participated in numerous area navigation flight demonstrations and evaluations for or with airlines, general aviation and military activities as well as in very close cooperation with the Federal Aviation Administration. I merely mention these brief points, Mr. Chairman, to indicate my basis of experience on the subject of area navigation.

Area navigation can bring many improvements to the air traffic control system, increase airspace utilization, help reduce traffic delays, expedite traffic flow with attendant savings in operating costs, and contribute to greater safety in the air. In this statement, I will address myself specifically to the application of area navigation in helping to prevent midair collisions.

One of the most obvious contributions which area navigation can make in reducing the possibility of midair collisions is to eliminate the need for aircraft to follow the present airway system which has the effect of concentrating aircraft over the ground navigation stations. FAA analyses of midair collisions and reported near misses show that a high percentage take place in the vicinity of these facilities.

Area navigation routes can be followed by the pilot as may be most effective in providing various multiple flight paths between airports and into and out of the different runways at a given airport, thus reducing traffic concentration.

Area navigation provides a means to restructure the airspace with overpasses, underpasses, and corridors to permit segregation of different classes of aircraft by category or performance. The pilot has the means to follow these highways of the air by reference to his airborne area navigation equipment; the controller's workload will be reduced by virtue of minimizing the radar navigating communications required at present.

The net result will be that the controller can more effectively realize his role of regulating the flow of traffic and monitoring aircraft movements for collision avoidance. With the area navigation concept, the pilot navigates the aircraft and the controller provides ground management of traffic flow. In itself, this modification in functioning of the air traffic control system should be a plus factor in collision avoidance.

Descent corridors from controlled airspace for high-performance aircraft can be established in which the high-performance aircraft are exposed to the lower airspace for a minimal period of time. Midair collision statistics show that a high percentage occurs below 10,000 feet and within 30 to 40 miles of an airport. With the more sophisticated area navigation equipment used by the high-performance aircraft, such aircraft can make a steep descent from the upper altitude strata to intercept the final approach gradient on any desired track and at any desired distance from the end of the runway.

This technique, known as a "two-segment approach," was carried out as part of a noise-abatement demonstration by American Airlines under the auspices of NASA at Moffett Field, Calif., in August and September of this year. By minimizing the exposure time of high-performance aircraft at low altitudes, the midair-collision hazard should be reduced proportionately.

Area navigation equipment for the pilot desiring to fly only in visual flight rules (VFR) can help him bypass congested and restricted areas of airspace protected for instrument flight rules (IFR) operations. VFR "freeways" may be established in which slower aircraft can move freely, yet at the same time multiple tracks can be reserved for the high-performance, fast-flying aircraft.

Area navigation also means that many airports and runways in this country can be opened up to operation in IFR weather as well as VFR with more reliability, due to the fact that aircraft can fly into such airports without the need necessarily of having to rely on locally installed navigation aids. This means a greater distribution of traffic to many airports such as reliever airports, and to auxiliary or supplemental runways at existing airports, again distributing the density of aircraft in the airspace and contributing to midair collision reduction possibility as a result of giving us "uncrowded skies."

These brief foregoing comments, Mr. Chairman, merely highlight some of the aspects of the area navigation concept which I believe can help in solving the problem of midair collisions. It is not the final or total answer, but it can play a very important part. Now, I would like to quote what the National Transportation Safety Board has had to say about this subject in their report of proceedings on midair collision problems adopted November 12, 1970, as follows:

> There is a considerable potential for lessening the exposure of aircraft to midair collisions through the application of area navigation (RNAV) equipment, techniques, and procedures in the airspace system. This conclusion is based on the premise that, by reducing the number of aircraft traversing a given volume of airspace, the exposure rate will be similarly reduced. In addition to reducing en route congestion, utilization of the RNAV system would permit efficient use of the total airspace, both by the aircraft operator and the air traffic controller.
>
> The Safety Board believes that the application of RNAV techniques will aid materially in the reduction of the midair collision potential. The increased capability of providing off-airway navigation, more efficient terminal area procedures, and instrument approaches to runways without local landing aids will

be feasible with RNAV systems without procurement or installation of any additional ground-based hardware. We support the FAA's program to implement the required procurement, procedural and regulatory actions at as early a date as possible for a full RNAV system.

The FAA also has taken a very forthright position in moving forward in the preparation of procedures, routes, and other operating concepts needed in the air traffic control system. This interest is further evidenced by a symposium on area navigation which the FAA is sponsoring in Washington on January 24 and 25, 1972.

However, notwithstanding the favorable atmosphere which appears to exist regarding the implementation of area navigation, the facts of the matter are that only a handful of aircraft today actually are equipped with area navigation systems. Although there are a number of economic incentives for installing area navigation equipment, which I have not attempted to outline in this brief statement, and variously priced area navigation equipment is available from a number of manufacturers, these incentives in themselves so far have not proven to be sufficient to cause a dynamic implementation program by the airspace users. On the other hand, the safety aspects of area navigation have not been given sufficient emphasis, I believe, especially in regard to the midair collision problem.

Therefore, in conclusion, Mr. Chairman, I would like to leave with your committee the thought that, in your consideration of S. 2264, attention should be given to the role which area navigation implementation can play in helping to reduce midair collisions. Implementation could be stimulated, I believe, with several options. One is by providing matching funds from the airport/airway user trust fund to civil aircraft operators to install such equipment, in the same way that matching funds are provided to local governments for airport improvements. Another possibility would be to call for implementation in certain airspace, under certain flight conditions, and in accordance with specific timetables, as a governmental (FAA) safety requirement.

Thank you, sir.

Senator CANNON. Thank you very much.

Do you have any cost statements as to what this type of equipment costs?

Mr. GILBERT. Yes, sir. I will start at the lower spectrum, and there are today several manufacturers manufacturing a two-dimensional—lateral and longitudinal guidance which is sufficient for the smaller general aviation aircraft—in the price range under $3,000.

Now, as we said here earlier, we know that volume brings prices down and I would venture to say if the volume were brought up to the thousands, you could say it certainly should be talking in terms of under $2,000 for the less sophisticated general aviation area navigation system.

Then, you move on up into various equipment with a third dimension giving you vertical guidance which would go into the top corporate type aircraft and into airline aircraft, and that kind of equipment runs in the price range of around anywhere from $25,000 to $40,000, depending on certain input devices. Then you can move on up the spectrum a ways to the inertial systems such as those used on the 747's today at about $125,000.

Senator CANNON. Senator Baker.

Senator BAKER. Did I understand you to say, sir, that a possible solution would be for us to use airport airway trust funds to help finance this?

Mr. GILBERT. Yes, sir; my suggestion would be to take a look at the airport airway user trust fund revenue as a way to stimulate the equipping of this sort of equipment in aircraft by the users on the basis of matching funds.

Now we are stimulating airport improvements by matching from the trust fund, say, 50 percent of an airport improvement program, with a municipality putting up the other 50 percent.

I am suggesting maybe something along these lines might be feasible to, say, if an aircraft user, be it general aviation or what have you, will invest 50 percent of the cost of the system of this type that will help the ATC system in general, then he would be eligible for 50-percent matching funds.

Senator BAKER. Do you know of any precedent for dedication of public funds for equipping of private aircraft in this manner?

Mr. GILBERT. No, sir; I do not. The only precedent I can cite at the moment would be the precedent in connection with the airport improvement program.

Senator BAKER. But even there, there is a restriction, is there not, to expenditure of these funds on publicly owned airports instead of privately owned airports?

Mr. GILBERT. I think it includes privately owned airports also. I may be wrong, but it is my impression that it does.

Senator CANNON. If it is, something got by us.

Senator BAKER. If it is, I am not aware of it.

Mr. GILBERT. Maybe it is under consideration.

Senator CANNON. Consideration by somebody but not by us.

Senator BAKER. I take it you are familiar with Senator Moss' bill, S. 2264?

Mr. GILBERT. Yes, sir.

Senator BAKER. As I understand your testimony, and I have some knowledge of the area navigation concept, and from the reading of Senator Moss' bill, I don't see how this proposal would comply with the requirements of Senator Moss' bill. Would it in your judgment?

Mr. GILBERT. The reason I suggested putting this sort of a statement in is that it is a—to me— a part of the general problem of collision avoidance, and it is my feeling that the intent of Senator Moss is to take a look at any ways and means that may be achieved in improving the air safety situation and helping to avoid midair collisions.

Senator BAKER. Of course, Senator Moss can speak for himself, obviously, but I am sure that is what all of us have in mind. But I am fairly sure your proposal would not fit the specification requirements of the Moss bill. Do you disagree with that?

Mr. GILBERT. I believe that would be up to Senator Moss to make that decision.

Senator BAKER. I think that is all, thank you.

Senator CANNON. Senator Moss.

Senator MOSS. Thank you, Mr. Chairman.

First, on the question of whether or not your proposal would fit the bill, I think perhaps it could because of the broad sweep of what we are trying to accomplish. Anything we can find in that area with an effective result—I am willing to accept or to modify the bill here—so that it would be acceptable.

I have just one question about the time frames of the bill. Are they realistic, or what is your opinion on that?

Mr. GILBERT. In regard to, for example, if you were to expand the implementation of certain of these time frames contained in the bill to an area navigation concept?

Senator MOSS. Yes, this says not later than January 1, 1973, that minimum standards be set, and that the requirement here is that by 1975, installation on all aircraft be required, and this would also include your navigation areas.

Mr. GILBERT. Speaking specifically on the subject of airborne area navigation hardware, I can assure you that there are approximately five manufacturers that can deliver equipment today. There are several others getting into the business. I understand that at the symposium next month, January, that I mentioned, there will be somewhere between 12 and 15 manufacturers exhibiting area navigation equipment of different levels of pricing. Therefore, your time frame for area navigation implementation, in my opinion, is well realizable for this particular kind of equipment.

Senator MOSS. Thank you very much.

Thank you, Mr. Chairman.

Senator CANNON. I may say that while there has been no press release put out on it, as I understand, it is a fact that the President has signed the bill that the Congress recently passed, which prohibits raids on the Airport Airways Trust Fund, such as you suggested. It would be extremely difficult for us to consider something of that nature without repealing legislation that we just have recently passed and was just signed into law within the past few days.

Senator Stevens.

Senator STEVENS. Do those "move it" field experiments involve consent of departure clearance as well as approach controls? Is it my understanding you are referring to approach primarily?

Mr. GILBERT. This particular demonstration was strictly on the approach phase of the noise abatement by bringing the aircraft down at steeper angles and thus reducing noise in the area extending from the end of the runway.

Sentor STEVENS. You say that it has secondary benefit of also reducing the probability of midair collision approach.

Mr. GILBERT. Yes, sir, because it brings the high-performance aircraft down from the higher levels of airspace into the immediate airport in a lower period of time than exists today when they are in many cases dragged at low altitudes for some periods of time through the low strata where they may be more exposed to other aircraft.

Senator STEVENS. As I recall, you stated that 10 miles below 10,000 feet is the general area of midair collision.

Mr. GILBERT. Below 10,000 and around 30 or 40 miles seems to be the area where a high percentage of midairs take place.

Senator STEVENS. Have you seen statistics as to the approaches as opposed to departing aircraft in terms of involvement?

Mr. GILBERT. I believe that the analyses that have been made—there is an airline pilots spokesman coming—I know they have been making extensive surveys on midair collisions, especially in the airport area, but my recollection is that theirs, and other studies, show that the higher percentage takes place in regard to arriving aircraft.

Senator STEVENS. All right.

I am sorry I have to go to—I would like to explore, perhaps with the other committee members, the Alaska Airlines crash in June which involved not a midair but a problem that developed because of a holding pattern which had to be followed by the scheduled aircraft to make way for a departing general aviation aircraft on an IFR clearance. Because of the problems of locating that aircraft, the Alaska plane went through a rather unique holding pattern, which I think attributes some of the problem involved there to that departing plane.

Mr. GILBERT. If I might just briefly comment on that, Senator the possibility with the area navigation concept, of course, as I mentioned here briefly is creation of overpasses and underpasses in the airspace, so that you in effect have a built-in form of segregation through the proper navigation by the pilot if he has the proper airborne equipment to carry it out.

Senator CANNON. It is hard to do, though, in a situation like the Senator.

Senator STEVENS. That is right.

If you examine the crashes we have had, for example in Pennsylvania, Virginia, and Alaska, they involved situations where the normal equipment we had available in other places is generally not reliable.

I would like to find out if we have any capability for developing more reliable systems, specifically complete area control as opposed to the system that we have now.

Thank you very much. I am sorry I have to leave.

Mr. GILBERT. Thank you, Mr. Chairman.

Senator CANNON. Thank you.

The next witness is Mr. Ken Miller, Wilcox Electric Co., Kansas City, Mo.

STATEMENT OF KEN MILLER, WILCOX ELECTRIC CO., KANSAS CITY, MO.; ACCOMPANIED BY ROBERT WOLIN, VICE PRESIDENT OF MARKETING; AND WILLIAM LEWIS, STAFF SCIENTIST

Mr. MILLER. Thank you very much, Mr. Chairman.

My name is Ken Miller. I am president of Wilcox Electric, Inc., of Kansas City, Mo. Wilcox Electric, Inc., hereafter refered to as Wilcox, is a subsidiary of Northrop Corp.

I have with me this morning on my left Mr. Bob Wolin, vice president of marketing, and on my right, Mr. Bill Lewis, staff scientist, with us.

Wilcox designs, manufactures, and markets airborne and ground-based communications and electronic navigational aids for aviation's safety and convenience.

The testimony which Wilcox wants to submit has been briefly summarized on these pages which I would like to have entered in the record.

The Wilcox Co. is grateful for this opportunity to present testimony which has a bearing on Senate bill S. 2264, submitted by Senator Moss.

We, at Wilcox, are in concert with the concern for safety which initiated this bill.

Points which I want to bring to the attention of this committee are:

Point 1, the time-frequency collision avoidance system as formulated by ATA in conjunction with Federal agencies, the avionics industry and others, has been ascertained to be technically sound by Wilcox. This engineering judgment is based upon tests conducted by Wilcox and Sierra Research using two CAS-equipped aircraft and one CAS ground station, plus the ATA tests conducted by Martin-Marietta.

Point 2, the Wilcox Co., after technically investigating many collision avoidance and proximity warning ideas, devices, and concepts, expended a sizable amount of company funds in the development of the airborne and ground-time frequency CAS equipment for the ATA/ FAA tests with full expectation that a safety-oriented program with technical soundness would certainly be adopted.

Point 3, a mixture of CAS-equipped aircraft, utilizing airspace with PWI-equipped aircraft, is not feasible unless the CAS-equipped aircraft also carries PWI equipment. The CAS-equipped aircraft must also have operational procedures or have a logic system common to the two equipments in order to eliminate contradictory maneuver between aircraft.

The fourth and final point is that we know, without any question, that technology presently exists which will allow aviation equipment companies, such as Wilcox, to develop, design, manufacture, and market time frequency collision avoidance equipment which aircraft operators and owners can well afford, thereby eliminating the need for PWI.

In support of the latter point, we are presenting an attachment to this testimony, which we would like to have entered in the record. Although this is somewhat like pointing out the hiding place for the family jewels, we have elected to use excerpts from our Wilcox proposal to develop just such an inexpensive airborne CAS equipment for general aviation.

The proposal was submitted to the FAA and to NASA's request for quotation in January 1971. Our Wilcox proposal has recently been updated for submission to the FAA as an unsolicited proposal to develop airborne CAS equipment on an FAA subsidized development.

The cost of this development is recoverable by the FAA through royalties on commercial sales by companies utilizing the design concepts contained in the Wilcox proposal.

The reference to Wilcox time-frequency CAS equipment, which was used in ATA's feasibility test, concerned the specific equipment which was developed primarily with Wilcox funds. The engineering work was done by Wilcox & Sierra Research of Buffalo, N.Y.

This feasibility equipment contained the functions which we believed were essential to business aviation, especially jets, turbofan, and the faster piston aircraft, designed for cruise altitudes above 18,000 feet.

The equipment was fully compatible with the ATA full-airline CAS, as well as providing protection against its own kind and with any other CAS device which might be designed to cooperate within the presently defined time-frequency system.

The equipment as described in the attached Wilcox proposal differs from the business aviation feasibility model in that the proposed equipment is specifically adapted to the slower aircraft, usually VFR and normally utilizing cruise altitudes of 10,000 feet or less.

This is the end of our statement.

I have with me, as I said, Mr. Wolin and Mr. Lewis. They have been closely associated with our collision avoidance investigation for many years, and any of us would be happy to answer questions pertinent to our positions and our development and need for CAS equipment. Thank you.

Senator CANNON. Now, you indicate here, then, that you probably have to have two completely different systems. One for slower and lower aircraft, and one for the high-performance aircraft, is that correct?

Mr. MILLER. We are suggesting that two systems be made available, one which we would recommend for the lower flying, less expensive aircraft, and would be confined to lower altitudes, and the more elaborate system for the higher flying aircraft which have higher speed performance and, of course, higher altitudes, such as the transports.

Senator CANNON. Those systems would both have to be fully compatible, would they not?

Mr. MILLER. Yes, sir, it is our proposal that they would be compatible.

Senator CANNON. Do you have any cost estimate information that is set forth in your study that you could relate to us that would be helpful?

Mr. MILLER. Yes, it is our feeling that the system which we would propose and which we have put together and intend to propose for the FAA would yield a system which will, in the quantities we foresee, sell for approximately $1,500.

This is for CAS, not PWI, but a CAS system which would be compatible with all aircraft flying with collision avoidance systems.

Senator CANNON. Senator Pearson?

Senator PEARSON. No, thank you.

Senator CANNON. Senator Moss?

Senator MOSS. Is that $1,500 for the smaller system, or are both covered by it?

Mr. MILLER. This would be for the smaller aircraft; that is, the non-jet or turbine type; that is, the single-engine aircraft.

The system which would be proposed and which is the type we have flown for the transports and the business jets or business fleet would be in the $6,000 to $8,000 category.

Senator MOSS. Now, how soon could this equipment be placed in production and be available if the decision were made to go ahead?

Mr. MILLER. If we had a decision to proceed, let's say, for example, today, we believe we could begin deliveries in the spring of 1973.

Senator Moss. That would be about 15 months?

Mr. Miller. Yes, sir.

Senator Moss. So that if the time frame set by this bill were followed, the 1975 deadline could be met?

Mr. Miller. There would be no problem meeting that.

Senator Moss. Does this also have the bearing measurement along with time-frequency in the system that you have?

Mr. Miller. It does not.

Mr. Lewis. This is truly a time-frequency CAS system. All the escape maneuvers are by altitude changes.

Senator Moss. Well, I see that there is an attachment to your statement, a rather complete description, and this will be most interesting and most helpful for us to examine in the committee.

Mr. Miller. It is rather detailed, and we didn't want to belabor this. We felt it was technical jargon that could be looked selectively at at a later time by those interested.

Senator Moss. We will let the staff look at those. Thank you.

Senator Cannon. What production figure were you using in that $1,500 estimate?

Mr. Lewis. About, as I recall, something in the neighborhood of $10,000 a year.

Senator Cannon. About $10,000 a year?

Mr. Lewis. Yes.

Senator Cannon. So if you actually got down to the neighborhood of $2,000 a year, what would your cost estimates be?

Mr. Lewis. Well, not too much different until you get—I would say the breaking point would start about at something between $2,000 and $3,000. When you get up past a couple thousand a year, there is little change between that and 10.

Mr. Miller. The main difference was in material, Senator, the feeling that the material would go up about 10 percent in these higher quantities.

Senator Cannon. Thank you very much, gentlemen.

We have a vote on the floor. The committee will stand in recess, subject to call of the Chair. Hopefully, it will not be longer than 15 minutes.

(Recess.)

(The attachment follows:)

ATTACHMENT I

DESIGN PROPOSAL

FOR

LOW COST "MINI-CAS"

FOR GENERAL AVIATION

Wilcox Electric, Inc.

Original Issue 27 January 1971

Revised 15 October 1971

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I. INTRODUCTION AND SUMMARY

A. Introduction

The successful conclusion of the flight test and evaluation of the Air Transport Association's cooperative Collision Avoidance System (CAS) by the Martin-Marietta Company and the subsequent adoption of an airline equipment characteristic by the Airline Electronic Engineering Committee indicates that CAS could soon be operational within the trunk airlines.

Mid-air collision history, however, shows that less than 1 percent occur between two airline aircraft and only about 5 percent occur between an airline and a general aviation aircraft. By far, the majority occur between two general aviation aircraft. It is readily apparent that to greatly reduce or eliminate mid-air collisions, a vast majority of the total fleet must be CAS equipped.

This proposal describes elements of minimum CAS equipments which can "play-in-the-system" and enumerates the tasks which we believe must be undertaken in order to provide adequate protection, minimum ATC interaction, and yet at a cost acceptable to the majority of general aviation owners.

B. Wilcox/Sierra Intercompany Agreement

This proposal results from much of the knowledge and experience in time-frequency systems which has been gained by the Wilcox Company through a team effort with Sierra Research of Buffalo, New York. The Wilcox/Sierra capability started with an inter-company agreement toward supporting ATA's CAS technical working group within the past few years and continuing through prototype designs. These prototypes were used in the system feasibility tests conducted by Martin-Marietta for ATA.

C. Summary

The ATA/CAS provides avenues through which CAS compatible equipment meeting general aviation's functional requirements can be developed and at a cost which will be acceptable.

II. THE PROBLEM

A. Need of the Proposed Effort

Assuming that most of the airlines will equip with CAS within the next few years, the next consideration is whether general aviation will follow. Market research conducted by this company indicates that with a reasonably priced (not over $10,000) equipment, the upper segment of business aviation will probably follow the lead of the airlines. This, however, leaves a much larger segment outside the cooperative system.

Quoting from the "Report of Proceedings of the National Transportation Safety Board-Midair Collision Problem", November 1969:

"during calendar 1968, there were 38 midair collisions involving 76 aircraft, a 46-percent increase in the number of midair collisions over the 1967 figure. In every 1968 midair collision accident, a general aviation aircraft was involved. In three cases, an air carrier was involved with a general aviation aircraft. In one case, a military aircraft was involved with a general aviation aircraft. In the remaining 34 instances, the collisions were between two general aviation aircraft."----------"a review of the 1969 midair collision accidents indicated that there were 28 collisions involving 56 aircraft, a 26-percent decrease from the 1968 figure of 38. In every 1969 midair collision accident, a general aviation aircraft was involved. As in the two previous years, three cases involved an air carrier aircraft with a general aviation aircraft. In one case, a military aircraft was involved with a general aviation aircraft. In the remaining 24 accidents, the collisions were between two general aviation aircraft."

To provide the mid-air protection which one would desire, the entire aviation community should be able to cooperate with the ATA/CAS.

To illustrate what it means if this were not achievable, let us look at some of the protection probabilities involved.

1. Protection Probability

To calculate the probability that any one CAS-equipped aircraft will prevent a mid-air collision, one must make numerous assumptions, the first being that the airspace is not homogenous. The airhours that unequipped aircraft co-occupy a prescribed air space with CAS-equipped aircraft, can be the basis for the probability calculation.

The curve which is shown on the following graph entitled "Protection Probability" depicts the collisions prevented in relation to the percentage of CAS-equipped airhours divided by the airhours in that common air space. The "collisions prevented" on the horizontal scale is shown as a percentage of the collisions expected in that same air space, if no aircraft were CAS-equipped. Note that if 50 percent of the airhours were with CAS-equipped aircraft, slightly less than 30 percent of the expected collisions within the common air space would be prevented.

a. Airlines Only - Using the above described method, let us first calculate the protection for our airline aircraft, assuming only airline type aircraft were CAS equipped. Other best judgement assumptions are: The ratio of equipped to non-equipped aircraft and the percent of time in air space which is occupied by equipped aircraft. The first computation then actually determines the hours of flying with CAS-equipped aircraft.

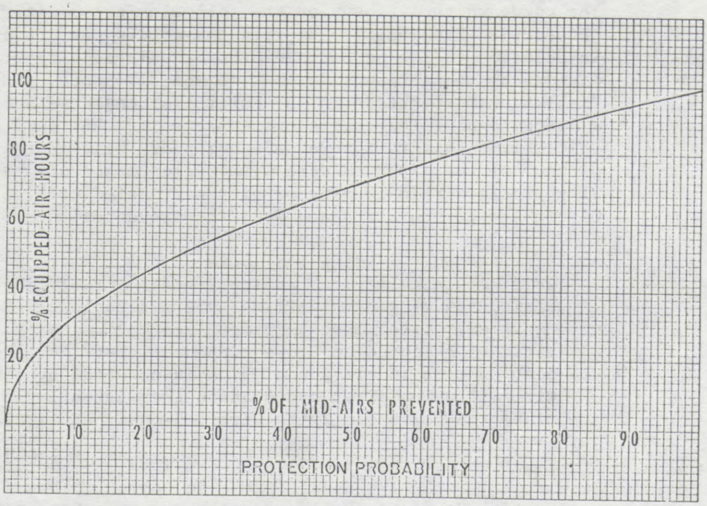
Type of Service	No. of Aircraft	% Equipped	Hours/Year Utilization	% Time in Common Space	CAS Equipped Million Hours in Common Space
Trunk Carriers	1400	90	2200	100	2.77
Local Service	700	75	1500	100	0.79

Equipped Hours - 3.56

The next computation determines the hours which unequipped aircraft commonly occupy airspace being used by CAS-equipped aircraft

Type of Service	No. of Aircraft	% Not Equipped	Hours/Year Utilization	% Time in Common Space	Unequipped Million Hours in Common Space
Trunk Carriers	1,400	10	2200	100	0.31
Local Service Carriers	700	25	1500	100	0.26
G/A Multi-Eng. Turbo Jet and Jet	30,000	100	300	60	5.40
Balance of General Aviation	135,000	100	180	10	2.43

Unequipped Hours - 8.40
in Common Space


100
80
60
40
20
% EQUIPPED AIR-HOURS
% OF MID-AIRS PREVENTED
10
20
30
40
50
60
70
80
90
PROTECTION PROBABILITY

The ratio of CAS-equipped time to total time in the common air space is:

$$\frac{3.56}{3.56 + 8.40} \times 100\% = 29.7$$

From the curve, 29.7 percent will prevent about 9 percent of the collisions in which any one airline aircraft might be expected to become involved. As airline aircraft are involved in only about 5 percent of the number of recorded collisions, this would reduce the number of expected collisions by 9 percent of 5 percent or about 1/2 percent.

b. Airlines and Business Aviation - If a version of limited CAS equipment were available which business aviation could afford for the G/A multi-engine, turbo jet and jet class, the calculation might look like the following:

Type of Service	No. of Aircraft	% Equipped	Hours/Year Utilization	% Time in Common Space	CAS Equipped Million Hours in Common Space
Trunk Carriers	1,400	90	2200	100	2.77
Local Service	700	75	1500	100	0.79
G/A, Multi-Eng. and Jet	30,000	60	300	60	3.24
				Equipped Hours -	6.80

Type of Service	No. of Aircraft	% Not Equipped	Hours/Year Utilization	% Time in Common Space	Unequipped Million Hours in Common Space
Trunk Carriers	1,400	90	2200	100	0.31
Local Service	700	25	1500	100	0.26
G/A, Multi-Eng. and Jet	30,000	40	300	60	2.16
Balance of G/A	135,000	100	180	10	2.43
				Unequipped Hours -	5.16

$$\frac{6.80}{6.80 + 5.16} \times 100 = 57\%$$

From the curve, 57 percent will prevent about 32 percent of the collisions in which any one airline or business aviation aircraft would be expected to be involved. These two aircraft classes account for about 20 percent of the mid-airs, therefore, about 6 percent of the expected mid-airs would be prevented.

c. Improvement Expected from Proposed Effort - If, however, a Mini-CAS version of equipment were available whose cost or versatility justified, economically, its installation on any aircraft expected to occupy the common air space, the protection probability would change drastically. It is assumed that airlines and business aviation would increase their participation because of reduced cost and/or increase protection. Also, as more of the total air space now becomes common, the percent time in that air space increases, especially for general aviation aircraft classes.

Type of Service	No. of Aircraft	% Equipped	Utilization	% Time in Common Space	CAS Equipped Million Hours in Common Space
Trunk Carrier	1,400	100	2200	100	3.08
Local Service	700	95	1500	100	0.99
G/A, Multi-Eng. and Jet	30,000	90	300	80	6.48
Balance of G/A	135,000	75	180	50	6.75
				Equipped Hours -	17.30

Type of Service	No. of Aircraft	% Not Equipped	Hours/Year Utilization	% Time in Common Space	Unequipped Million Hours in Common Space
Local Service	700	5	1500	100	.05
G/A Multi-Eng. and Jet	30,000	10	300	80	.72
Balance of G/A	135,000	25	180	50	3.04
					3.81

$$\frac{17.30}{3.81 + 17.30} \times 100 = 82\%$$

From the curve, 82 percent will prevent about 67 percent of the mid-airs. However, the protected types now include almost all of the aircraft classes which are expected to be involved in mid-air collisions. This, coupled with the reasoning that the majority of unequipped general aviation aircraft would be those which seldom expect to occupy commercial airlanes, would lead one to believe that commercial aviation mid-airs would be near zero.

B. Factors Influencing the Solution

1. The General Aviation Environment

The primary deterrant to equipping all of general aviation is cost of the equipment. This cost is related to the safety, and reliability with which that equipment can operate with other CAS-equipped aircraft.

However, when one relates types of equipment with the various classes of aircraft, it becomes apparent that many of the costly features can be compromised or eliminated in some of the aircraft classes. To determine those possibilities one must analyze the characteristics of the various classes of aircraft. Velocity, climb and descent rates, cruise altitudes, etc., have a large bearing on the CAS function. Depending upon the aircraft characteristic, one might eliminate the function entirely, might alter the concept in the use of the function or decrease the accuracy in the measurement or calculation for that function.

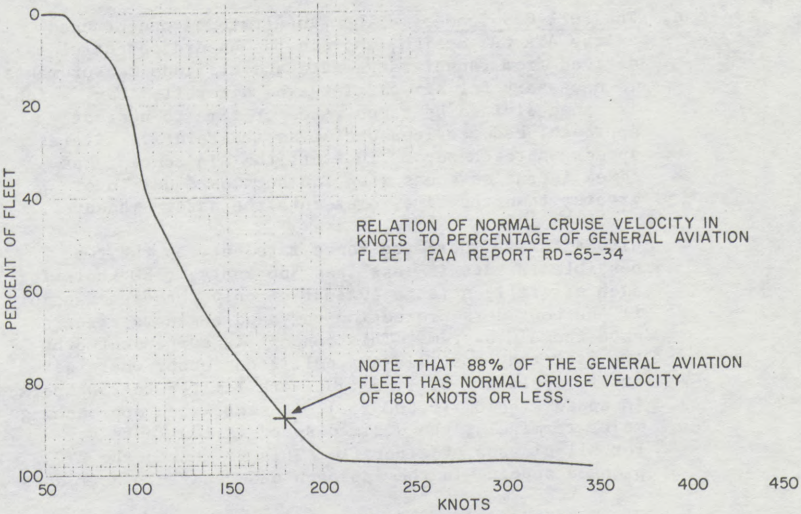
For example, the airline CAS is designed for velocities of Mach 3 and altitudes to 80,000 ft. This requires a CAS communication range of about 40 miles. However, all civil aircraft, when operating below 10,000 ft., are limited to 250 knots. That aircraft class which has a normal cruise altitude of 10,000 ft. or less, has no requirement for the high power transmitter extremely sensitive receiver nor the high altitude protection logic required for the Mach 3 application.

a. Aircraft Classes vs CAS Functions - The aircraft/CAS relationship for civil aircraft, generally falls into four fairly distinct classes as shown in the chart on the following page.

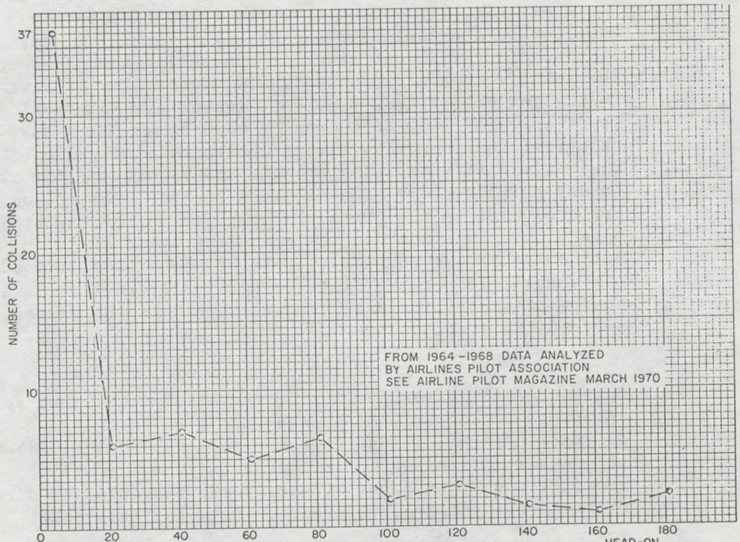
We believe that a concentrated effort be directed towards serving the largest general aviation group at the lowest cost to the owner. It is obvious from the aircraft classification chart and from the graph of section II.A.2.b that the largest group is composed of aircraft with cruise velocities of 180 knots or less, with published climb rates of 750, ±500 ft. per minute and, generally, with a normal cruise altitude of 10,000 ft. or less.

The level of CAS equipment found adequate for this class of aircraft must, necessarily, be compatible with the other aircraft classes which utilize different levels of CAS equipments.

Category	Cruise Velocity	Cruise Altitude	Climb Rate	Estimated Aircraft by 1980	ANTC-117 System
1	Mach 1 to Mach 3	Up to 80,000 ft.	Above 3000'/min.	50-75	Full CAS
2	300 Knot to Mach 1	30,000 ±15,000	3000'/min. ±2000'	15,000	Full CAS or Limited Level 1
3	180 Knot to 300 Knot	20,000 ±10,000	1250'/min. ±750'	50,000	Limited Level 1
4	180 Knot and Below	10,000' and Below	750'/min. ±500'	155,000	Limited Level 2



CRUISE VELOCITY



MID-AIR APPROACH ANGLES

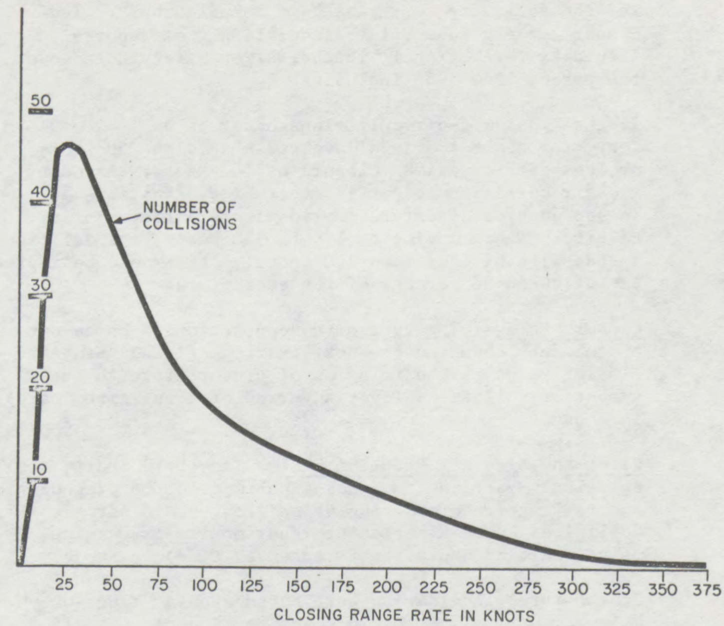
2. Rationale Towards Elimination of Some of Costly CAS Functions

a. The Full-CAS Concept - The Tau/Altitude concept used in the ATA CAS design, wherein the hazard potential is derived from range, range rate and altitude measurements is necessary for air carrier type aircraft. Tau, which is range divided by range rate, or time to nearest approach, becomes less useful as the relative aircraft speeds approach zero. In fact, the ATA concept has fixed intrusion zones when Tau becomes equal to or greater than the time to execute the safety maneuver.

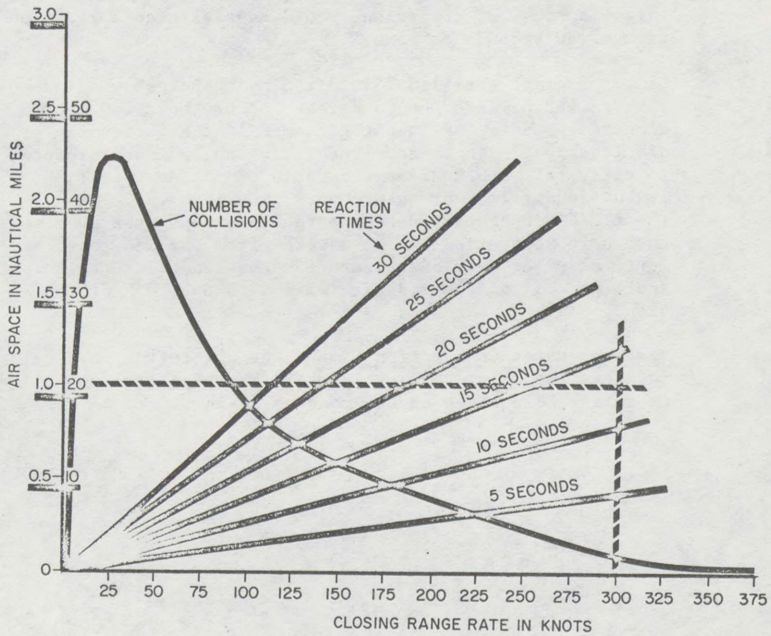
With aircraft where the range rate between the two possible threats is less than 360 knots, (180 knots for each aircraft) a range evaluation only, becomes feasible if one considers protection only and neglects effects upon the ATC system. This concept is supplemented by the fact that most mid-air collisions occur where aircraft, including airline type, are limited to 250 knots in speed, (below 10,000 ft.) In fact, when approaching major terminals, the desired speed is 180 knots for all classes of aircraft. This is due to the ATC planned spacing in the approach and departure corridors.

b. CAS Related to Aircraft Characteristics - From the graph on the following page, we see that about 88 percent of the general aviation fleet has cruise velocities of 180 knots or less. In encounters, the velocities rarely add, due to the fact that the majority of mid-air collisions occur with one aircraft overtaking another where the relative velocity, essentially, equals the difference in the two velocities. However, recent ATC interaction studies by NASA, by NAFEC and by members of ATA's CAS technical working group brings one to seriously question the advisability of using the air space required for a "range only" system. The solution of this problem, we believe, will be the primary accomplishment of the proposed effort whether done by effecting trade-off's between equipment complexity, protection probability and ATC inneraction or by "brute force" cost reduction in an equipment which provides essentially all of the presently defined CAS functions.

c. Approach Angle as a Function of Number of Collisions - The graph on the following page, entitled "Mid-Air Approach Angles", illustrates the relation of the number of mid-air collisions, over the past five years to the approach angle, with the slower of the two involved aircraft as the point of reference. Data for this chart



MIDAIR CLOSING RATES



REACTION TIME

and the following chart has been compiled by Mr. Ted Linnert of Airlines Pilot Association from reports issued by the National Transportation Safety Board over the period 1964-1968 inclusive.

In that most mid-air collisions occur below 10,000 feet, the highest speeds involved should be 250 knots or less with a maximum closure of 500 knots. As most mid-air collisions occur in overtaking situations and in approach or departure corridors where the majority of aircraft are moving at 140 to 180 knots, the relative speeds will be less than 360 knots. This would be representative in 95 percent of the encounters.

d. Closure Rates - The foregoing supposition is borne out by the data shown on the next chart, entitled "Mid-Air Closing Rates". The relation of closure rate to the number of collisions (over a period of about five years) is shown.

e. Pilot and Aircraft Reaction Time - The third chart, entitled "Reaction Time" has superimposed the preceding chart (Relation of Closing Velocities vs Mid-Air Collisions) upon a series of reaction times (warning, pilot reaction and aircraft maneuver time) vs range.

If the threat evaluation were based upon a "range-only" measurement, we see that a reaction time of 10 to 15 seconds would require a fixed-range alarm of about one mile for the maximum closure rate of 360 knots between two like equipped aircraft. Note, however, that the large majority of collisions would have allowed a reaction time of 30 seconds or more.

From the graph entitled "Mid-Air Closing Rates" we find that something less than 5 percent occur above 360 knot closure, however, an investigation of these accidents disclose that high speed aircraft, which would be expected to carry full-CAS equipment capable of making threat evaluations from Tau measurements, are involved. As the ATA/CAS concept has been established upon the premise that safe separation can be assured from the Tau measurement, assuming only one aircraft maneuvered, then this small percent of the mid-airs will also have CAS protection.

f. Vertical Rates vs Reaction Time - The aircraft's vertical rate has the major bearing upon the reaction time to execute the required escape maneuver. In figure 4-7 of

NASA Report No. 0079, Volume 1, dated 2 March 1970, the airframe manufacturer's climb rates vs the cruise velocities are shown for general aviation aircraft. This data, developed for continuous "climb-out", neglects the fact that short time climb rates, many times above that shown, can be attained by sacrificing velocity for upward acceleration. A very limited number of tests have convinced us that separations of several hundred feet can be obtained by aircraft having normal cruise velocity without falling below stall speeds, in much less than one-half the time expected if one considered only the published climb rates. Due to problems of attitude control, this maneuver is thoroughly acceptable for those aircraft flying VFR. However, it must be recognized that the greater majority of the general aviation fleet with cruise velocities below 180 knots are not equipped for anything but VFR flight. This fact, coupled with the fact that higher speed aircraft will have made a Tau measurement and started a complementary maneuver, should make encounters of this type perfectly safe. IFR aircraft could make the same maneuver, however, may be limited to lesser vertical acceleration.

g. CAS/ATC Interaction - Although the interaction between CAS-directed aircraft movement and normal air traffic control is considered a major problem by all those truly concerned with air derived separation assurance, we at Wilcox are firmly committed to the supposition that the collision avoidance system can be designed to provide protection only when dangerous blunders occur in the established air traffic control system. We are of the opinion that a warning of an intruding aircraft, which has entered some definitized protection zone, should not be considered a false alarm unless an aircraft movement is commanded which is not necessarily related to safety, and/or is accompanied by a subsequent command causing another aircraft in the ATC environment to unnecessarily modify its course, altitude or velocity.

Most studies and analyses of this interaction, to date, especially when related to terminal activity, have been addressed to worst case situations, head-on in many cases. Due to high relative velocities, the Tau zones becoming much enlarged, further resulting in warning and/or commands. These warnings/commands are considered by many as a false alarm because the aircraft was under ATC with supposedly safe separation.

If the historical accident data is realistically studied, only a very small percentage occur due to these worst case situations. In the other cases, a warning of nearby aircraft may be welcomed by a pilot under ATC, if not followed by an unnecessary command to change altitude.

Notwithstanding, when the CAS system becomes universally used by more than 200,000 aircraft expected before 1980 and terminal congestion become commonplace, historical data may be misleading and a thorough study may indicate that the Tau concept, with its minimally optimized protection zone, cannot be compromised.

If the above supposition is substantiated by the tests and simulations which are in being or have been planned by the CAS Technical Working Group, FAA's NAFEC facility, and others, then the major task of this proposed effort becomes that of designing an airborne equipment that is compatible with the ATA system in regard to range, range rate and altitude. The task of designing the least expensive equipment is then concerned with the cost trade-off's which relate to power, receiver sensitivity, single-frequency receiver-transmitter, range accuracy, range rate accuracy, altitude accuracy, the boundaries of ones own threat logic and the timing and extent of the escape maneuver.

3. Avionic Equipment Cost Analysis

The price which an aircraft owner pays for avionic equipment contains many individual costs. To attain a minimum user price, one must understand and thoroughly analyze each element of the cost build-up.

a. Cost Build-Up - In order to determine how the cost to the ultimate CAS user might build up, one can analyze the aircraft owner's cost of a similar equipment now being procured by a large segment of general aviation. Such an equipment is the general aviation transponder with 4092 codes and altitude reporting capability. The unit used in this example is the Wilcox Model 1014 transponder which was designed expressly for twin engine and jet aircraft, (primarily business aviation).

The unit includes an external control head and an antenna. The published list price is $2093. This published price, as in the automotive industry, is a figure which a franchised dealer may use during the negotiation of the sale. The published price does not necessarily reflect the manufacturing or distribution costs. The average uninstalled unit price paid by the user is $1700 for the above three pieces.

To this $1700 the purchaser must add an encoding altimeter, presently priced at $1650 to $2400. Suppliers have announced encoding altimeters at lower prices, however, none are yet available to the general aviation buyer. An installation plus cables, connectors and minor necessary installation hardware is priced at about $150. Total price to the user is now $3500 or more.

The build-up to the $3500 is shown below. The $1700 price for the basic transponder, the control head and antenna is covered in the first 12 lines.

Line No.			
1	Material	$ 550	(Purchased in production lot quantities of 100 units.)
2	Labor	130	(Utilizing tooling optimized for 2000 units.)
3	Burden	280	(Includes engineering and tooling costs amortized over 2000 units.)
4	Factory Cost	960	
5	General and Administrative	170	(Includes all sales expense and warranty estimated at 1-1/2% of net sales.)
6	Cost to Sales	1130	
7	Manufacturer's Pre-Tax Earnings	230	
8	FOB Factory Net Price	1360	
9	Average Ship Cost	5	
10	Cost to Dealer	1365	
11	Average Dealer Mark-Up	335	(Includes cost of maintaining a factory authorized service facility for "after-sales-support")
12	Average Sales Price to User	1700	
13	Installation	125	
14	Installed Unit Price	1825	
15	Altimeter with Dealer Mark-Up	1650	
16	Altimeter Installation	25	
17	Total Price to User	$3500	

If we analyze the various elements of the costs which make up user installed prices, we find the following:

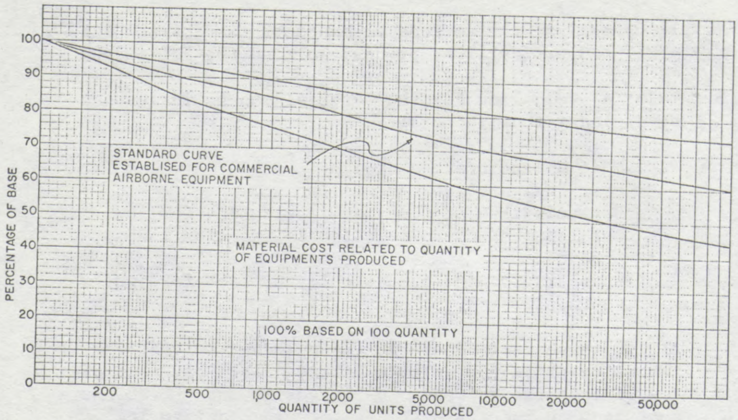
b. Material - In line #1, the material can be influenced by at least four factors:

Initial engineering design
Post design value engineering
Determination of the risk in planning for the total number of units which is expected to be produced
Whether procured domestically or from foreign sources.

All of these factors are inter-dependent in that the number of projected units will definitely have a bearing on both the approach to the design and the extent that one can justify post-design value engineering. Also, one should not consider foreign manufacture on quantities of less than 5 to 50 thousand.

The effect of engineering design and value engineering on the material cost is covered later in this proposal discussion of respective elements of the equipments block diagram. The effect of unit quantity is shown on the following graph entitled "Material Cost". The lower bound is for equipment which incorporates a high content of "state-of-the-art" components. The upper is used for equipments designed around components which have been available for many years. We propose that a part of this study be expended in the determination of this factor. Obviously, the lesser parts cost emerges when one can be assured of a production quantity of 50,000 to 100,000 equipments in a period of not over five years.

(1) Encoding Altimeter - Presently, the largest cost and most significant cost, is that of the encoding altimeter shown in line 15 of the sample cost analysis. With proposed Mini-CAS equipment requiring the same function, this item must be given major attention. The present practice of combining an altitude display for the pilot (corrected barometrically to MSL) with the encoded altitude input based on zero altitude at 29.92 inches of mercury (uncorrected pressure), further complicates an already complex mechanism.



MATERIAL COST

We are certain that a fixed pressure transducer, integral to the CAS equipment, which converts almost directly to the time encoded input for the transmitter will account for the largest single savings in the equipment. We are proposing to thoroughly study this possibility. It is reasonable to assume that this particular approach will also improve the altitude reporting accuracy. In addition, it should improve the overall reliability, thereby, further decreasing cost-of-ownership.

(2) Use of LSI and/or MSI Components - Much of the decision logic, the frequency determining circuitry, the encoding circuitry, etc., is adaptable to large scale integration (LSI). In the technical discussion of the various elements of the block diagram given later in this proposal, it is shown that the use of LSI becomes practical. As an example of how the cost might be projected for CAS design, let us consider a similar LSI which this company is using on an airborne DME. The LSI is a 24-lead module which contains some 150 logic functions. Conventional solid-state circuitry using a mixture of discrete component and individual IC's, was estimated to cost about $50. The parts were to be procured in 100-lot quantity and assembled with tooling optimized for 2000 quantity. The LSI tooling costs $25,000.

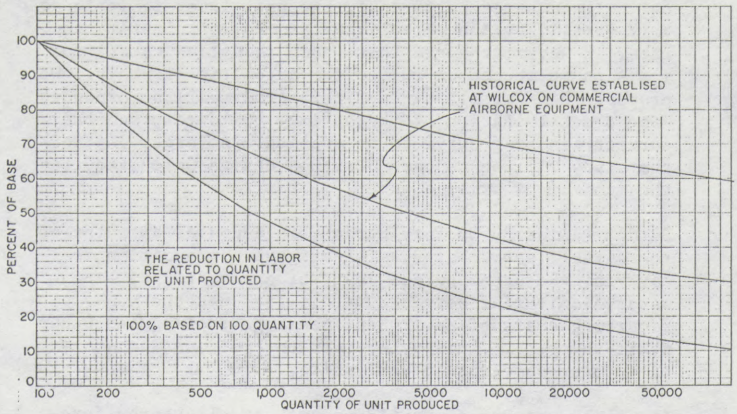
The primary reason for designing around an LSI was to obtain a space and weight advantage for the airborne box. However, when the LSI costs were projected beyond 1970 and 1971, we found that we also obtained a cost advantage.

The manufacturer has provided firm quotes through 1971 with projected estimates through 1975 as shown on the following page. The quantity figure is the number produced per year.

24 Lead LSI			
100 Qty.	1000 Qty.	5000 Qty.	10,000 Qty.
$60.00	$45.00	$	$
$45.00	$31.00	$	$
$21.00	$15.75	$13.10	$10.50
$18.00	$12.60	$10.50	$ 8.50
$14.00	$10.10	$ 8.40	$ 6.60
$11.40	$ 8.10	$ 6.70	$ 5.20
$ 9.20	$ 6.50	$ 5.40	$ 4.10

	36 Lead LSI		
Year	1000 Qty.	5000 Qty.	10,000 Qty.
1969	$	$	$
1970	$	$	$
1971	$21.00	$17.50	$14.50
1972	$16.80	$14.00	$11.40
1973	$13.50	$11.20	$ 9.00
1974	$10.75	$ 9.00	$ 7.20
1975	$ 8.60	$ 7.20	$ 5.70

c. Labor - Line #2, the fabrication and assembly labor is influenced by the same three factors, however, in a different manner. The following graph entitled "Labor Cost", illustrates the spread of this factor as related to a planned quantity. Paradoxically, the higher curve is applied to equipments which are designed and heavily tooled for assembly by inexperienced labor and when the learning is accomplished early in the production process. Due to the high cost of first assemblies, sophisticated and complex type units generally follow the lower curve, due to the high degree of learning.


PERCENT OF BASE
0
10
20
30
40
50
60
70
80
90
100
HISTORICAL CURVE ESTABLISED AT WILCOX ON COMMERCIAL AIRBORNE EQUIPMENT
THE REDUCTION IN LABOR RELATED TO QUANTITY OF UNIT PRODUCED
100% BASED ON 100 QUANTITY
100
200
500
1,000
2,000
5,000
10,000
20,000
50,000
QUANTITY OF UNIT PRODUCED

LABOR COST

As in the case of parts cost, the unit labor is influenced very greatly by the established production quantity and rate. However, the greatest labor reduction comes from a design which can be tooled for automatic assembly. We propose that a small part of this study will be expended upon a determination of the optimum build rate and the correct learning curve to be applied. A larger part of the study will be concerned with a design which requires the minimum of skilled labor.

d. Burden - Line 3, factory burden, is added as a factor of the direct labor charge. This figure, in addition to carrying the usual burden costs of space, light, heat, water, janitorial services, etc., includes the non-recurring costs of design engineering, tooling and other start-up costs. This non-recurring cost must be amortized over some quantity of units.

At Wilcox, airborne quantities are established by forecasting sales over a four-year period. The non-recurring start-up costs plus a reasonable return on that "fixed" investment is amortized against each unit expected to be sold over that four-year period.

In the example cited, this non-recurring cost amounts to almost one-half of the applied burden. If this non-recurring cost was to be financed by some Government-sponsored development, the burden reduction would amount to about $250 reduction in the $1800 user price.

e. General and Administrative Expense - Line 5 is the G&A expense which includes all usual administrative marketing and advertising expense as well as the cost of factory warranty. Wilcox history has established this warranty at 1-1/2 percent of net sales. This is about $19 in our cost example. This is considered a user cost with which little can be done.

The only other G&A factor is in the repeat business. If CAS production was guaranteed and becomes a major portion of the plant's output, the G&A expense would be materially reduced, due to a reduced sales expense. Over one-third of the G&A is marketing and advertising expense, which can be partially eliminated with a multi-year, large quantity contract. Some thought and effort during the design phase should be expended upon ways and means of accomplishing this objective.

f. Manufacturer's Earnings - Line 7 is the manufacturer's profit, or his pre-tax return on the investment made on:

(1) The initial market survey
(2) The development
(3) The non-recurring tooling and start-up
(4) The continuing material, labor and burden
(5) The investment in marketing, dealer training and necessary plant inventory to satisfy customer requirements.

Normally, this will amount to 20 percent of the net sales. This percentage is, however, affected greatly by inventory turnover; i.e., time between parts procurement (payment), labor payments and sale of the equipment. For example, equipment which takes two months to procure and fabricate, two months to assemble, test and ship, can tolerate about one-half the profit of equipment which requires double the time for parts procurement, assembly, testing and shipment to a customer.

The foregoing leads one to the supposition that a manufacturer's per unit earnings can be materially reduced on a large unit quantity contract and when component part deliveries, assembly and subsequent sales are accurately scheduled with a relatively fast turn-over. The supposition is completely correct. Profits assessed each unit can be reduced to a fraction of the usual amount, however, only if correctly planned and executed.

A part of the proposed effort will be to determine the optimum manufacturing rate and estimate the earnings for the "turn-over" time established for that rate.

g. Dealer Mark-Up - Dealer mark-up accounts for a fairly large part of the user's final price. In our cost example, it is $335, exceeding all other item costs except parts cost. Today, to be a successful supplier of avionics equipment, the dealer must maintain an FAA-approved service facility which means a capital investment of $50,000 to $100,000 in approved test equipment, tools, parts inventory, etc. For this investment, and depending on technical capability, he may qualify to be an authorized sales and service outlet and can recover a part of this investment through this profit on sales, service and installations.

The primary incentive for a dealer to reduce the usual mark-up is to:

(1) Provide products which have a removal rate of near zero; i.e., exceptional reliability, and
(2) For the manufacturer to produce a product which, because of price, additional functions, or ease of operation, will allow the dealer to turn over in less than average time. As in manufacturer's turn-over, the dealer realizes a greater return on his investment, on the largest number of inventory turn-over's.

If a plan was to be instituted, whereby the total Mini-CAS inventory was under the control of a Government-supported program, dealer mark-up could be materially reduced or completely eliminated. A dealer could then realize a return on installations and factory-paid or customer-paid service, without his funds being tied up on equipment inventory. A portion of the effortwill be directed to the exploration of such a support program.

h. Installation - The majority of avionics is sold and installed by dealers operating at the major airfields. Some, of course, are installed during the manufacture of the aircraft. It is obvious that the installation cost is somewhat higher when accomplished after aircraft delivery. However, in these instances, the user has a much greater choice of equipment.

The actual cost is governed primarily by the time and the skill required of the installer. If the equipment fits standard pre-planned cut-out's and mountings in the airframe and interwiring is minimized, the time and skill and the resulting cost will be low. Much attention must be given to this aspect in the design of minimum cost CAS equipment. Ideally, the control, the display, and the alticoder should be integral to the "black-box" with connections made only to power, to the antenna, and some cases, to the aircraft's static source.

III. TECHNICAL APPROACH

A. TASK I - System Definition

System definition will be accomplished by careful consideration and execution of the following steps:

Identify the requirements and constraints of the system.

Identify the components of the system and their specifications.

Evaluate the possible approaches which will satisfy the requirements.

Select the best approach, using the best trade-offs regarding system performance versus cost.

1. System Requirements

The design of a general aviation collision avoidance system is very difficult because an extremely difficult technical requirement must be achieved with relative low cost equipment. Unfortunately, one unique solution is not possible because of the restrictions imposed by the complex interaction between cost, performance, and system implementation. Such interaction dictates that trade-offs and compromises must be made to produce a system which will result in a high degree of safety for all equipped aircraft at minimal cost. The determination of what trade-offs are necessary will be influenced by the following major system requirements:

System must be compatible with ATA CAS.

Protection afforded versus cost ratio must be very high.

System must be very efficient with regards to air space utilization.

Protection capability must be high for all mixes of equipped aircraft.

Availability of synchronization signals.

Operational and maintainability aspects for the equipment.

a. ATA CAS - The current ATA CAS system has been proven to be an excellent system with regards to the protection capability, but the fact remains that the system is technically complex and relatively sophisticated. Fortunately, the ATA system has been designed with the general aviation problem in mind and the framework of the system has sufficient latitude to allow deviations and compromises to be made. Specifically, equipment complexity may be decreased by taking advantage of system parameter compromises made possible when the restrictions of the flight capability and performance of the vast majority of general aviation aircraft are considered. Such compromises will not necessarily compromise the safety criteria of the overall ATA/CAS system. Although the ATA system was designed with general aviation aircraft in mind, most of the tests, computer simulations, and published system analysis have been based on the equipment that will be used by commercial and high performance general aviation aircraft. Such tests and studies have verified the validity of the parameter tolerance specified in ANTC 117, but no analysis addressed specifically to evaluating the system with compromises made in behalf of parameter changes based on general aviation aircraft performance limits have been made.

b. Protection/Cost Ratio - One of the most difficult problems of evaluating different trade-offs as applied to system performance is finding a means of measuring the merits of combinations of individual or groups of trade-offs with system cost used as a common base. If a means of weighing the different system parameters is developed, then a mathematical model can be constructed and a relative rigorous system analysis can easily be made. The performance-cost compromises are as inter-related and so numerous that it is almost impossible to make a best choice judgement based on intuitive reasoning and educated guesses. The generation of a math model of the system is considered to be the most important step in evaluating the various approaches that must be made before the general aviation hardware specifications can be finalized. The parameters which are considered to be the key elements of the model are listed below:

Power budget
Pilot reaction time
Aircraft climb-dive characteristic
Range resolution and accuracy
Minimum range boundary
Tau
Altitude resolution and accuracy
Aircraft population and mix.

c. Air Space Requirement - The amount of air space required or the size of the protection envelope needed to ensure safety is an extremely important system consideration. An envelope which is too large will result in causing unnecessary evasive maneuvers to be made. This increases the pilot workload as well as destroys his confidence in the system. Unfortunately, the cost of those circuits which have the most effect on the protection volume are the most expensive to produce and their cost is inversely proportional to the size of the protection envelope. For example, a non-coherent transmitter is not nearly as expensive to produce as a coherent one. The coherent transmitter for the same power output requires a larger number of stages and consequently cost is increased. If a non-coherent transmitter is used, intruding aircraft cannot make a Tau measurement, so the protection envelope for both aircraft must be increased to a point where minimum range criteria will provide adequate safety. Obviously, as the minimum range boundary is increased, the system is more vulnerable to unnecessary maneuvers. It follows that a unit capable of making a Tau measurement is more expensive than one employing range only logic. This is one of the prime areas requiring careful study in the interest of selecting the optimum trade offs between system performance and cost.

d. Aircraft Mixes - Since general aviation aircraft will be mixed with all types of aircraft, it is necessary for the equipment to be compatible with air carrier equipment as well as other equipped general aviation aircraft. In fact, when operating in areas without ground synchronization signals, it is imperative that the equipment be capable of being synchronized by the full CAS system. When operating in areas where there are no ground stations, the power budget of the general aviation aircraft must be sufficient to allow synchronization and frequency adjustments to be made before a potential threat situation can develop between it and an aircraft which is synchronized in the CAS system.

2. System Components

The system is composed of various components which must work together or support each other and the degree of interface between them is very cost dependent. The various components that effect overall system performance and those that must be considered in the study are as follows:

Ground station implementation
Aircraft class versus equipment complexity
Hardware capability
ATC environment

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a. Ground Stations - It has long been recognized that a complete network of ground stations will greatly reduce the complexity of the equipment needed by general aviation and make the CAS system much more effective. The fact that various levels of equipment are required to satisfy the requirements imposed by different classes of aircraft also applies to ground station implementation. Some areas will require ground equipment with high levels of performance. Other areas can certainly be served with minimal performance equipment. Master ground stations with hierarchy 0 will be required in high density areas, but units operating with a hierarchy level as low as 40 would be very beneficial in low density areas and located at enroute sites. The number and performance level of ground stations is a very important factor and one that must be considered before a system definition can be made. The number of CAS stations required for a ground based synchronization network is discussed in NASA Report No. E0079 on the "System study for the application of time reference techniques to general aviation of collision avoidance". If the stipulation is made that only a very few ground stations will be available during early years of implementation then the resulting airborne equipment will be correspondingly much more expensive. This, of course, assumes that protection is required in areas where synchronization signals are not available. Ground station availability is probably the one most significant factor that effects cost and effectivity of the system. The presence of ground stations has a very large influence on the power budget and the quality of time base required. The cost of the equipment is very sensitive to both parameters. It is imperative that general aviation airborne equipment design and production schedules must be closely coordinated with ground station implementation.

b. Aircraft Class Versus Equipment Complexity - As discussed in B.1.a., the equipment complexity required is proportional to the level of performance of the aircraft. This fact has been used in the design philosophy for the current ATA system. The airline full CAS system has the capability of carrying time and can synchronize limited and mini-CAS equipment. Also, the fly over airline system will update the minimum performance ground stations. As mentioned before transmitter power and receiver sensitivity are dependent upon synchronization acquisition. If the power budget is adequate for acquiring and maintaining reliable synchronization then it will be sufficient to work a threat situation.

c. <u>Aircraft Characteristics</u> - The climb and dive rate characteristics of the various aircraft also influences the design philosophy of the threat logic. The ATA system is designed to ensure safety if only one aircraft maneuvers, and then the climb or dive maneuver is restricted to an acceleration of only one-quarter G. Such restrictions are necessary where occupants may move around the cabin area and passenger comfort has high priority, but it is certainly of secondary importance where occupants are always seated. As noted in Section II of this proposal, recent studies have been based on the aircraft manufacturer's published climb-dive rates rather than the rates realizable for short time periods. The maneuver capability of aircraft plus pilot reaction are key factors which must be considered before setting up threat logic parameters. These have been carefully analyzed for the higher performance aircraft in the ATA CAS system, but it is felt that further investigation is justified regarding low performance aircraft.

To illustrate the significance of a one-quarter G restriction on the total maneuver time, it is interesting to compare the time required to change altitude by 500 feet, if a 1 G maneuver is considered. Although it is an over-simplification of the problem, assume that an aircraft pulls up without loss of forward velocity, from a level flight cruise velocity of 180 knots and continues the maneuver at a 1 G rate until an altitude difference of 500 feet is obtained. It may be shown that the required maneuver time is approximately 11 seconds. Since acceleration is inversely proportional to time squared, it follows that

$$t_2 = \frac{a_1}{a_2} t_1 = \frac{1}{2} t_1$$

where t_2 is the maneuver time for an acceleration of 1 G (a_2) and t_1 is the maneuver time for an acceleration of one-quarter G (a_1). For the 180-knot case, it follows that t_2 is approximately 5.5 seconds. The five-second difference is a large percentage of the total reaction time, therefore, it has a large influence on the range boundary limits used in the threat logic. The assumed 1 G maneuver is a modest requirement since it will subject a climbing aircraft to a 2 G load which is the same as that encountered in a coordinated 60-degree bank.

3. <u>Approach</u>

The philosophy adopted by Wilcox is to start the design effort based upon a system which will have essentially all of the basic characteristics of ANTC 117 for the level 2 limited system. Initial effort will be directed simultaneously toward work on Task I, Task II, and Task III. While information is accumulated for the math model, work will be concentrated on the design and cost estimates for those circuits of the system which are not as expensive and sensitive to performance cost trade-offs, such as receiver i-f, video amplifiers, portion of the power supply, some portions of the logic, etc. If it is found through system analysis and cost evaluation of critical circuits that the design goal is out of reach, then a system compromise will be made which will cause the least degradation of system performance as possible. As soon as a "ball-park" cost of the initial design is established, based on the quantities and production factors discussed in Section II, it will be easy to evaluate the cost savings associated with the decreased performance determined from the system analysis.

a. Proposed Equipment Characteristics - The proposed equipment design which will be used as a base at the on-set of the study has the following characteristics:

(1) Will use altitude difference, and range conditioned by range rate in making threat evaluation.

(2) Altitude threat logic limited to 10,000 feet and below. No altitude rate logic.

(3) Clock oscillator stability requiring resync information at 15-30 second intervals, unless operating in back-up mode.

(4) Will not propogate master time.

(5) Will transmit range and altitude pulses.

(6) Will not incorporate bi-phase modulation; therefore, no time hierarchy.

(7) Will contain a modified backup mode to provide protection when out of synchronization range.

(8) Will make threat evaluation within a single co-altitude band which is divided into above and below. Band limits will be defined as a result of the study.

(9) Design goal will include utiliziation of an internal alticoder with no connections to an external digitizing altimeter.

(10) Coherent transmitter with a nominal power output of 50 watts.

(11) Single frequency transmitter, evenly distributed on f_2, f_3 and f_4 at time of manufacture.

(12) Four frequency receiver.

(13) A simple display, not combined with a vertical speed indicator.

(14) Will have a minimum of self-test features.

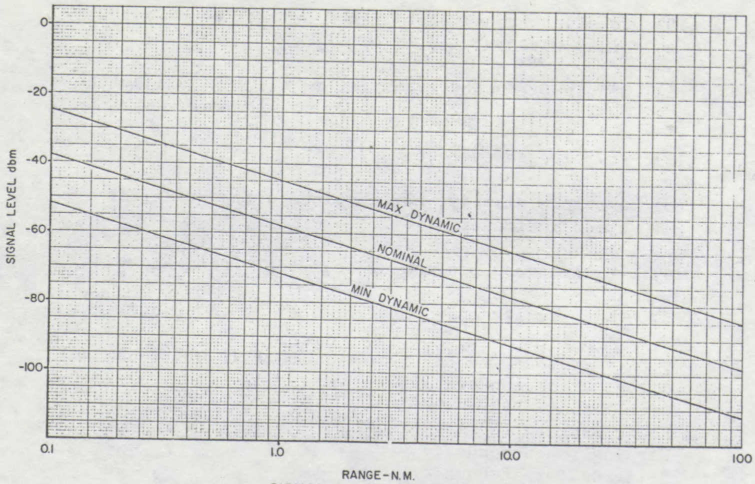
(15) Power supply operates from 9 to 30 volts d.c.

b. Key Parameters - The key system parameters which demand the most attention are:

Power budget
Warning range boundary
Altitude threat boundary
Clock stability

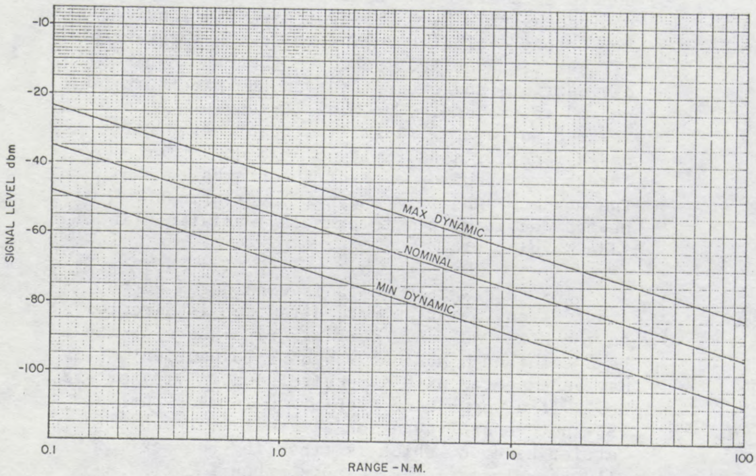
(1) Power budget - As mentioned previously, the power budget is dictated by synchronization range and not necessarily by the signal strength required for threat evaluation. The following three graphs illustrate the effective range that the Mini-CAS, air carrier, and ground station equipment are expected to produce. The Mini-CAS equipment is assumed to have a transmitter power of 50 watts and a receiver sensitivity of -78 dbm. Three curves are shown on each of the graphs to show the maximum and minimum dynamic variations expected due to system tolerances, variations in fade margin, etc.

To illustrate why 50 watts is considered to be a sufficient power output, attention is directed to the Mini-CAS - Air Carrier graph where it may be noted that a nominal range of 10 nautical miles may be expected with a receiver sensitivity of -78 dbm. If a worse case assumption is made that a 180-knot general aviation aircraft meets an air carrier head on, which is traveling the maximum allowed velocity of 250 knots, then the closing rate is 430 knots. Now assume that the general aviation aircraft has not been synchronized for a relative long length of time, thus it must have a minimum of 10 epochs or 30 seconds to update its clock. At a closure rate of 430 knots, the two aircraft will have decreased their spacing by 3.6 nautical miles in 30 seconds. The resulting range separation (approximately 7 nautical miles) is still considerably greater than that



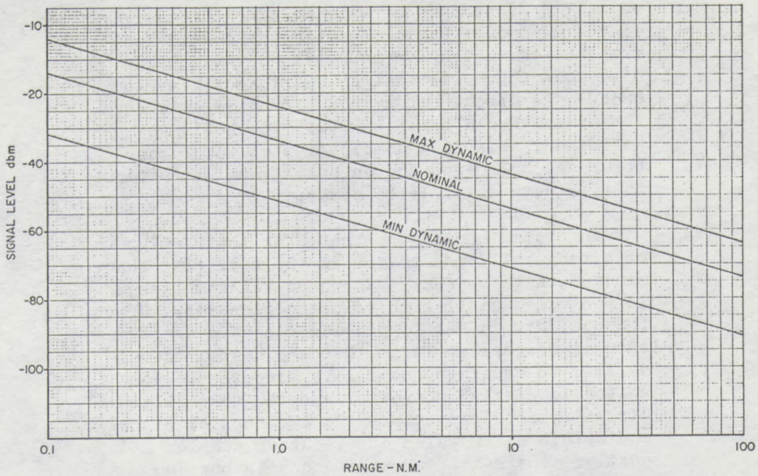
SIGNAL LEVEL VS RANGE

MINI CAS TO AIR CARRIER
XMTR PWR = 50 WATTS



SIGNAL LEVEL VS RANGE

MINI CAS TO MINI CAS
XMTR PWR = 50 WATTS



SIGNAL LEVEL VS RANGE

GROUND STATION TO MINI CAS

XMTR PWR = 2000 WATTS

needed if 20 seconds of warning time is required. If the minimum dynamic condition is considered, then the communication range is only 2 nautical miles and there will not be sufficient time to update the clock. If such a situation existed, the system could fail; however, it should be noted that this is a combination of worst case tolerance build-up, and an operational situation that is very unlikely to occur.

(2) Warning range boundary - The major shortcoming of a range-altitude system is the fact that the minimum range boundary has to be relative large to protect against high velocity closures. When the boundary is set to provide adequate safety, then it becomes so large that the system is vulnerable to causing unnecessary maneuvers. The analog to digital converter and the computation circuitry required to process the doppler signal and obtain a Tau value are relative complex and costly. Instead of providing continuous Tau measurement, Wilcox proposes a design which gives a warning range conditioned by closure rate. The graph on the following page shows two possible design choices. A system configured to perform according to the range steps associated with the 20-second line would satisfy the 20-second warning time specified in ANTC 117D. The steps result in decreasing the system protection volume efficiency as compared to a system making a Tau measurement; however, the proposed system is much more efficient than a range only system. It is expected that the study will result in locating the steps on a line some place between the 10-second and 20-second lines shown. The number of collisions versus closure rate curve has been shown with the warning range steps to illustrate that the coverage of the proposed system is very good.

(3) Altitude threat boundary - The optimum altitude threat boundary will be determined during the course of the study. The altitude threat boundary is primarily dependent upon the alticoder accuracy, climb-dive characteristics of the aircraft, and pilot reaction time. All of these parameters will be considered in the study.

(4) Clock stability - Clock stability is a serious problem because it is difficult to produce an inexpensive design and it poses maintainability problems in the field. Ease of field maintenance will be a prime consideration during the investigation.

c. <u>Protection in an Unsynchronized Community</u> - The ATA/CAS includes a back-up mode of operation which provides protection between unsynchronized aircraft. The back-up system will accommodate only a few hundred aircraft within communication range. This is considered sufficient in those areas where synchronization is not available. The ATA back-up mode operation adds an amount of logic which almost equals the Mini-CAS logic needed for synchronized CAS operation. Today's cost for that logic leads one to believe that this is one CAS function which could be eliminated for this class of aircraft. With adequate ground stations and/or numerous overflights by CAS equipments capable of propogating master time, back-up mode possibly should not be an absolute requirement, especially when one considers the mid-air accident record.

Study into the design towards use of a modified back-up mode requiring simpler logic, coupled with the use of LSI, probably will reverse the opinion that Mini-CAS backup mode is cost prohibitive.

d. <u>Protection when Mini-CAS is Operated Above 10,000 Feet</u> - Altitude accuracy is primarily dependent upon the alticoder's operating range, temperature and static source error. At high velocities, the static source error can become significant depending upon degree of compensation, placement, and type of aircraft.

Fortunately, static source errors are insignificant for the class of aircraft which will use Mini-CAS equipment. Extension of the alticoders altitude range above 10,000 feet is not as difficult as it is for the higher performance aircraft.

When Mini-CAS equipped aircraft is operating above 10,000 feet, protection is provided even though the threat logic is tailored for the lower altitude. Any intruding high performance aircraft will have equipment which sees the lower speed aircraft as a beacon and will have made his assessment of the threat based upon a Tau computation, employing his high altitude logic. A maneuver may or may not be indicated.

Assuming a maneuver command, the slower aircraft will be directed to make a complementary maneuver, if the threat conditions as assessed by his logic requires a maneuver. The difference between this operation and an encounter of two airline type CAS equipments, is that the command in the slow aircraft can occur at a different time, either slightly earlier or later than in the airline type. Maneuvers would be complementary and safe, especially when one considers that the ATA/CAS logic design was established to provide safe separation when only one aircraft maneuvered. Obviously, another aircraft equipped with Mini-CAS will have threat maneuvers indicated identical to operation below 10,000 feet.

B. TASK II - System Design

1. Clock - The basis of a time frequency CAS system is precise frequency and/or time. Present ATA CAS system specification controls frequency to a few parts in 10^8. Considerable study and actual flight testing has proven that accurate doppler measurements for high speed aircraft does require frequency sources with this kind of accuracy (short term stability). In addition to short term stability, a clock for CAS must possess other qualities. Those qualities are aging rate, resetability, mechanical ruggedness, warm-up time, and size. Oscillators that meet the above requirements are currently available from a few vendors but, at present, are cost prohibitive for low cost general aviation CAS. It is the opinion of this manufacturer that some of the requirements for the clock oscillator can be relaxed without a loss of system performance if other conditions are met. The number of ground stations (sync sources) available has considerable influence on requirements placed upon the airborne clock. The availability of sync signals in any location of threat possibility eliminate the need for long term stability and fast warm-up. Eliminating these two requirements would considerably reduce size (by eliminating an oven), and greatly reduce cost.

2. Transmitter - The transmitter for a coherent pulsed system, such as CAS, presents its own special set of problems. State-of-the-art design mandates the use of vacuum tube amplifiers at the CAS frequency and power requirements. The primary problem encountered in CAS transmitters is that of phase stability during the 200-microsecond pulse. To appreciate the effects of phase instability, one has only to remember that a one-degree of phase shift during the range pulse translates to about 6 knots of error in the range rate measurement.

   The acceptable power budget for a general aviation system will ultimately determine the complexity of the CAS transmitter. For a coherent transmitter, the complexity transition is around 50 watts, that is, for power levels below 50 watts a single stage tube amplifier would suffice, and at power levels much above 50 watts, a two-stage tube amplifier would be required. These numbers are based on both technical feasibilities and economic practicality. A non-coherent transmitter (if found to be practical) with one tube in a pulsed-oscillator configuration would be capable of delivering well over 50 watts output. It should be pointed out that it is not a simple case of one tube vs two tubes. The coherent transmitter is a power amplifier preceded by several stages of solid-state amplifiers operating at lower levels with near zero phase shift whereas the non-coherent transmitter may be a self-excited power oscillator.

3. Recevier - The receiver for a general aviation CAS presents a minimum of major technical problems. The receiver cost, as might be expected, is directly related to performance and complexity. The power budget for general aviation CAS will greatly influence the degree of sophistication and therefore cost of the receiver. ATA power budgets have been based on the assumption that general aviation CAS must be capable of communicating over sufficient range to provide enough time for synchronization to take place between the general aviation aircraft and an airliner that is a collision threat. A network of CAS ground stations would ensure synchronization to the general aviation aircraft and therefore reduce the communication range necessary for the airborne CAS. A reduction in communication range below ANTC-117 (level 2 limited equipment) allows the use of less sensitive and therefore slightly lower cost receivers. This slight cost reduction is presently considered insignificant. Other system parameters which would reduce the receiver complexity and ensuing cost would be the adoption of a three-frequency system instead of the present ATA system which employs four frequencies. A three-frequency system, with general aviation using one of the frequencies, would simplify the receiver design by a factor of about one-half.

   The processing of range rate (doppler) information, adds considerable complexity to the receiver. The discriminators, (primarily crystal type) which are currently available, are such that the first i-f frequencies must be considerably higher than the discriminator frequency, therefore, additional mixing, limiting and filtering is required for processing doppler information. The Wilcox company currently has satisfactorily performing models of phase lock discriminators. Performance of these discriminators appear to be equal to or better than present day crystal discriminators. The phase lock approach using reproducible solid-state circuitry, can, if produced in quantities, provide a very substantial cost savings in making the range rate measurement.

4. Logic - The logic circuitry for a general aviation CAS accounts for a significant portion of total parts cost. CAS functions that can be safely eliminated or simplified will result in some cost savings in logic circuitry. The possibility of eliminating or modifying Tau calculations and range rate processing looks attractive when one is considering cost and complexity of logic hardware. A single-frequency system for general aviation would further reduce logic hardware numbers. Certainly, panel mount equipment, with its desirable working environment, would allow using less expensive logic circuits. Perhaps the most significant factor governing the cost of logic circuits will be the quantities procured by any one manufacturer. If production quantities were large, medium scale integration or large scale integration would certainly become economically feasible. The amount of logic needed to decode multiple synchronization triplets could be reduced if general aviation could be assured of having an adequate network of ground stations to provide sync. However, once the system logic is completely

defined and frozen, the cost of one set of parameters as measured against another set has little economic importance. The total number of 24 or 36 lead chips is the greatest cost factor. This is now estimated at about four 36 lead LSI.

5. Altitude Information - Present ATA CAS is designed to derive altitude information from the standard ATCRBS altitude encoder. The cost of present day altitude encoders would be prohibitive to most of general aviation. We believe that it is imperative that an altitude sensor be included in the CAS equipment to provide an overall system cost savings to the general aviation customer. The ATCRBS encoder utilizes a rather cumbersome reflected binary code that requires considerable logic circuitry to convert to the time position code used in CAS. An altitude sensor that would provide frequency/time information as a function of altitude will drastically reduce the amount of logic needed for CAS altitude encoding. The following diagram entitled "Altitude (Pressure) Transducer and Converter" is one method favored by this company to accomplish the altitude encoding. First, converting pressure to frequency gives one the ability to linearize the pressure, time relationship by well-known and relatively simple trimming and padding oscillator techniques. Secondly, the circuitry can be easily temperature compensated to offset temperature effects in the pressure transducer. Thirdly, the conversion circuitry is adaptable to medium scale integration, with no mechanical devices except the pressure diaphram.

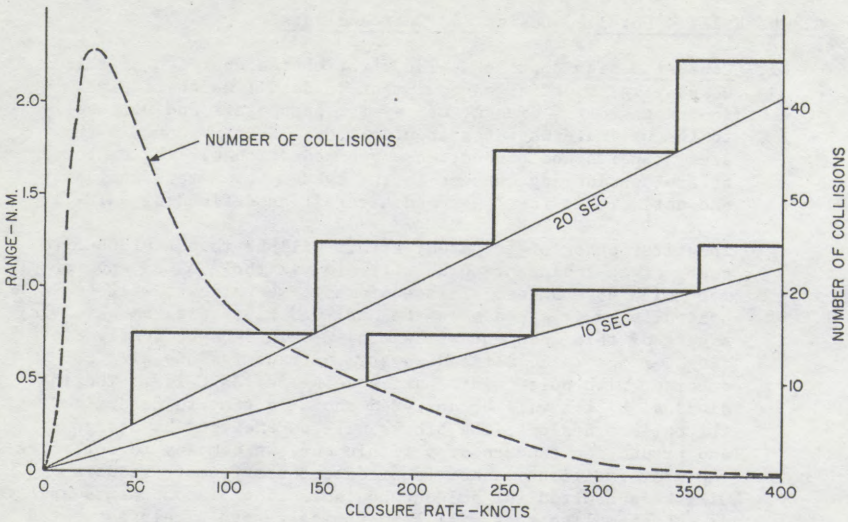
C. TASK III - Detailed Design and Cost Analysis

1. General Design Approach - The first choice approach of this company is to define an equipment in detail which requires no change to the present CAS system parameters and will sell to the ultimate user for about $1,500. Every avenue in the area of parts and production costs reduction will be explored before considering changes to the system parameters including encounter logic for low-speed aircraft as defined by ANTC-117.

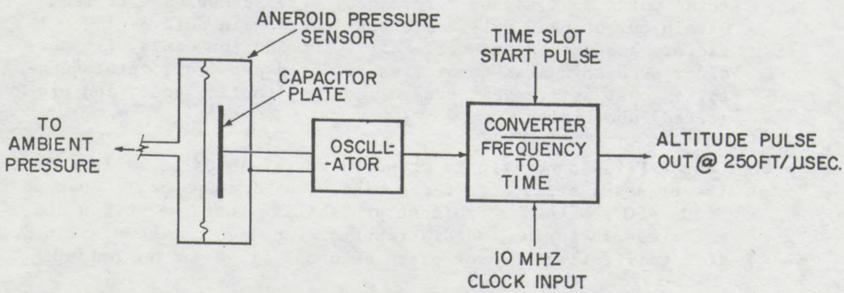
   The first phase of the study effort will be to establish firm costs of an equipment which will play in the ATA CAS environment with no changes. This equipment, we believe, will be basically as it appears in the Mini-CAS block diagram which is a part of this document. The Mini-CAS will be basically a range, range rate, altitude system. Transmissions will be coherent with pulse widths and spacing per ANTC-117. The individual blocks will be analyzed one at a time to determine the optimum design. The blocks will be analyzed by design and production experts from within our own company to determine the most efficient manner to produce these items. Vendors will be consulted for guidance on selecting of components and/or subassemblies that will lend themselves to highly automated manufacturing techniques. Firm pricing information on components will be obtained from foreign and domestic vendors so that total parts cost may be determined. Production experts from within our company will assist engineering in determining factory production and test costs. Production costs will consider such things as quantities produced per year, total quantities over a five-year production run, tooling cost, and projected labor rates.

2. Cost - First hand efforts at parts cost lead us to believe that the proposed study effort can achieve a Mini-CAS parts cost of $550, ±50. With a 50 percent probability that the burden and other manufacturing and distribution expenses can be minimized, this will reflect a user price of about $1500 in the period 1973-1978.

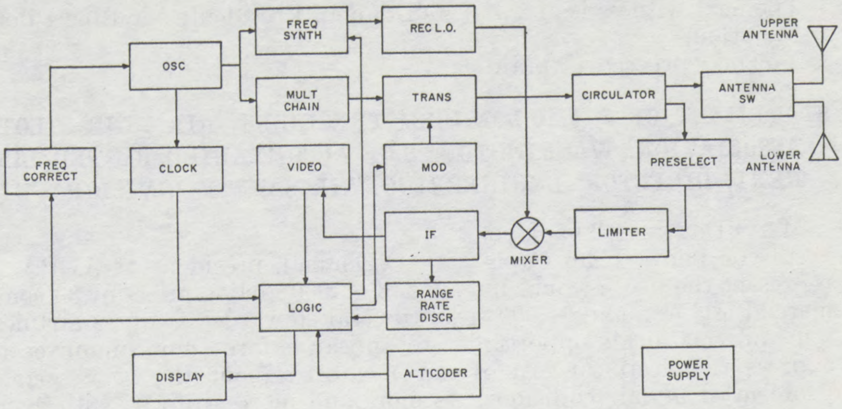
3. Initial Cost Analysis of Mini-CAS - Methods for reducing costs through optimum design, optimum production rates, etc., have been discussed in many places in Sections II and III. The following chart provides the various elements of the block diagram, based upon present day pricing in production lots of 100-200 units. Estimates in the second column are based upon quantities of 10,000 units per year in the period 1973-1978.



WARNING RANGE BOUNDARY VERSUS CLOSURE RATE



ALTITUDE (PRESSURE) TRANSDUCER AND CONVERTER



MINI/CAS BLOCK DIAGRAM

Senator CANNON. The hearings will come to order.

The next witness is Mr. J. J. O'Donnell, President, Air Line Pilots Association.

You may proceed, Captain.

STATEMENT OF J. J. O'DONNELL, PRESIDENT, AIR LINE PILOTS ASSOCIATION, WASHINGTON, D.C.; ACCOMPANIED BY TED LINNERT, DIRECTOR, ENGINEERING, AIR SAFETY DIVISION

Mr. O'DONNELL. Thank you.

As you know, I am Capt. J. J. O'Donnell, president of ALPA. I represent the professional interests of 31,000 airline pilots of 39 commercial airlines, and 15,000 stewards and stewardesses of 22 airlines.

I appreciate this opportunity to appear before your committee to express the deep concern of our members about the very serious problem of midair collisions. As more and more aircraft, with ever-increasing capacity and speed, take to the skies, it is obvious that the hazard of midair collisions also increases.

Thus far in 1971, there have been four midair collisions worldwide in which airline aircraft have been involved—a number that has been exceeded only three times since 1946. In the past 25 years, there have been 70 such midair collisions distributed as follows:

Airline to airline aircraft	12
Airline to military	20
Airline to general aviation	38

Over the years, the Congress has shown its concern with the midair collision problem, and this has been appreciated by all who fly. Bill S. 2264, to which I am addressing myself today, is a bill which has the complete support of the Air Lines Pilots Association. By identifying the differing requirements for small aircraft, the bill will greatly facilitate the acquisition of such devices. The establishment of definite compliance dates will also emphasize the urgency of the problem and take it out of the "study" category.

Congressman Fascell has introduced a bill in the House of Representatives which calls for an amendment to the Federal Aviation Act of 1958 to empower the FAA to "make available as soon as possible" a collision avoidance system for all aircraft.

The early passage of either or both of these bills should be of considerable help in getting a working collision avoidance program implemented. But while this type of legislation will greatly assist in reducing the collision threat, it must be emphasized that without full acceptance by the entire aviation community, there can be no really effective protection of any aircraft.

As an illustration of this point, you may recall that Piedmont Airlines recently anounced the purchase of collision avoidance equipment for its fleet of 36 airplanes. One might be led to believe that such a procurement will mean the end to the danger of in-flight collisions for Piedmont Airlines. Such is not the case. It means only that the probability of collision between two Piedmont aircraft has been reduced, but there is still the possibility that Piedmont aircraft could collide with other aircraft of other airlines, military aircraft, or general-aviation airplanes. The reason is that, under present collision warning concepts, all aircraft must have the same or compatible systems installed in order to be alerted to a collision threat.

We do not wish to degrade Piedmont's decision; rather, they should be congratulated because someone has to get the process started. But there is no record, to our knowledge, of two aircraft of the same airline ever colliding in flight. It is obvious, therefore, that action must be taken on all fronts within the aviation community.

For those who may doubt that something must be done immediately to solve the midair collision problem, they should know that 2 years ago, the Department of Transportation's Air Traffic Control Advisory Committee predicted that by 1980 "we would expect approximately 10 midair collisions per year" between air carrier and general-aviation aircraft within the United States alone. Until now, this figure exceeds the total for any one year, worldwide, between air carriers and all other classes of operation. It is absolutely essential, therefore, that immediate action be taken by all available means to stop this needless slaughter of innocent people.

It is the considered opinion of the Air Line Pilots Association that the midair collision can be drastically reduced or eliminated if two actions are taken. The first of these requires an immediate decision on the part of the U.S. Government that the use of adequate collision avoidance systems or proximity warning indicator should be made mandatory for every aircraft operated within controlled airspace. The other action requires that the Federal Aviation Administration take a more realistic and sophisticated approach to in-flight segregation of military and general aircraft from airline and other high-performance aircraft.

With regard to the first requirement, ALPA has for many years pressed for action to develop and equip all appropriate aircraft with suitable collision-avoidance devices. We have pointed out repeatedly that there is plenty of talent in the FAA, NASA, DOD, and especially private industry, to produce such equipment once the Government has decided upon the appropriate criteria.

At the present time, there are several differing technologies being offered as solutions. ALPA does not endorse any particular proposal. We feel very strongly, however, that all of the possibilities should be demonstrated and fully evaluated in a live environment rather than by simulation, since most have been tested many times in the laboratory. Following an accelerated evaluation the Government, with the cooperation of the airspace users, must make a firm decision on the best system. This then would become the national standard to which interested manufacturers could quickly produce equipment in a competitive manner.

Admittedly, the installation of an adequate electronic anticollision device will take time but there is something that could be accomplished immediately and that is the installation of inexpensive xenon strobe light for all aircraft. These lights have been installed and proven to aid in collision prevention. These lights have been used in quantity on many aircraft for at least 15 years. Our association feels that these lights offer a simple and reliable complement to any collision avoidance system. We have urged its adoption for years and have petitioned the FAA for a rule to make such equipment mandatory on all aircraft. The FAA, however, prefers to continue research and development

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on strobe lights although pilots know that they work reliably and can be seen for great distances—long before the aircraft using them can be detected with the human eye.

The second of ALPA's proposals has to do with the air traffic control procedures and airspace configurations to achieve proper segregation of traffic. While many of the procedures are satisfactory, a large number appear to be designed to lighten the controller's workload rather than to make the system more efficient.

For many years, ALPA has urged FAA to "get control of the aircraft back in the cockpit" instead of it being handled by the controllers. But to provide the pilot with the capability to operate his aircraft under instrument flight conditions in the same way he operates under visual conditions, he must be provided with some additional equipment. This need can be met with a traffic display in the cockpit which would enable the pilot to "see and avoid" other aircraft in his vicinity and to navigate his aircraft more effectively, particularly in airport terminal areas. Such a display is in the research stages now and the FAA should, with the assistance of pilots, increase the development efforts in an attempt to expedite its installation in the aircraft fleet.

In regard to more realistic procedures, the association has also pressed very strongly for the adoption of the corridor concept for air traffic control in airport terminal areas. This concept is easy to fly and certainly much less confusing to understand than the Terminal Control Area concept that the FAA insists is its answer. Although the corridor concept has been endorsed by representatives of the majority of airspace users, the FAA has virtually ignored all of our efforts to prove its value. The application of the corridor concept would ensure the separation of controlled and uncontrolled aircraft, thus reducing the midair collision potential. The lowering of the area positive control base will also help to accomplish this objective by providing additional airspace within which controlled flight may operate free from conflict with uncontrolled traffic.

Pilots recognize that, at present, the primary means of preventing midair collisions, lies in the air traffic control system. Experience has shown, however, that the system cannot be relied upon or we would not have the large number of near-misses that take place daily.

Therefore, it is essential that collision avoidance equipment be available to complement it and provide a much needed redundancy.

While it can be anticipated that at least some airline companies will provide collision avoidance equipment for their own aircraft fleet when it is approved, it is highly unlikely that the owner of a small single-engine aircraft would be expected to do likewise because of the cost. Nevertheless, accident statistics indicate that the small aircraft will be involved in most of the midair collisions affecting airline aircraft. ALPA believes, therefore, that the government must develop a plan to assist the small plane owner to finance the purchase of suitable equipment. Perhaps this may call for some form of tax relief or significant reductions in insurance and licensing costs.

I would like to deviate at this point and say the association would object strenuously to any attempt by anybody to use the airways/airport trust fund for any purposes than those intended by Congress.

The development of such a plan must proceed simultaneously with the development of the equipment.

To sum up, the Air Line Pilots Association strongly recommends the following actions by the appropriate government agencies:

1. Make a decision immediately in regard to the specifications and criteria for a collision avoidance system.

2. Conduct an accelerated live evaluation of the several systems now available.

3. Make a rule requiring all aircraft operating in controlled airspace to use operable collision avoidance hardware.

4. Develop a plan to finance the acquisition of the required collision avoidance equipment by general aviation aircraft owners.

5. Begin ICAO action to standardize on a worldwide basis the criteria developed in the United States for collision avoidance.

6. Respond to the plea of responsible airspace users regarding improved procedures that will improve the air traffic control system and reduce the midair collision hazard.

7. Expedite research and development of traffic situation displays in the cockpit with a view toward early inflight testing and evaluation of such equipment which will lead to installation at an accelerated rate.

While the above recommendations relate primarily to collision avoidance, we also strongly recommend that the FAA's "near collision reporting program" be continued at least through 1972. This program grants immunity to both pilots and controllers to report the circumstances relating to their "near collision" thus enabling possible improvement in the present air traffic control system. It also points out the inadequacies of the system and the great need for expediting installation of proven collision avoidance hardware.

In order to support bill S. 2264 more effectively, we will be most interested in studying the technical testimony presented at this hearing. We feel that the additional data being provided will enable our association to contribute more fully to the efforts of your committee.

We respectfully request that the two attached papers prepared by the director of ALPA's Engineering and Air Safety Department be included in the record to provide detailed technical information regarding collision avoidance. In addition, I am providing a copy of the statement I made at a House hearing on "Aircraft Collision Avoidance Systems" chaired by the Honorable Jack Brooks on August 3, 1971. I respectfully draw the attention of your committee to that testimony and the presentation that accompanied it.

Again, thank you for the opportunity to appear before you on a matter of such great concern to pilots, the air traveling public, and the entire aviation community.

I would be pleased to answer any questions you may have on this subject.

I would like to introduce Mr. Ted Linnert, director of the Engineering and Air Safety Department of the Air Line Pilots Association.

Senator CANNON. The attachments will be made a part of the files and we will certainly give them full consideration.

Earlier one of our witnesses testified concerning the area navigation system, that this might reduce the incidents of exposure.

Have you had opportunity to use this system on some of the current aircraft now?

Mr. O'DONNELL. Our ATC committee had demonstrations of that, Mr. Chairman. I also flew it on several instances in the Boston-New York area. The system separates you from a limited number of other aircraft but it doesn't separate you from the uncontrolled aircraft at lower altitudes where most of our collision potential is.

Senator CANNON. It doesn't seem to reduce the high incidence of risk which is close in around the airport or within 30 to 40 miles of the airport and below 10,000 feet.

Mr. O'DONNELL. It doesn't reduce that risk, sir. I believe the area navigation concept was conceived by the industry to get some of their aircraft out of the high traffic flow between point A and point B and to take some of the bends out of the routes, and it is for multiple airways.

If you take out the bends it can reduce substantially the operating costs.

Senator CANNON. It should facilitate the control problem as well.

Mr. O'DONNELL. Yes, sir.

Senator CANNON. Senator Baker?

Senator BAKER. What particularly would you recommend to assist in financing the acquisition of the collision avoidance equipment for general aviation aircraft that you refer to in your statement?

I understand from your statement that you are opposed to dipping into the trust funds for that purpose. I agree with you, but what would you recommend?

Mr. O'DONNELL. If you look at the price that some of the general aviation aircraft operators today are being charged for landing fees and the taxes on their equipment and the aircraft itself, perhaps credits could be given for installation of CAS equipment. So perhaps part of the cost could be absorbed by the Federal Government in tax credits to these operators.

Senator BAKER. What sort of credit? Do you mean credit against his income tax?

Mr. O'DONNELL. I mean credit against the taxes presently being paid on the aircraft. Otherwise we would have everybody buying airplanes and getting tax credits on the purchase of equipment.

Senator BAKER. Of course you would get a tax credit for buying an airplane; and, for that matter, for buying the equipment.

Mr. O'DONNELL. Perhaps there could be insurance premium reductions for that type of installation. There was a statement made that perhaps there could be a 5-percent credit. If you reduce the potential for the liability coverage they put on the 747 and air bus, et cetera, they may be willing to pass some of these on to the general aviation operators.

Senator BAKER. Have you talked to the insurance companies about it?

Mr. O'DONNELL. I personally have not.

Senator BAKER. Has anybody done so that you know of?

Mr. O'DONNELL. Members of our Collision Avoidance Systems Committee, made up of three airline captains around the country, have talked about this in committee meetings. I am not aware of the outcome.

Senator BAKER. I guess the overall and most general and I believe the most important question involved in this particular line of inquiry is whether or not you believe that the state of the art has progressed to the point where by governmental action we are in a position by tax incentives, by statute or otherwise to require the installation of this equipment.

Are you convinced that we are at that state of the art in development?

Mr. O'DONNELL. We believe we are now. In fact we believe we have had the capability for many years but no action has been taken on it. Not a forceful action. I think that if we don't get on with it now we will be sitting 10 years from now still explaining about midair collisions and still researching some collision avoidance systems.

Senator BAKER. I am not trying to argue the merits of it, but I want your opinion: Are you convinced that we have reached a stage of technological development where, through a system of tax credit, rulemaking, or statute, we are ready to commit ourselves to a national collision avoidance system?

Mr. O'DONNELL. With very little more proof and testing of the equipment that presently exists and inflight actual experience rather than depending only on computer analysis and similation we believe we are at that state of the art right now.

Senator BAKER. How much more testing?

Mr. O'DONNELL. We would not like to put a time frame on it, but we think we are in the short strokes of the program. We think little testing is necessary.

Senator BAKER. Is this a matter of days, weeks, or months?

Mr. O'DONNELL. In months, I am not talking about a year. I would hope they would have it within a 6-month period.

Senator BAKER. Do you have any estimate or does your association have an estimate of the total cost to the civil air fleet for equipping them with this equipment?

Mr. O'DONNELL. No, there were some figures given by the Air Transport Association at one of the previous hearings on total cost. We don't have them, sir.

Senator BAKER. Do you have some estimate? I'm talking about general aviation and airlines—all aircraft except military aircraft.

Mr. O'DONNELL. We don't have that figure, sir.

Senator BAKER. Maybe someone else could come up with it. I am trying to figure out whether we are talking about $10 million or a billion dollars.

Mr. LINNERT. I would recommend that be directed to the ATA witness and to the manufacturing witnesses. It seems to vary; we can't pin it down.

Mr. O'DONNELL. We have had figures quoted from $300 to $1,500 and from $2,500 to $8,000 for air carrier installations. I have heard figures at the August hearing that it was $25,000 per installation.

Senator CANNON. Do you have any idea what the Piedmont system cost?

Mr. O'DONNELL. We would have to refer that to the ATA witness because they purchased the EROS II and they purchased it for 36 aircraft, I don't know what the total figure would be.

Senator CANNON. We will ascertain that.

Senator Moss?

Senator Moss. Thank you.

Captain O'Donnell, I want to commend you for your emphasis of the urgency of coming to grips now with this rather than studying it indefinitely and I accept your suggestions we ought to find some way to assist the general aviation owners to install the system.

I know there is a degree of apprehension among those owners of small general aviation aircraft that this might be so expensive that it would discourage many of them from flying because they couldn't afford it. We wouldn't want anything that would impair general aviation, at the same time they are the major factor in the safety problem we need to solve. So we do need some incentive perhaps by way of tax relief and registration fees or relief from some other kind of cost that they have to bear anyway to help share the burden. I do appreciate your testimony very much.

Senator BAKER. May I ask one more question, Mr. Chairman?

Senator CANNON. Yes, sir.

Senator BAKER. I was trying to identify for my own purposes what sort of credit we would be establishing. We have established that we both oppose raiding the trust fund, but the only taxes I know of that you pay for general aviation aircraft are the annual fees based on takeoff weight and fuel tax. Don't both of them go to trust fund and wouldn't this amount to a raid on the trust fund anyway?

Mr. O'DONNELL. One of the reasons—they also pay excise tax. Another thought was we ought to perhaps provide a long term financing for them at some controlled interest rates rather than the 8, 10, 11, and up to as high as 18 percent for some of their purchases. We are in favor of any vehicle that will reduce their cost and exposure and encourage them to put that equipment in.

Senator BAKER. I agree in principle but I am trying to see how we can accommodate that purpose and still keep from raiding the trust fund. Because I am afraid that any credit we make will amount to that.

Senator Moss. Except insurance premiums. That is another area spoken of.

Mr. O'DONNELL. Yes.

Senator BAKER. All right, thank you.

Senator CANNON. Thank you very much, Captain O'Donnell.

(The statement follows:)

AIRCRAFT COLLISION PREVENTION: A WORLDWIDE PROBLEM

by

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Presented at the IFALPA Technical Symposium
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This IFALPA Technical Symposium provides an excellent opportunity to speak on a worldwide basis regarding the collision prevention subject which is so very important to sound aviation growth. Our compliments to those who planned the agenda for this meeting.

Knowing that other speakers will cover the air traffic control aspects of collision avoidance, the main thrust of this paper is directed toward expediting the achievement of a midair collision prevention system which is independent of the air traffic control (ATC) system, and in no case a substitute for the ATC system. Collision prevention must provide redundancy to the air traffic control system in the same manner that an aircraft has redundancy in its hydraulic or electrical systems for sustaining flight when one system fails.

To present ALPA's views, this paper will concentrate on the following for the prevention of midair collisions:

-- Aircraft lighting (strobe);
-- Collision avoidance systems;
-- Proximity warning indicator (Infrared and others).

Before presenting our views on the aforementioned three subjects, some background data, such as the need for priority funding, collision accident costs, U.S. congressional interest and statistics will indicate how obviously serious this matter is, worldwide, and stress the need for expediting the solution of the midair collision problem. Progress in the past has, in our opinion, been extremely slow. However, it is gratifying to see an accelerated tempo toward solving the problem.

One indication of the U.S. FAA's increased research and development efforts in the field of anticollision systems is that the agency has budgeted a total of $3.6 million for fiscal 1972, as compared to a total of $4.5 million that the agency has spent for this purpose over the past 15 years.

Another indication is that 14 electronic equipment firms have met with ALPA representatives to discuss their proposed collision prevention systems. A competition is now in evidence which is most gratifying, considering that about five years ago virtually no appreciable civil aviation collision avoidance research and development work was in progress.

To bring the problem of terminal area midair collisions into perspective, it is considered advisable to call attention to a four-year U.S. analysis of midair collisions, during reported VFR weather, occurring below 10,000 feet in the terminal area involving airline aircraft and general aviation aircraft. (See Appendix A.)

While considerable information is depicted in Appendix A, the data obviously discloses that the present ATC system does not provide adequate aircraft separation and as testified at the November, 1969, U.S. National Transportation Safety Board's Midair Collision Hearing, "ATC is not and never will be infallible." Appendix A also shows that it is impossible to prevent collisions by the long obsolete "see and avoid" method. While Appendix A shows that the collision course closure speeds are quite slow, little time for an "outside watch" in all directions is possible, especially when inside cockpit time consuming duties must be performed.

Speaking at the March 26, 1971 "Midwestern Aviation Conference," our FAA Administrator John Shaffer (referring to U.S. aircraft) predicted that for the next ten years there will be "a growth in the number of airline aircraft from 2,580 to 3,640" and an "expansion of the general aviation fleet from 134,000 to 232,000" aircraft. Obviously, more airplanes will be flown with more hours in the air, and unless a collision prevention system is implemented, collisions will increase. This, of course, emphasizes the urgent need for shortening the time frame for achieving a collision avoidance system.

PRIORITY FUNDING FOR R&D

Is the research and development effort to produce midair collision prevention hardware progressing rapidly enough--especially with respect to its importance in regard to safety and aviation growth?

An excellent example of a successful attack on the midair collision problem is the manner in which the U.S. Army has rapidly equipped its helicopter fleet at Fort Rucker, Alabama, with a satisfactory proximity warning system. The training load at the U.S. Army Aviation School at Fort Rucker had increased to a level in late 1967 at which the midair collision hazard affected the pilot training, and the need for a proximity warning system became very evident. Development was initiated in 1968 with an invitation to the electronics industry to submit proposals for applicable devices for a competitive flight test evaluation. Five companies responded. After a pre-production evaluation, a production contract for 222 units was awarded to one electronic equipment manufacturer. Delivery of the units started in December 1969 and was completed in August 1970. Installation of the units in helicopters started in January 1970 and by September 1970 there were 200 helicopters operating with proximity warning indicators. Latest information discloses that these installations have accumulated more than 275,000 in-flight hours without a midair collision.

This shows what can be done when an aggressive, properly funded research and development program of high priority is implemented.

The U.S. aviation community is aware of the number of million-dollar-plus grants to many research and development projects--all no doubt worthy of effort. However, in connection with the need for adequate funding for a collision avoidance system, the following is of real concern:

Excerpt from ALPA's paper presented during the U.S. National Transportation Safety Board's Hearing on the Midair Collision Problem, November 4-10, 1969:

> "More than four years have passed since the U.S. National Aeronautics and Space Administration Research Advisory Committee on Aircraft Operating Problems passed its strongly worded resolution to highlight the importance of the problem. The May 1969 NASA Report No. TN-5174 entitled, 'Compilation of Data from Related Technologies in the Development of an Optical Pilot Warning Indicator System,' states the research effort was conducted ' . . .mostly on a less-than-full-time basis.' This is a shocking statement because the midair collision problem is so serious that research should have been and should continue to be conducted on an overtime basis. Directing attention to this report is not intended to adversely reflect on NASA scientists and the commendable research they have conducted, but rather to emphasize that their efforts should be augmented and adequate funds be provided without delay." (Underline supplied.)

Excerpt from Aviation Week, March 22, 1971:

> "Modest-level study of a low-cost anti-collision system for general aviation aircraft which would be compatible with the Air Transport Association-sponsored time/frequency collision avoidance system will be funded by NASA's Langley Research Center. Nine companies submitted proposals, including Bendix, Sierra Research and Wilcox, which participated in the development of airline time/frequency equipment. McDonnell Douglas, which had previously conducted a study of low-cost general aviation versions for NASA's Electronics Research Center, declined to submit a proposal on the grounds that it was ready to build flight hardware." (Underline supplied.)

Excerpt from ICAO's July 2, 1971 letter relating to the ICAO Seventh Air Navigation Conference (April, 1972), Agenda Item 7:

> "Systems for collision avoidance: Consideration of the need for standardization of system specifications and applicability provisions for collision avoidance systems including proximity warning indicators:
>
> Experimental activities, including operational and simulation trials of collision avoidance systems (CAS) and proximity warning indicators (PWI), have been taking place using a number of different concepts for several years and this item presents an opportunity for States which have

> been active in this field to make known the results of these studies. It is hoped that developments will have reached the stage where there can at least be a discussion of the system concepts and characteristics that may result in eventual standardization. It is also believed it would be desirable for the Conference to discuss CAS (including PWI)/ATC integration problems in order to determine the impact, adverse or otherwise, that the use of CAS might have on the ATC system. However, the Air Navigation Commission has indicated that it expects these problems to be dealt with in general terms and not explored in depth at this time." (Underline supplied.)

Here again, one of the aviation world's greatest potential hazards, the midair collision, continues to be given "modest-level study." It is no wonder that approximately 15 years of "mostly on a less-than-full-time-basis" effort have resulted in little progress toward decision-making on a collision avoidance system.

Hopefully, the ICAO Air Navigation Commission will reconsider its treatment of Agenda Item 7, "Systems for Collision Avoidance," and provide adequate discussion time to examine collision prevention planning in depth. Further, that the IFALPA representatives attending this meeting stress to their governments the importance of expediting solution of the midair collision problem.

THE COST OF MIDAIR COLLISIONS

The expense of a collision avoidance system can be justified by an examination of the forecast cost of midair collisions in the U.S. for the period 1970-1980, as shown by the table, "Disbenefit Estimates for Air Carrier/General Aviation Collisions."

Disbenefit Estimates for Air Carrier/General Aviation Collisions:

1970 - 1980

1. Cost Estimate Base:

Average value of air carrier aircraft				$7,000,000
Average value of general aviation aircraft				$ 30,000
Minimum base for human life	=	$14,750 (discounted at 6% for 25 years*)		
	=	$189,000 (230,000 at 4% discount)		
Government investigation costs	=	$200,000		

2. Estimates using sample of 10 collisions (1965-69):

a) Total fatalities	=	221 ×	189,000	=	$41,769,000
b) GA aircraft destroyed	=	8 ×	30,000	=	240,000
c) AC aircraft destroyed	=	4 ×	7,000,000	=	28,000,000
d) GA aircraft substantial damage (1/3 value)	=	1 ×	10,000	=	10,000
e) AC aircraft substantial damage	=	2 ×	2,300,000	=	4,600,000
f) Investigation costs	=	10 ×	200,000	=	2,000,000
TOTAL					$76,619,000

Average/Collision = $7,700,000

*Based on HEW study by D.Rice, "Estimating the Cost of Illness," Health Economic Series #6, May 1966.

This table, excerpted from FAA's Staff Study entitled, "An Analysis of ARTS III Terminal Area Automation System Benefits and Costs," does not take into account the result of retarding the acceptance of air travel by the public, loss of life, or the adverse effect on the purchase of new general aviation airplanes.

The March 3, 1971 Washington Star (Washington, D.C.) newspaper contained an article relating to one collision accident indicating that negotiations were taking place for "damage claims of some $70 million." Further, that a December 16, 1960 collision between two airliners "produced payments of more than $29 million."

Based on qualified estimates, the cost of a midair collision between two jumbo jets would go a long way toward equipping the entire U.S. air carrier fleet with collision avoidance systems.

The above estimates in loss of lives and equipment will continue to increase in cost yearly. According to current estimates it may be approximately 1978 before collision avoidance systems will be operating to prevent midair collisions. It is in the best public interest that this time frame be substantially shortened.

U.S. CONGRESSIONAL INTEREST

U.S. Congressional interest in the midair collision problem has been evident over the years. In fact, essentially the Congress established the need for the Federal Aviation Act of 1958 in the United States, due to the midair collision of two airliners over the Grand Canyon on June 30, 1956, when 128 lives were lost.

On July 24, 1967, Congressman Fascell introduced a Bill (H.R. 11677) in the House of Representatives; quoted as follows:

> "A BILL"
>
> "To amend Section 312(c) of the Federal Aviation Act of 1958, relating to research and development, to require the Federal Aviation Administrator to provide for the development of a proximity warning device for use on all civil aircraft of the United States in the interest of safety in air commerce.
>
> "Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That section 312(c) of the Federal Aviation Act of 1958 (49 U.S.C. 1353(c)), which relates to research and development, is amended by inserting '(1)' immediately after '(c)' and by adding at the end thereof the following new paragraph:
>
> > "(2) In carrying out his functions, powers and duties under this section pertaining to aviation safety, the Federal Aviation Administrator shall undertake or supervise such research, developmental work, and service testing as he may deem necessary to develop, and make available as soon as possible, a proximity warning device for use on all civil aircraft of the United States to improve safety in air commerce. Such proximity warning device shall be designed to give aircraft pilots and other members of the operating crew adequate warning of the proximity of any other aircraft and indicate the location and direction of flight of such other aircraft so as to enable the pilot and other crew members to avoid in-flight collisions in air commerce. Such device shall be designed so that it can be manufactured and sold at a cost

which the Administrator determines is sufficiently reasonable that its required use on all civil aircraft of the United States will not impose an unreasonable economic burden on air carriers and other aircraft owners and operators."

The Bill was obviously not enacted upon but was "referred to the Committee on Interstate and Foreign Commerce."

Recently, we were encouraged by a Subcommittee of the U.S. Congress scheduling a hearing on August 3, 1971 to determine the status of research and development, and availability of collision avoidance hardware. Several highly respected electronic aviation equipment manufacturers testified to the effect that they had progressed to the point that they had the capability of providing, for flight test, collision prevention hardware. Some of this equipment has already been extensively flight evaluated. ALPA provided testimony relating to again pressing for funds for expediting R&D to produce flight and service testing of hardware to enable early installation of collision avoidance means.

We were also encouraged by continued Congressional interest in solving the midair collision problem when we received a copy of a Bill (S. 2264) which Senator Moss introduced to Congress on July 12, 1971, quoted as follows:

"A BILL"

"To amend Section 601 of the Federal Aviation Act of 1958 to require the installation of collision avoidance and pilot warning indicator systems on certain aircraft, and for other purposes.

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That Section 601 of the Federal Aviation Act of 1958 (49 U.S.C. 1421) is amended by adding at the end thereof the following new subsection:

"COLLISION AVOIDANCE AND PILOT WARNING INDICATOR SYSTEMS"

"(e) Not later than January 1, 1973, minimum standards pursuant to this section shall include requirements that--

(1) a collision avoidance system shall be installed on any aircraft having a maximum certificated takeoff weight of 12,500 pounds or more (5700 kg); and

(2) a pilot warning indicator system shall be installed on any aircraft having a maximum certificated takeoff weight of less than twelve thousand five hundred pounds.

"Section 2. The Administrator of the Federal Aviation Agency is authorized and directed to require, not later than January 1, 1975, that a collision avoidance system or pilot warning indicator system shall be installed on public aircraft as defined in section 101 (30) of the Federal Aviation Act of 1958."

This Bill was "referred to the Committee on Commerce." We hope it will aid in stimulating rapid progress toward the implementation of collision prevention hardware. At this writing it is indicated that a hearing will be held to obtain industry testimony relating to "Bill S. 2264."

WORLDWIDE COLLISION STATISTICS

Since this is an international meeting, some information on worldwide collision statistics is offered to show that no nation is exempt from the collision potential. To date, 19 nations have had at least one midair collision resulting in a total of 1,209 fatalities. In addition, 98 passengers and crew members who survived sustained serious injuries. A total of 69 persons on the ground also sustained serious injuries from falling debris.

Figure 1 shows that during the span of years from 1946 to August, 1971, a period of about 25 years, that 70 midair collisions occurred involving airline aircraft. Thus far in 1971 there have been four midair collisions. In 1969 the Department of Transportation in the U.S. predicted that by 1980, "We would expect approximately 10 midair collisions per year" between air carrier and general aviation aircraft within the United States. Using forecasts of increases in numbers of airplanes by 1980, it can readily be seen that we must get on with solving the midair collision problem.

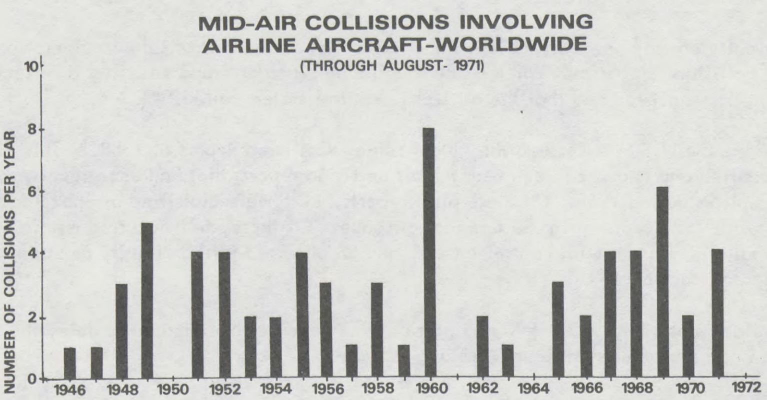


FIG. 1

Statistics shown in Figure 2, relating to the three categories of collision accidents involving airline aircraft, discloses the extent of the problem.

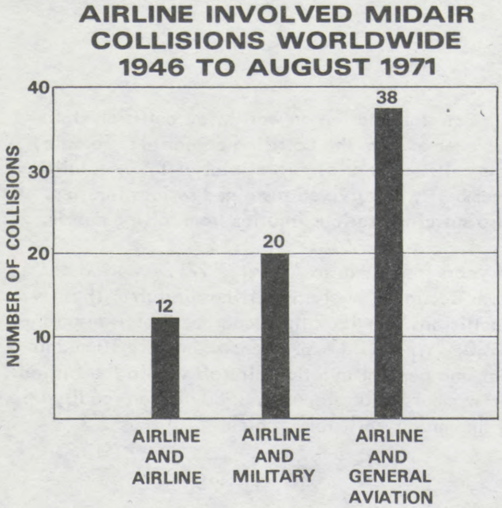


FIG.2

Not shown, but widely known, is the very disturbing number of midair collisions between two general aviation airplanes.

We also frequently read about two military airplanes colliding.

NEAR COLLISION STATISTICS

To realistically portray how very serious the situation is, we must take into consideration the "near collision" statistics. When a "near collision" incident report is filed it reflects a virtual midair collision and that the air traffic control system failed.

In July 1969, the U.S. FAA issued the "Near Midair Collision Report of 1968." This report classified and analyzed 2230 near midair collision reports that had been received from U.S. pilots during 1968. Of these pilot reports, 1128 were classified as "hazardous" to flight, with 719 occurring in the terminal airspace. Of these, 621 occurred within a 30-mile radius of airports with control towers, and 98 occurred in the vicinity of airports without control towers.

While similar reports for 1969, 1970 and part of 1971 have not been issued to date, the following U.S. near collision figures are available:

1969:	Total near midairs	=	1,444
	Hazardous	=	966
	No Hazard	=	478
1970:	Total near midairs	=	1,456
1971:	Total near midairs	=	409 (January thru May)

To date the reports for 1970 and 1971 have not been classified or evaluated. It must also be borne in mind that the analysis of the statistics relate only to those reported. A great many are not reported.

AIRCRAFT STROBE LIGHTING

The struggle to gain recognition of the fact that strobe lights aid in reducing the collision hazard has lasted far too long. Strobe lighting on aircraft for minimizing the collision hazard was demonstrated to the Association and industry in 1954 by Captain H. W. (Bill) Atkins of NWA during ALPA's Annual Air Safety Forum. He is to be credited and commended for personally conducting in his own airplane, an early unrelenting design and flight testing effort toward getting strobe lighting recognized as a means to minimize the collision hazard. In 1963 and 1969, at ALPA Air Safety Forums, strobe light manufacturers conducted "fly-bys" which demonstrated the superiority of the strobe lights on aircraft. ALPA testified at congressional hearings that strobe lights would aid in minimizing the midair collision hazard. ALPA petitioned for FAA rule making.

On August 11, 1971, the U.S. Federal Aviation Regulations were amended to permit the use of either aviation red or aviation white anticollision light systems. The amendments also increased the minimum intensity of the lights. Similar action to require the use of condenser discharge strobe lights will unfortunately not be taken until a current evaluation program has been completed.

The "Report of Proceedings of the National Transportation Safety Board (NTSB) into the Midair Collision Problem, November 4-10, 1969," is most revealing. The report discloses that nine major segments and consultants of the aviation industry stated they supported the installation of strobe lights as an aid toward minimizing the midair collision hazard.

Also of great significance is that the October, 1970 USAF Midair Collision Conference, passed the following recommendations on "Aircraft Lighting" as a result of discussions:

"1. The adoption of white lighting of the high intensity strobe variety versus red lighting due primarily to the higher intensity available from a given power source.

"2. USAF through DOD support the FAA position to require anticollision light(s) on all aircraft.

"3. Take immediate action to procure and install 360° white strobe lights on the upper and lower fuselage of all USAF aircraft, to be operated during both day and night flying operations."

The foregoing USAF recommendations have the stature of being classified as a Phase I recommendation which is to be considered for accomplishment in one year.

In 1966 the U.S. National Aeronautics and Space Administration (NASA) determined that the strobe lights emitted an infrared signal which could be utilized in an economical proximity warning indicator. Additional research and development is continuing and has progressed to the point where proximity warning systems are considered feasible and are in flight test evaluation. Thus, this is another reason for pressing on with a mandatory strobe light requirement for all airplanes.

Airline pilots and air traffic controllers report that aircraft equipped with strobe lighting are more easily locatable and assist in providing separation, thereby reducing the collision hazard.

Also very worthy of mention are statistics which indicate that airplanes equipped with the strobe anticollision lights minimize the "bird strike" potential. This was described in an article in the March 1970 AIR LINE PILOT magazine entitled, "Mandatory Strobes" by Captain James Golden of Mohawk Airlines.

The accident/incident records disclose that bird strikes result in (1) fatal accidents; and (2) major aircraft damage. It is then significant that, in addition to providing considerable protection from the midair collision and near-collision potential, a strobe light can provide protection on large--and especially small--aircraft from encountering a bird strike resulting in a potentially fatal accident or costly damage to the aircraft.

It is in the best public interest to require strobe lights on all aircraft. This requirement has industry and military support. The strobe lights are readily available ranging from $100 per installation on small aircraft to a higher priced installation of several strobe lights for large airplanes. If a pilot sees a strobe light flashing sufficiently far ahead, he can evaluate the conditions and make a gentle maneuver rather than a violent one which is unnerving to pilots and frightening to passengers. Information relating to midair collisions is difficult to obtain; however, to our knowledge, airplanes involved in midair collisions during the past five years DID NOT have strobe lights installed.

COLLISION AVOIDANCE SYSTEM (CAS)

The U.S. Air Transport Association has commendably funded a costly and revealing research and development program for a collision avoidance system. Testing of the system using airline-type airplanes has been completed. The system successfully demonstrated that high and low speed collisions can be prevented in IFR and VFR weather by airplanes equipped with the time/frequency system.

The airline-sponsored time/frequency CAS, which has undergone extensive flight testing and computer simulation, has a singificant lead over much of its competition in terms of demonstrated capability and early availability. Extensive flight tests of airline and business aircraft type hardware were conducted in 1968-69 using both jet and piston-engine aircraft.

The FAA is now conducting simulation tests at its Atlantic City facility to determine the effect of the CAS and its vertical escape maneuver on air traffic control procedures. Tests so far have demonstrated that the only potential problem might be in the terminal areas which employ two parallel runways.

Presently, research and development is well on the way toward providing a low cost unit for general aviation airplanes which will be compatible with the airline system. The objective is to provide collision avoidance means in ALL aircraft.

The design of a CAS has progressed to the point where an instrument display providing command information for the pilot to use to prevent a collision has been selected. A similar pilot display for the general aviation CAS is being developed. Within a month, the FAA expects to request industry bids for the development of a ground station that can be used to synchronize precisely each airborne equipment of the time/frequency type.

CAS concepts in development by electrical companies are (1) time/frequency; (2) radar Doppler; (3) transmitter/receiver; and (4) transponder.

By definition, a CAS provides the pilot with command information to take evasive action during VFR/IFR weather. Proximity warning indicator systems differ from CAS in that a PWI system provides the pilot with an aural alert and in some systems a directional indication of the potential collision threat, and the pilot must see the other airplane and initiate evasive action.

Lack of adequate funding must not delay installing CAS units in airline and general aviation aircraft for extensive flight evaluation. An accelerated program to accomplish this goal as soon as possible is in the best public interest.

PROXIMITY WARNING INDICATOR (PWI)

Several proximity warning indicator systems have reached the status of flight evaluation. Others are being evaluated in the laboratories. Industry interest in the United States is at an all time high. The previously mentioned NTSB report discloses that a significant number of aviation authorities and representatives from the industry endorse expediting research and development for PWI systems. Some systems provide only an alert for the pilot to "see and avoid" another aircraft. Some provide an alert plus directional information to assist the pilot to rapidly detect another airplane on a potential collision course. PWI devices, while limited in range, can provide considerable "see and avoid" time as shown in Appendix B. Also worthy of special note is that the Chart, Appendix A, illustrates that the collisions involving airliners and general aviation airplanes occurred at low altitudes and low closure speeds, providing at least 20 or more seconds for the pilot to take evasive action, when PWI devices provide a 2-mile range for collision detection. PWI specifications are being evaluated in the laboratories, by simulation, and in flight to determine the time required to assure to a high degree that the pilot can "see and avoid" another airplane.

In a statement prepared for the 1969 NTSB "Hearing into the Midair Collision Problem," ALPA analyzed 124 midair collisions that occurred during five years (1964 through 1968). Of the 124 analyzed, it was only possible to collect data from 105, because 19 midair collision accidents were of a nature that the airplane's flight path prior to collision was unknown. The analysis did disclose that the 105 midair collisions occurred at (1) low altitudes (below 10,000 feet) and (2) at low closure speeds (below 250 knots). These are factors which are favorable for a low cost PWI and also adaptable to a more sophisticated collision avoidance system.

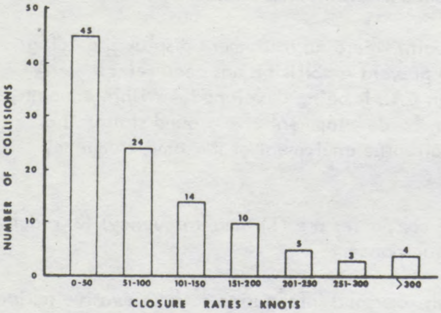


Figure 3.

Figure 3 illustrates a breakdown of the number of collisions vs. the closure rate which is such an important factor in determining human reaction time required to determine an evasive maneuver.

Additionally, the 105 midair collision accident analysis discloses the flight path convergence angles as shown in Appendix C which provides data for PWI and CAS specifications considerations.

The U.S. Federal Aviation Administration Administration expects to solicit proposals for several types of airborne proximity warning indicators within several months and hopes to fund two or three of the more promising concepts for development. The "Request for Proposals" will define performance requirements and leave open the technique to be used.

All avenues to expedite research and development should be examined to determine the merits of PWI for minimizing the collision hazard.

CONCLUSION

The urgent need for expediting midair collision prevention can be seen by the emphasis placed by the major segments of the U.S. aviation community on:

(1) Strobe anticollision lighting on aircraft as an aid for reducing the collision hazard;

(2) Expanded research and development of a collision avoidance system for all aircraft;

(3) Expanded research and development for a proximity warning indicator.

It must be apparent that, while this paper has principally discussed the collision hazard situation as it applies to the United States, a similar situation also applies to many other countries. In fact, since the airlines of most countries operate into the U.S., they are exposed to the same midair collision hazards. Collisions and near midair collisions have occurred in the vicinity of airports all over the world, even those having a relatively low density of traffic. Because of this, it is incumbent upon all of us to extend every possible effort to encourage all government agencies to establish the prevention of midair collisions as a top priority item.

The Air Line Pilots Association greatly appreciates the invitations received from industry and government to participate in the effort of achieving prevention of aircraft collisions.

RECOMMENDATION

In view of the great concern of the aviation industry toward the attainment of an early solution to the midair collision problem, it is strongly recommended that aviation authorities worldwide endorse a solution of the problem as a very high priority item for receiving adequate funding for research and development of hardware and accelerated testing programs to assure the earliest practical date for the implementation of midair collision avoidance means.

REFERENCES

1. "Report of Proceedings of the National Transportation Safety Board Hearing into the Midair Collision Problem, November 4-10, 1969," Report No. NTSB-AAS-70-2.

2. National Transportation Safety Board Accident Investigation Reports, 1967 through 1970, relating to midair collisions.

3. "The Urgent Need for a Low Cost Short-Range Collision Prevention Device," 1969 report by Ted Linnert, U.S. Air Line Pilots Association.

4. "Midair Collision Conference Report," United States Air Force, October 1970.

5. "World Airline Accident Summary," Air Registration Board.

ALPA MID-AIR COLLISION ANALYSIS

(BELOW 10,000' AND VFR)

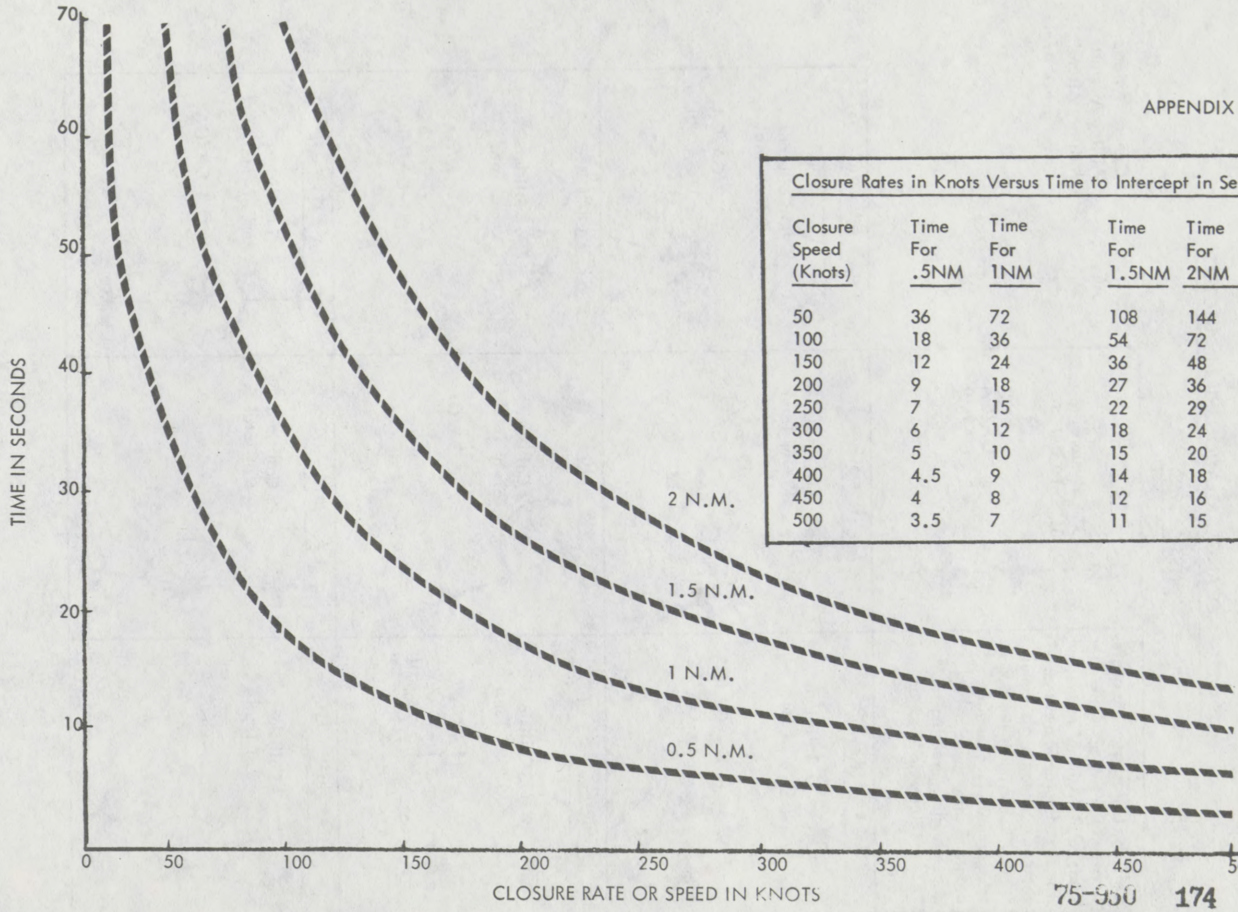
INVOLVING GENERAL AVIATION AND AIRLINES

(1967 - 1970)

Date	Location	Aircraft Type	Weather Condition	Approx. Airspeed (Knots)	Climb, Descent or Level	Straight or Turn	Convergence Angle in Degrees	Flight Regime	Impact Altitude (Feet)	Closure Speed (Knots)	Seconds Warning Time 1/2 N.M. Range	Seconds Warning Time One N.M. Range	Seconds Warning Time 1-1/2 N.M. Range	Seconds Warning Time 2 N.M. Range	Distance From Airport (Miles)	Remarks
3/9/67	Urbana, Ohio	DC-9 Beech B-55	Day/VFR	323 168	Descent Descent	L-Turn Straight	31-50	Approach Enroute	4,525	222	8	16	24	32	25	26 Fatalities
7/19/67	Hendersonville, North Carolina	B-727 Cessna 310	Day/VFR	230 140	Climb Level	L-Turn Straight	131-150	Takeoff Enroute	6,132	349	5	10	15	20	8	82 Fatalities
3/27/68	St. Louis, Mo.	DC-9 Cessna 150	Day/VFR	135 94	Descent Descent	Straight L-Turn	11-30	Approach Approach	1,100	57	32	64	96	128	1.5	2 Fatalities in Cessna
5/12/68	Denver, Colo.	B-727 Cessna 377	Day/VFR	250 66	Descent Descent	Straight Straight	71-90	Approach Approach	9,000	247	7	14	21	28	20	Minor Damages. Both landed safely.
8/4/68	Milwaukee, Wisconsin	CV-580 Cessna 150	Day/VFR	190 80	Level Level	Straight Straight	31-50	Enroute Enroute	2,500	140	13	26	39	52	11.5	2 Fatalities in Small Aircraft
2/6/69	Harlingen, Tex.	DC-9 Piper PA-28	Night/VFR	140 80	Descent Descent	Straight L-Turn	0-10	Approach Approach	300	64	28	56	84	112	0.25	Piper destroyed No Fatalities
8/3/69	Fort Worth, Tex.	B-707 C-172	Day/VFR	220 110	Level ?	Straight Straight	131-150	Approach Enroute	8,500	312	6	12	18	23	12	2 Fatalities -- C-172
9/9/69	Indianapolis, Indiana	DC-9 Piper PA-28	Day/VFR	256 100	Descent Level	Straight Straight	91-110	Approach Local	2,800	283	6	12	18	25	18	83 Fatalities
3/1/70	Vancouver, B.C.	Viscount Ercoupe	Day/VFR	180 87	Descent Level	Straight R-Turn	71-90	Approach Enroute	1,500	186	10	20	30	40	8	One Fatality
7/20/70	Tarragona Spain	B-737 Cherokee	Day/VFR	160 100	Descent Climb	R-Turn Straight	11-30	Enroute Enroute	1,750	75	24	48	72	96	2	3 Fatalities

APPENDIX A

APPENDIX B



Closure Rates in Knots Versus Time to Intercept in Seconds

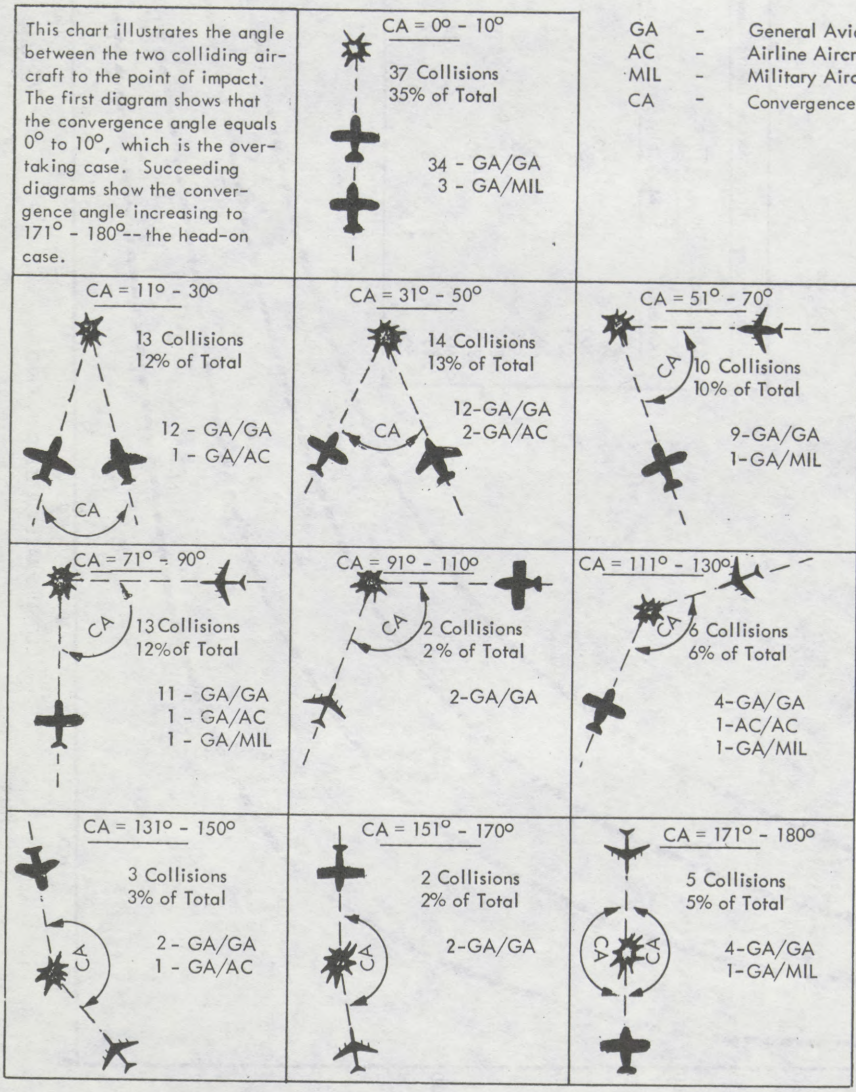
Closure Speed (Knots)	Time For .5NM	Time For 1NM	Time For 1.5NM	Time For 2NM
50	36	72	108	144
100	18	36	54	72
150	12	24	36	48
200	9	18	27	36
250	7	15	22	29
300	6	12	18	24
350	5	10	15	20
400	4.5	9	14	18
450	4	8	12	16
500	3.5	7	11	15

APPENDIX B

APPENDIX C

CONVERGENCE ANGLE RELATIONSHIPS IN DEGREES

(1964 - 1968)



GA - General Aviation
AC - Airline Aircraft
MIL - Military Aircraft
CA - Convergence Angle

PRESENTED AT A HEARING
BEFORE A
SUBCOMMITTEE OF THE COMMITTEE
ON
GOVERNMENT OPERATIONS
HOUSE OF REPRESENTATIVES
AUGUST 3, 1971

STATEMENT OF
CAPT. JOHN J. O'DONNELL, PRESIDENT
AIR LINE PILOTS ASSOCIATION
ACCOMPANIED BY
CAPT. A.C. BONNER, FIRST VICE PRESIDENT, ALPA
AND
TED LINNERT, DIRECTOR OF ENGINEERING AND AIR SAFETY, ALPA

I am John J. O'Donnell, President of the Air Line Pilots Association. I represent the professional interests of 31,000 airline pilots of 39 commercial airlines and 12,000 stewards and stewardesses of 22 airlines.

I appreciate this opportunity to appear before your committee to express the extreme concern our members have about this very serious problem. As more and more aircraft, with ever increasing capacity and speed, are taking to the skies over this Nation and indeed the world, the hazards of more midair collisions also increases.

Unfortunately, just recently another collision between a commercial jetliner and a military fighter has taken place over California while the industry continues to debate over the need for a collision avoidance system. This recent tragedy only dramatizes further the overwhelming need for a collision avoidance system that should be installed in all aircraft as soon as possible.

It is a simple escape mechanism to attempt to place the responsibility of a midair collisior on the pilot of one aircraft or the other. In fact, the true blame rests with those who foster and perpetuate a system that will allow two aircraft at the same altitude at the same time and at the same place.

In Tokyo this past weekend a military trainee and his instructor were arrested on suspicion of "negligence" following a midair collision.

The military aircraft struck an All Nippon Airways 727 resulting in the death of 162 people.

As a result, Japan's Defense Minister resigned in shame, at a special cabinet meeting, because he believed the defense forces which he commanded were responsible for this collision.

An analysis of the reports on the midair collisions over these United States for the past 10 years will produce reams of differing opinions as to whom is to blame. Repeatedly, however, throughout these collision reports you will find airline pilots speaking out consistently and loudly for positive separation, positive control, a fail-safe on-board collision avoidance system and a modern air traffic control system which will remove the heartbreak caused by midair collisions.

This is not a new requirement. It has existed for many years. It will continue to exist until we have a system that will give advance warning to all pilots that a possible collision between their aircraft and another is imminent.

While it seems everyone recognizes the need for a collision avoidance system and other kinds of hardware to help solve the midair collision problem, there has not been sufficient effort on the part of the Government to give it a proper research priority. There has not been sufficient creative research followthrough. The airline companies themselves must put stronger emphasis on the need for a CAS.

The FAA, NASA, and private research institutions should be tackling this very serious hazard to safe flight with vigor and every resource they can muster. Human lives depend on an expedited solution to this problem.

It is the recommendation of the Air Line Pilots Association that major emphasis be placed immediately by the Government on five major areas of collision avoidance research and installation:

1. Expedited installation of strobe anticollision lighting on all aircraft.

2. Expanded and expedited research and development of a collision avoidance system for all aircraft and regulations for accelerated installation of reliable fail-safe systems.

3. Expanded research and development for a proximity warning indicator system.

4. Continual research and operational inflight testing of on-board air traffic display systems.

5. Immediate lowering of the floor of the area of positive control to 10,000 feet over all of the contiguous 48 States.

For years there has been much resistance to some of our recommendations. The FAA has given the problem a relatively low priority over the past 15 years. Owners of small aircraft do not want to have to buy new, or possibly expensive devices. Some airlines view collision avoidance equipment as an unnecessary expense. Some representatives of these factions want to cling to the eyeball philosophy which puts the burden for collision avoidance largely on the eyesight of the pilot. The "see and be seen" concept should have gone out in the early 1940's.

Mr. Chairman, the pilots who fly the airliners of this Nation firmly believe the days have long since passed when the lives of the 170 million U.S. air travelers must depend on the archaic rule of "see and be seen." The days when pilots can depend solely on their own eye-sight to detect another aircraft converging on them in flight are over. Closure speeds of 500 to 2,000 miles per hour are just too great to expect reaction in time to prevent collisions.

There are far too many aircraft flying on VFR flight plans or under visual rules without flight plans in restricted visibility and marginal weather conditions, often in high density areas interwoven with many airliners operating under controlled instrument flight rules.

Radar in use today -- used as a primary tool by air traffic control -- still has not been perfected to the extent that it can be relied upon in all instances to prohibit collision potentials.

The installation of an appropriate collision avoidance system and a fully integrated air traffic control system must be accelerated. In our judgment, it is a miracle that we have not had more midair collisions than we have had to date. Luck has been on the side of the flight crews, the cabin crews, the passengers and the Government when you consider the number of aircraft aloft at any given moment of the day; and this with an intermix of controlled and uncontrolled aircraft.

Running a national transportation system on luck only can mean disasters and more grief are in store for us. The American people have had enough grief. They are saying that if we are brilliant enough to walk and drive on the moon, we must certainly be smart enough to design a system that will tell aircraft pilots when they are about to run into somebody else cruising in the earth's air space.

Mr. Chairman, at this point I would like to deviate from my prepared statement in the next three paragraphs because in the typing there were errors. I will submit, if you will accept it, a corrected statement.

Mr. Brooks. Without objection.

Mr. O'Donnell. It must be remembered the essence of the need for the Federal Aviation Act of 1958 was determined by the midair collision over the Grand Canyon on June 30, 1956, when 128 lives were lost. That is over 15 years ago.

I would like to quote portions of the House conference reports on those acts.

No. 1, S. 1181 dated July 9, 1958. No. 2, S. 2360, August 2, 1958. No. 3, S. 2556, August 12, 1958. Accompanying that is the Senate Report 3880. The page is 3742 of the House Report 2360:

> This is not hastily conceived legislation. Air space use and air safety problems have been under consideration for a long time by this committee and the Senate Committee on Interstate and Foreign Commerce.
>
> The magnitude and critical nature of the problem came first to general public notice, perhaps, as a result of the midair collision of two airliners over the Grand Canyon on June 30, 1956, when 128 lives were lost. Following this disaster were fatal air crashes between civil and military aircraft operating under separate flight rules established in the Civil Air Regulations.

Additional information on airspace use problems was developed by this committee in an investigation of these and later acts. The results of those investigations were given to the Congress in House Report No. 2927 entitled "Air Space Users Study," also House Report 1272 entitled "Air Transportation Development and Air Space Use Problems."

On June 13, 1958, the President submitted a message to Congress recommending the development of an independent agency saying:

> Recent midair collisions of aircraft, occasioning the tragic loss of human life, have instituted the need for a system of air traffic management which will prevent them, within the limits of human ingenuity.
>
> In this message, accordingly, I am recommending to Congress the establishment of an aviation organization in which would be consolidated, among other things, all of the functions necessary to accommodate the need for our civil and military aviation.

Mr. Chairman, I will tell you when I get back into this prepared statement. I have only one more page here.

The Air Line Pilots Association submits that the response of the FAA to their obligation under the act has not reduced the hazards of midair collisions by one iota. The following brief summary supports this statement. In the years between 1950 and 1971, there were 30 midair collisions involving air carriers, resulting in the deaths of 562 persons, including 472 passengers and 58 crew members and 32 other persons. This count does not include nine midair collisions in which no fatality occurred. But for this fortuitous circumstance, all of the 890 passengers aboard these aircraft would have been killed. Between 1956 and 1970 there were three midair collisions between air carriers, 14 between air carriers and general aviation planes, four between air carriers and military airplanes. There 35 between general aviation and military aircraft. The total fatalities in all reported midair collisions numbered 966 through 1970.

In 1967-68 hearings before the House, the FAA disclosed plans for a system that would effectively prevent midair collisions. Reference was made to a so-called three-dimensional radar by a Deputy Administrator of the FAA, David D. Thomas. According to Mr. Thomas, three companies had developed such a system, basically Holographic, Hughes Aircraft, and ITT. The Hughes system, Thomas said, had been used by the Navy while the ITT system was used in Atlantic City. However, despite its earlier promises, the 3D radar has proved disappointing and has been abandoned.

The Air Line Pilots Association, in the interest of safety for the passengers and crew members, would insist on an immediate response from the FAA, together with a definitive timetable not to exceed 2 years, for a system usable in all types of aircraft. The installation should be required by proper Federal air regulations.

I have submitted a more detailed presentation attached to my statement prepared by our Engineering and Air Safety Department, which presents the views of the Air Line Pilots Association on collision avoidance. It was made at the FAA National System Planning Review Conference last April.

In the interest of conserving your time and for full inquiry of all participants, particularly ourselves, I request permission to insert this supplementary data into the record.

I would be glad to respond to any questions at this time.

* * * *

COLLISION AVOIDANCE PLANNING

FOR THE

NATIONAL AVIATION SYSTEM

by

Ted G. Linnert, Director
Engineering & Air Safety Department
Air Line Pilots Association

Presented at the

FAA NATIONAL AVIATION SYSTEM

PLANNING REVIEW CONFERENCE

WASHINGTON, D. C.

April 27, 1971

* * * * *

Air Line Pilots Association, International
1329 E Street, N.W.
Washington, D. C. 20004

PREPARED FOR THE FEDERAL AVIATION ADMINISTRATION (AV-1)

COLLISION AVOIDANCE PLANNING FOR THE NATIONAL AVIATION SYSTEM

by

Ted G. Linnert, Director
Engineering & Air Safety Department
Air Line Pilots Association

We appreciate that the National Aviation System planning includes collision avoidance. In this regard, and knowing that other speakers will cover the air traffic control aspect of collision avoidance and planning, the main thrust of this paper is directed toward expediting the achievement of a Collision Avoidance System (CAS) which is independent of the Air Traffic Control (ATC) system, and in no case a substitute for the ATC system. The system must provide redundancy to the Air Traffic Control system in the same manner that an aircraft has redundancy in its hydraulic or electrical systems for sustaining flight when one system fails.

To present ALPA's views on "Collision Avoidance Planning for the National Aviation System," this paper will concentrate on the following areas which constitute the basis for the prevention of mid-air collisions:

Aircraft lighting (strobe);

Collision Avoidance System (Time/Frequency Concept);

Proximity Warning Indicator (Infrared and others).

Before presenting our views on the aforementioned three subjects, some background data, priority funding needs, and collision accident costs will, we are confident, indicate how obviously serious this matter is, and stress the need for expediting the solution of the mid-air collision problem. Progress in the past has, in our opinion, been extremely slow. However, it is gratifying to see an accelerated tempo toward solving the problem.

Background Data:

During the November 1969 National Transportation Safety Board hearing into the "Midair Collision Problem," ALPA presented a paper which analyzed a five-year period of 105 mid-air collision statistics (1964-1969) and a chart showing air carrier/general aviation airplane collisions.

Continuing this analysis discloses that there were two mid-air collisions in 1970 involving general aviation airplanes and airliners. Thus far in 1971, one general aviation airplane and an airliner collided. Again, as in past years, all three collisions occurred in good weather, near to the airport, at low altitude and at relatively low closure speeds.

To bring the mid-air collision problem into perspective, it is considered advisable to call attention to a four year jet age analysis of mid-air collisions involving only airline aircraft and general aviation aircraft. (See Appendix 1.) The reason for limiting the analysis to airline aircraft and general aviation aircraft is that these collisions occur with the closure speeds associated with the airline aircraft speed regime, which is such a challenging factor in the design of collision prevention systems.

While considerable information is depicted in Appendix 1, the following items are worthy of special note:

(1) All collisions occurred below 10,000 feet, where the 250 knot maximum speed restriction is in affect by regulation.

(2) All collisions occurred in reported VFR weather.

(3) All collisions occurred at relatively low closure speeds.

Speaking at the March 26, 1971, "Midwestern Aviation Conference," FAA's Administrator John Shaffer predicted that for the next 10 years there will be ". . . A growth in the number of airline aircraft from 2,580 to 3,640 . . ." and an ". . .expansion of the general aviation fleet from 134,000 to 232,000" aircraft. Obviously, more airplanes will be flown with more hours in the air, and unless a collision prevention system is implemented, collisions will increase. These statistics emphasize the urgent need for shortening the time frame for achieving a collision avoidance system.

Priority Funding:

Is the research and development effort to produce mid-air collision prevention hardware progressing rapidly enough, especially in its importance in regard to safety and aviation growth?

The aviation community is aware of the number of million-dollar-plus grants on many research and development projects--all no doubt worthy of effort. However, in connection with the need for adequate funding for a collision avoidance system, the following is of real concern:

> Excerpt from ALPA's paper presented during NTSB's Hearing on the Midair Collision Problem, November 4-10, 1969:
>
> "More than four years have passed since the NASA Research Advisory Committee on Aircraft Operating Problems passed its strongly worded resolution to highlight the importance of the problem. The May 1969 NASA Report No. TN-5174 entitled, 'Compilation of Data from Related Technologies in the Development of an Optical Pilot Warning Indicator System,' states the research effort was conducted '. . . mostly on a less-than-full-time basis.' This is a shocking statement because the mid-air collision problem is so serious that research should have been and should continue to be conducted on an overtime basis. Directing attention to this report is not intended to adversely reflect on NASA scientists and the commendable research they have conducted, but rather to emphasize that their efforts should be augmented and adequate funds be provided without delay."

Excerpt from Aviation Week, March 22, 1971:

"Modest-level study of a low-cost anti-collision system for general aviation aircraft which would be compatible with the Air Transport Association-sponsored time/frequency collision avoidance system will be funded by NASA's Langley Research Center. Nine companies submitted proposals, including Bendix, Sierra Research and Wilcox, which participated in the development of airline time/frequency equipment. McDonnell Douglas, which had previously conducted a study of low-cost general aviation versions for NASA's Electronics Research Center, declined to submit a proposal on the grounds that it was ready to build flight hardware."

Here again, one of the aviation world's greatest potential hazards, the mid-air collision, continues to be given, "modest-level study." It is no wonder that approximately 15 years of less than "full-time" effort have resulted in little progress toward decision-making on a collision avoidance system.

The solution of the mid-air collision problem requires an aggressive program similar to the attention given toward solving the following:

(1) Hijacking prevention (sky marshals and devices);

(2) Clean engine programs to minimize pollution;

(3) Quieter engines to reduce noise.

To accomplish the aforementioned objectives requires large sums of research and development money.

Although we are aware that it is difficult to obtain appropriations, it is apparent that increased funding is also required for the rapid development of an effective collision avoidance system. Can this be achieved through curtailment, or postponement of certain current appropriations now devoted to projects not as essential in the public interest?

An excellent example of a successful attack on the mid-air collision problem is the manner in which the Army has rapidly equipped its helicopter fleet at Fort Rucker with a

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satisfactory proximity warning system. The training load at the U. S. Army Aviation School at Fort Rucker, Alabama, had increased to a level in late 1967 at which the mid-air collision hazard affected the pilot training, and the need for a proximity warning system became very evident. Development was initiated in 1968 with an invitation to the electronics industry to submit proposals for applicable devices for a competitive flight test evaluation. Five companies responded. After a pre-production evaluation, a production contract for 222 units was awarded to one electronic equipment manufacturer. Delivery of the units started in December 1969 and was completed in August 1970. Installation of the units in helicopters started in January 1970 and by September 1970 there were 200 helicopters operating with proximity warning indicators. Latest information discloses that these installations have accumulated more than 275,000 in-flight hours without a mid-air collision.

This shows what can be done when an aggressive, properly funded research and development program of high priority is implemented. Obviously, the accomplishment was expensive, but not in proportion to tax dollars saved in equipment and lives.

The Cost of Mid-air Collisions:

The expense of a Collision Avoidance System can be justified by an examination of the forecast cost of mid-air collisions for the 1970-1980 period, as shown by a table on the following page. This table, excerpted from FAA's Staff Study entitled, "An Analysis of ARTS III Terminal Area Automation System Benefits and Costs," does NOT take into account the result of retarding the acceptance of air travel by the public, loss of life, or the adverse effect on the purchase of new general aviation airplanes.

Disbenefit Estimates for AC/GA Collisions
1970 - 1980

1. Cost Estimate Base:

Average value of air carrier aircraft = $7,000,000
Average value of general aviation aircraft = $ 30,000

Minimum base for human life = $14,750 (discounted at 6% for 25 years*)
= $189,000 (230,000 at 4% discount)

Government investigation costs = $200,000

2. Estimates using sample of 10 collisions (1965-69):

a)	Total fatalities	=	221 x $189,000 =	$41,769,000
b)	GA aircraft destroyed	=	8 x 30,000 =	240,000
c)	AC aircraft destroyed	=	4 x 7,000,000 =	28,000,000
d)	GA aircraft substantial damage (1/3 value)	=	1 x 10,000 =	10,000
e)	AC aircraft substantial damage	=	2 x 2,300,000 =	4,600,000
f)	Investigation Costs	=	10 x 200,000 =	2,000,000
	TOTAL			$76,619,000

Average/Collision = $7,700,000

*Based on HEW study by D. Rice, "Estimating the Cost of Illness," Health Economic Series #6, May 1966.

The March 3, 1971 Washington Star contained an article relating to one collision accident indicating that negotiations were taking place for ". . . damage claims of some $70,000,000." Further, that a December 16, 1960 collision between two airliners "produced payments of more than $29 million."

Based on qualified estimates, a mid-air collision between two jumbo jets would cost the airlines between $180-190 million, which is also the approximate cost of equipping the entire air carrier fleet with collision avoidance systems.

The above information regarding loss in lives and equipment can continue to increase in cost yearly. According to current estimates it will be approximately 1978 before collision avoidance systems will be operating to prevent mid-air collisions. It is in the best public interest that this time frame be substantially shortened.

Aircraft Strobe Lighting:

The struggle to gain recognition of the fact that strobe lights aid in reducing the collision hazard has lasted far too long. Strobe lighting on aircraft for minimizing the collision hazard was demonstrated to the Association and industry in 1954 by Captain H. W. (Bill) Atkins of NWA during ALPA's Fourth Annual Air Safety Forum. He is to be credited with conducting an early unrelenting design and flight testing effort toward getting strobe lighting recognized as a means to minimize the collision hazard. In 1963 and 1969, during the Tenth and Sixteenth Annual ALPA Air Safety Forums, strobe light manufacturers conducted "fly-bys" which demonstrated the superiority of the strobe lights on aircraft. ALPA testified at congressional hearings that strobe lights would aid in minimizing the mid-air collision hazard. ALPA urged FAA rule making. On May 28, 1970, the FAA issued a Notice of Proposed Rule Making on anti-collision lighting which was distributed to industry and is still under study by FAA. ALPA, along with other industry segments, strongly endorsed rule making to require strobe lighting for minimizing the collision hazard.

The "Report of Proceedings of the National Transportation Safety Board into the Mid-Air Collision Problem, November 4-10, 1969," is most revealing. The report discloses that nine different major segments and consultants of the aviation industry stated they supported the installation of strobe lights as an aid toward minimizing the mid-air collision hazard.

Also of great significance is that the October, 1970 USAF Mid-Air Collision Conference, passed the following recommendations on "Aircraft Lighting" as a result of discussions:

> "1. The adoption of white lighting of the high intensity strobe variety versus red lighting due primarily to the higher intensity available from a given power source.
>
> "2. USAF through DOD support the FAA position to require anti-collision light(s) on all aircraft.
>
> "3. Take immediate action to procure and install 360° white strobe lights on the upper and lower fuselage of all USAF aircraft, to be operated during both day and night flying operations."

The foregoing USAF recommendations have the stature of being classified as a Phase I recommendation which is to be considered for accomplishment in one year.

In 1966 NASA determined that the strobe lights emitted an infrared signal which could be utilized in an economical proximity warning indicator. Additional research and development is continuing and has progressed to the point where proximity warning systems are considered feasible and are in flight test evaluation. Thus, this is another reason for pressing on with a mandatory strobe light requirement for all airplanes.

Air Traffic Controllers report that aircraft with strobe lighting are more easily locatable and assist controllers in providing separation, thereby reducing the collision hazard.

Also very worthy of mention are statistics which indicate that airplanes equipped with the strobe anti-collision lights minimize the "bird-strike" potential. This was described in an article in the March 1970 AIR LINE PILOT magazine entitled, "Mandatory Strobes," by Captain James Golden of Mohawk Airlines.

The accident/incident records disclose that "bird-strikes" result in the following:

(a) Fatal accidents; and

(b) Major aircraft damage.

It is then significant that, in addition to providing considerable protection from the mid-air collision and near-miss potential, a strobe light can provide protection on large--and especially small--aircraft from encountering a bird strike resulting in a potentially fatal accident or costly damage to the aircraft.

In summary, the National Aviation System must require strobe lights on all aircraft. This requirement has industry and military support. The strobe lights are readily available ranging from $100 per installation on small aircraft to a higher priced installation of several strobe lights per airplane. If a pilot sees a strobe light flashing sufficiently far ahead, he can evaluate the conditions and make a gentle maneuver rather than a violent one, which is so unnerving to pilots and frightening to the passengers. Information relating to mid-air collisions is difficult to obtain; however, to our knowledge, airplanes involved in collisions during the past five years DID NOT have strobe lights installed.

Collision Avoidance System (CAS):

The Air Transport Association has commendably funded a costly and revealing research and development program for a collision avoidance system. Testing of the system using airline-type airplanes has been completed. The system successfully demonstrated that collisions can be prevented in IFR and VFR weather by airplanes equipped with the time/frequency system.

Presently research and development is well on the way toward providing a low cost unit for general aviation airplanes which will be compatible with the airline system. The objective is to provide collision avoidance means in ALL aircraft.

As a result of the October 1970 USAF "Mid-Air Collision Conference," it was recommended that the USAF take an active part in the further development of collision avoidance systems in order that procurement for all military aircraft as well as general aviation is cost feasible and meets the requirement of both.

Commendable research and development being conducted by several electronic companies has been extensively documented. The design of a CAS has progressed to the point where an instrument display providing command information for the airline pilot to use has been selected and a similar pilot display for the general aviation CAS is being developed. Lack of adequate funding must not delay installing several units in airline and general aviation aircraft for flight evaluation.

The chart (Appendix A) clearly illustrates the very urgent need to develop CAS to the degree that it will be within the price range of the general aviation airplane owners.

The chart also discloses that the present ATC system does not provide collision prevention and that a CAS is required. An accelerated program to accomplish this goal as soon as possible is in the public interest.

Proximity Warning Indicator (PWI):

Several proximity warning indicator (PWI) systems have reached the status of flight evaluation. Industry interest is at an all time high. The previously mentioned NTSB Report discloses that a significant number of aviation authorities and representatives from the industry endorse research and development for PWI systems.

PWI performance varies from VFR to IFR capability. Some systems provide only an alert for the pilot to "see and avoid" another aircraft. Some provide an alert plus directional information to assist the pilot to rapidly detect another airplane on a potential collision course. PWI devices, while limited in range, can provide considerable "see and avoid" time as shown in Appendix B. Also worthy of special note is that the chart, Appendix A, illustrates that the collisions involving airliners and general aviation airplanes occurred at low closure speeds providing at least 20 or more seconds for the pilot to take evasive action, when PWI devices provide a two-mile range for collision detection. PWI specifications are being evaluated to determine time required to assure the pilot has the time to "see and avoid" another airplane.

The National Aviation System planning should examine all avenues to expedite research and development to determine the merits of PWI for minimizing the collision hazard.

Conclusion:

The urgent need for "Collision Avoidance Planning for the National Aviation System" can be seen by the emphasis placed by the major segments of the aviation community on:

(1) Strobe anti-collision lighting on aircraft as an aid for reducing the collision hazard;

(2) Expanded research and development of a collision avoidance system for all aircraft;

(3) Expanded research and development for a proximity warning indicator.

Recommendation:

In view of the great concern of the aviation industry regarding early solution to the mid-air collision problem, it is strongly recommended that the National Aviation System planners list solution of the problem as a very high priority item for receiving adequate funding for research and development of hardware and accelerated testing programs to assure the earliest practical date for implementation of visual and electronic mid-air collision avoidance means.

References:

(1) "Report of Proceedings of the National Transportation Safety Board into the Midair Collision Problem, November 4 through 10, 1969," Report No. NTSB-AAS-70-2.

(2) National Transportation Safety Board Accident Investigation Reports, 1964 through 1971, relating to mid-air collision accidents.

(3) "The Urgent Need for a Low Cost Short-Range Collision Prevention Device," 1969 Report by Ted Linnert, Air Line Pilots Association.

(4) "Mid-Air Collision Conference Report," United States Air Force, October 1970.

ALPA MID-AIR COLLISION ANALYSIS

INVOLVING GENERAL AVIATION AND AIRLINES

(1967 - 1970)

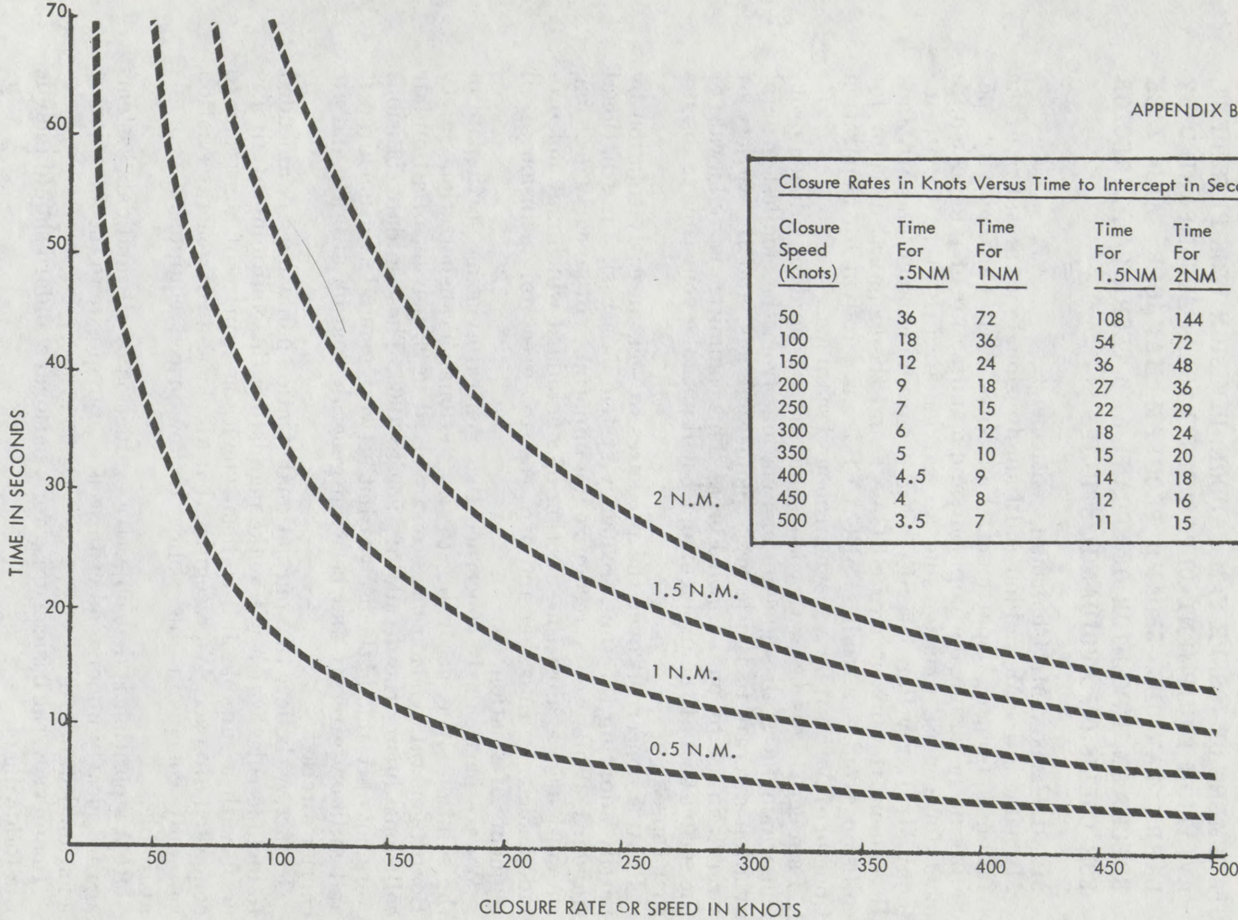
Date	Location	Aircraft Type	Weather Condition	Approx. Airspeed (Knots)	Climb, Descent or Level	Straight or Turn	Convergence Angle in Degrees	Flight Regime	Impact Altitude (Feet)	Closure Speed (Knots)	Seconds Warning Time 1/2 N.M. Range	Seconds Warning Time One N.M. Range	Seconds Warning Time 1-1/2 N.M. Range	Seconds Warning Time 2 N.M. Range	Distance From Airport (Miles)	Remarks
3/9/67	Urbana, Ohio	DC-9 Beech B-55	Day/VFR	323 168	Descent Descent	L-Turn Straight	31-50	Approach Enroute	4,525	222	8	16	24	32	25	26 Fatalities
7/19/67	Hendersonville, North Carolina	B-727 Cessna 310	Day/VFR	230 140	Climb Level	L-Turn Straight	131-150	Takeoff Enroute	6,132	349	5	10	15	20	8	82 Fatalities
3/27/68	St. Louis, Mo.	DC-9 Cessna 150	Day/VFR	135 94	Descent Descent	Straight L-Turn	11-30	Approach Approach	1,100	57	32	64	96	128	1.5	2 Fatalities in Cessna
5/12/68	Denver, Colo.	B-727 Cessna 377	Day/VFR	250 66	Descent Descent	Straight Straight	71-90	Approach Approach	9,000	247	7	14	21	28	20	Minor Damages. Both landed safely.
8/4/68	Milwaukee, Wisconsin	CV-580 Cessna 150	Day/VFR	190 80	Level Level	Straight Straight	31-50	Enroute Enroute	2,500	140	13	26	39	52	11.5	2 Fatalities in Small Aircraft
2/6/69	Harlingen, Tex.	DC-9 Piper PA-28	Night/VFR	140 80	Descent Descent	Straight L-Turn	0-10	Approach Approach	300	64	28	56	84	112	0.25	Piper destroyed No Fatalities
8/3/69	Fort Worth, Tex.	B-707 C-172	Day/VFR	220 110	Level ?	Straight Straight	131-150	Approach Enroute	8,500	312	6	12	18	23	12	2 Fatalities -- C-172
9/9/69	Indianapolis, Indiana	DC-9 Piper PA-28	Day/VFR	256 100	Descent Level	Straight Straight	91-110	Approach Local	2,800	283	6	12	18	25	18	83 Fatalities
3/1/70	Vancouver, B.C.	Viscount Ercoupe	Day/VFR	180 87	Descent Level	Straight R-Turn	71-90	Approach Enroute	1,500	186	10	20	30	40	8	One Fatality
7/20/70	Tarragona Spain	B-737 Cherokee	Day/VFR	160 100	Descent Climb	R-Turn Straight	11-30	Enroute Enroute	1,750	75	24	48	72	96	2	3 Fatalities

APPENDIX A

APPENDIX B

Closure Rates in Knots Versus Time to Intercept in Seconds

Closure Speed (Knots)	Time For .5NM	Time For 1NM	Time For 1.5NM	Time For 2NM
50	36	72	108	144
100	18	36	54	72
150	12	24	36	48
200	9	18	27	36
250	7	15	22	29
300	6	12	18	24
350	5	10	15	20
400	4.5	9	14	18
450	4	8	12	16
500	3.5	7	11	15



Senator CANNON. The next witness is Mr. Joseph F. McCaddon, division vice president of RCA.

STATEMENT OF JOSEPH F. McCADDON, DIVISION VICE PRESIDENT, AVIATION EQUIPMENT DEPARTMENT, RCA; ACCOMPANIED BY LARRY PARSONS, SECANT PROGRAM MANAGER; AND JACK BRECKMAN, INVENTOR OF SECANT AND TECHNICAL DIRECTOR FOR COLLISION AVOIDANCE STUDIES

Mr. McCADDON. Mr. Chairman, gentlemen:

My name is Joe McCaddon and I am divisional vice president of the aviation equipment department, Van Nuys, Calif. My activity specializes in the design, development, and manufacture of avionics equipment for general aviation and air carrier aircraft. I have with me today Mr. Larry Parsons, SECANT program manager, and Mr. Jack Breckman, the inventor of SECANT and the technical director for collision avoidance studies. SECANT is an acronym for Separation Control of Aircraft by Nonsynchronous Techniques.

I am here to discuss with you a solution to the midair collision problem which faces all segments of aviation, from the smallest general aviation aircraft to the largest commercial jets, and the variety of aircraft in use by our Armed Forces. This committee is well aware of the seriousness of the problem and I will not take your time to discuss that aspect.

RCA is concerned over the pressures to seek an early solution by hastily adopting the time frequency system as a basis for a national standard. While we too recognize the importance of an early decision, we must urge against the selection of a standard which may not provide sufficient protection and at a cost too great for inclusion of all segments of aviation.

We are particularly concerned that general aviation participate in the solution since, according to the National Transportation Safety Board, general aviation has been involved in 98 percent of all midair collisions during the decade of 1959 to 1969. Those midair collisions were not only among themselves, but between general aviation aircraft and military aircraft and between general aviation aircraft and air carrier aircraft.

In fact, we believe that our national aviation policy must be amended to include rules which will make mandatory the equipping of all aircraft with a suitable anti-collision device as a price of admission to congested airspace. We recognize that all elements of general aviation can only concur in this policy if low priced equipment is made available.

RCA's position is that objective evaluation of all candidate systems against clearly understood criteria is a prerequisite to the adoption of a national standard.

In our view, the basic criteria for a national standard should include the following:

(1) Involvement of all segments of aviation with due regard to the financial burden on the various classes of operators.

(2) Capability to handle not only today's traffic, but also the forecast traffic for the next decade and beyond. A system adopted initially should not be obsoleted within a few years as traffic grows.

(3) High reliability in detecting threats without false alarms. False alarms must be near zero. Repeated false alarms can cause a pilot to ignore the alarms and even turn off the system when it may be needed most.

(4) Compatibility with the ever improving ground-based air traffic control system. Escape maneuvers should cause the least impact on the ground controller's handling of traffic. These escape maneuvers could require horizontal as well as vertical vectors or a combination.

(5) Operability over the whole of the United States, not merely along airways; and in view of the international air commerce and military needs, global operations must be considered as well.

Gentlemen, RCA has such a system under development. The basic units are in flight tests and the system meets the above criteria. We know of no other system that does meet these criteria. RCA's system is a nonsynchronous transponding system with a unique technique of sorting out valid signals from the many unwanted signals.

Transponding systems have not been able to do this before without synchronization such as used by time frequency. We can. Flight tests have proven this. RCA conducted 92 flight encounters in tests in California. These same equipments are being independently evaluated by the Navy at the Naval Air Development Center, Johnsville, Pa. Approximately 200 encounters have been flown by the Navy. Practically all tests have been flown with a special traffic generator aboard which electronically simulates the multitude of unwanted signals which many transponder equipped aircraft would generate in the dense traffic of the 1990's.

These flight tests confirm to us and to observers who have witnessed the tests that SECANT can select the wanted signals from the unwanted, and will identify and track the truly threatening aircraft.

As a result of these tests, RCA is convinced SECANT can be made operational and all aircraft appropriately equipped before time frequency can. In addition, according to FAA plans, it will take years to emplace the ground synchronization stations vital to time frequency, but which are not required by SECANT.

May I outline the advantages of SECANT and its family of compatible equipments, which meet the needs of the lowest performance propeller-driven aircraft to the highest performance jets:

(1) It accommodates general aviation, not only because of its low cost proximity warning indicator, but it will function anywhere, giving protection to general aviation from other general aviation aircraft, from military aircraft and from air carriers if all are equipped with equal or more sophisticated SECANT equipments.

(2) It does not require a large FAA investment in ground synchronization stations.

(3) It can communicate with the ground air traffic control system to whatever extent is desired.

(4) It will measure relative bearing and thus permit computation of miss distance for use as a powerful threat discriminate. It also has the capability of both horizontal and vertical avoidance manuever, or a combination of both.

(5) It will provide a minimum of 45 seconds escape time with 60 seconds being the norm.

(6) It will not saturate in the projected traffic densities in the rest of this century. We have proven this in our tests. And its false alarm rates will be minimized.

Our executive vice president, Mr. Kessler, recommended to the Brooks subcommittee of the House that there be an early flight evaluation of the airborne collision avoidance systems that have been proposed. I should like to reaffirm Mr. Kessler's recommendations to this subcommittee.

We are convinced that the growing national and international concern over accidents will demand timely action. Based on past experience, stastics show that we must expect further midair collisions.

RCA, therefore, recommends that this committee use its authority and prestige to press for a valid, objective analysis of candidate systems followed by flight test validations. We are pleased that discussions are under way among DOD, FAA and NASA on the development of a national plan for evaluation. Much work, however, remains to be done. We suggest the following:

(1) A competent, objective evaluation group must be established.

(2) Common descriptive nomenclature must be developed to eliminate misunderstandings which plague the aviation community. There must be clear, unambiguous definitations for such important terms as false alarm, threat, warning time, et cetra.

(3) Common traffic models must be developed against which analysis and evaluations can be judged.

(4) Rules must be ectablished by which the judges will evaluate satisfactory, marginal or unsatisfactory performance.

(5) Analytical studies should be conducted first and responsive candidates be invited to participate in flight test validations.

(6) With adequate priority the flight test validations could begin in the summer of 1972.

RCA believes that SECANT is the most economical solution to the elimination of midair collisions, not only in dollars, but, more importantly, in human life.

RCA is therefore continuing its development of the total SECANT concept. We volunteer our participation to whatever extent is appropriate in the development of the criteria and the establishment of standards for evaluation. We will be prepared to participate in an analytical evaluation and in subsequent flight test validations.

Thank you, sir.

Senator CANNON. What are you referring to in your paragraph (6) above where you say "with adequate priority the flight test validations could begin in the summer of 1972"? What do you refer to as adequate priority?

Mr. MCCADDON. Our reference there, sir, is that we assume a truly valid evaluation and flight test demands establishment of a fairly comprehensive plan. We think that this cannot be done in a day and that it would take a period of time to establish the criteria necessary to provide for the test range and the precise measurement facilities so that the tests are meaningful.

I must be candid here, in reference to the system under Navy test, that system would have to be added to and it would take us a few months to complete that addition. This addition is the threat logic and data exchange capability. So these two points are the reason for the approximate time referenced.

Senator CANNON. What are you talking about in the way of cost?

Mr. McCADDON. Precisely we referenced a family of equipments and the proximity warning indicator is priced right at $1,000. The vicinity traffic finder system is priced from $3,000 to $5,000, and the full collision-avoidance systems such as would be applicable to a large air carrier aircraft would be priced from $15,000 to $20,000. Those prices are based on quantities of about 10,000 units.

Senator CANNON. Well now, your most elementary system there for general aviation aircraft, what would that actually do? Would it give you a warning? Would it give you a resultant evasive action to take? Or what would it be?

Mr. McCADDON. The PWI would advise a general aviation aircraft so equipped that someone had penetrated a shield of a distance set by a pilot. Once he had been warned that the shield had been penetrated, he would then have to acquire that aircraft visually.

Senator CANNON. So it does not give him any directional information, any altitude information or anything else?

Mr. McCADDON. No, sir, the PWI does not. It gives him range information because of the fact the shield was penetrated and the PWI does provide altitude information to intruding aircraft.

Senator CANNON. What range does the shield give you?

Mr. McCADDON. Three to 5 miles, sir.

Senator CANNON. So in and around an airport that would be lit up all the time, I take it?

Mr. BRECKMAN. If I can remark to that, the range would be setable. The pilot would have the option of setting the range to accommodate whatever flight area he happens to be in and he can set it out to as far as 5 miles, but he can set it to something less depending on——

Senator CANNON. Similar to a radar? You can switch your distance range?

Mr. BRECKMAN. Yes; it is a knob, and it reads from, say, one-tenth of a mile or so out to about 5 miles, and he selects whatever range is appropriate.

Mr. McCADDON. It is a variable.

Senator CANNON. Senator Baker.

Senator BAKER. If this $1,000 unit were installed, say, in a general aviation aircraft and the $25,000 installation were aboard an airline carrier, the airline carrier would have the full range of information, distance, bearing, and what else?

Mr. McCADDON. Yes, time to potential collision and evasive commands.

Senator BAKER. Is it necessary for the general aviation aircraft to have the $1,000 unit in order for the airline carrier to detect its presence?

Mr. McCADDON. No, sir; it is not necessary; however it will detect it with the $1,000 unit. But there is an even more economic device which we term the remitter, approximately an $800 device that says electronically "I am here." It receives no information, but anybody equipped with the PWI or the more sophisticated members of the family of systems would be able to read that signal.

Senator BAKER. So for $800 you would have an active system, and you would have a minimum warning to the airplane carrying equipment.

Mr. McCADDON. Yes, sir.

Senator BAKER. What doesn't this do? You have outlined the advantages of your system in a most systematic manner. Tell us frankly what it fails to do.

Mr. McCADDON. I think what—this may be a parochial view of the two technologies available to the solution of midair collisions. The SECANT technology is a—uses nonsynchronous techniques and correlates the wanted from unwanted signals. It does not therefore require a time accurate time in space for all members participating in the system.

Other technologies are functioning similarly but require accurate synchronization either through airborne clocks or ground based synchronization stations. The functions performed by these technologies are grossly similar. There are differences in the degree of accuracy in the inclusion or exclusion of additional information such as swept bearing. SECANT uses swept bearing as a further threat discriminant and to further refine and predict miss distance, which therefore enhances the total accuracy of the system. I think that the principal differences lie in that area.

Senator BAKER. So the principal difference, as I understand you, between the synchronous system and the nonsynchronous system is the ability to discriminate in——

Mr. McCADDON. And lack of requirement for timing; an overall economy is another way of saying it.

Senator BAKER. All right. Thank you.

Senator CANNON. Senator Moss?

Senator MOSS. Do you want to press ahead? I have a few questions.

Senator CANNON. We can go until the 7½ minute warning.

Senator MOSS. I was very much impressed with your testimony. Have you built and flown a complete collision avoidance system?

Mr. McCADDON. No, sir. We have not flown a complete avoidance system. The system now flying with the Navy Department is complete with this exception: that is, it does not have a data exchange aspect flying. It does derive range, range rate, and so on. We did not include data exchange in the interest of time, in that the technique is well known and well established and we have done this in other programs, in other applications. The data exchange aspect itself is not a complex aspect to the system.

This is one of the things I was referencing when I said it would take us a few months to add that for complete evaluation. Now, I should hasten to say that the evaluation system would not have the bearing aspect in it, but it would perform and render the same type of information that the time frequency system would provide.

Senator MOSS. You could build and fly this within a matter of months. How many? Four? Five months?

Mr. McCADDON. Yes, sir, in that order with the addition of the relatively simple data exchange feature.

Senator CANNON. Gentlemen, we have another vote on. I think this will be a good time to take a recess. It seems that these votes are running about one an hour, so maybe we should recess until 1:45. We will resume the hearings at 1:45, and that should put another vote in between.

Thank you.

(Whereupon, at 12:25 p.m., the hearing was recessed, to reconvene at 1:45 p.m., this same day.)

AFTERNOON SESSION

Senator CANNON. The hearings will come to order.

I think Senator Moss was in the process of asking you some questions when we recessed.

Mr. McCADDON. Yes, sir.

Senator MOSS. Thank you, Mr. Chairman, and I think I had asked whether a complete system had been built or flown and your answer was that it had not as yet; is that right?

Mr. McCADDON. Yes.

Senator MOSS. Have you flown equipment that provided the altitude transmission required for an avoidance system?

Mr. McCADDON. No, sir, that is part of the answer and if I may, I will attempt to clarify that. I recognize I didn't answer properly.

Senator MOSS. Thank you.

Mr. McCADDON. May I preface the response by making two assumption? One, that the objective national evaluation spoken to is established say within the next 2 months. That sort of time frame. And the actions along the lines we recommended are initiated. The second assumption is that the evaluation will be based on the use of the vertical escape logic as defined in the ATA ANTC–117 documents so that, based on these assumptions, RCA will, by the end of January, implement its plan to build additions to our current equipment now in test. These additions will enable us to participate in the flight validations so recommended in the time frame we discussed.

You mentioned 3 to 5 months, summer 1972.

Senator MOSS. Yes.

Mr. McCADDON. Now this system under evaluation will include all of the SECANT collision avoidance system capability except the measurement and use of bearing. However we intend to continue the bearing development parallel with that since we firmly believe there is a need for the full SECANT capability.

To your specific point, sir, we are not flying a system that exchanges altitude information. That is not being flown, but that is precisely what we will add to what we are now testing.

We further recognize that a collision avoidance system involves two fundamental aspects. The first is choice of system technique for locating and gathering data on the intruder and the second deals with the operational choices of threat definition and the selection of escape maneuvers to be employed.

SECANT and time frequency differ in fundamental and mutually exclusive manner in the first area. However in the operational area the SECANT system differences are ones of augmentation and enhancement rather than in opposition. The enhancement that the total SECANT system can provide can be evolutionary. In other words, we can employ the vertical logic and go on to adding horizontal logic with the bearing capability. The SECANT system functions required to meet the ATA specification, can be divided into two parts. The first is data gathering and the second is data processing and pilot display.

We are currently demonstrating in the Navy test the most challenging of these, that is, the data gathering. Design and implementation of the processing and display function are straightforward engineering tasks and full advantage would be taken of the already developed threat logic and other display specifications of ANTC–117.

This partial limitation of SECANT for flight validation provides a system that retains the major advantages of not requiring time synchronization. Additionally, SECANT is currently demonstrating its ability to gather precise data and therefore would provide a superior performance with respect to warning and false alarms and would do so at a significantly reduced cost.

Senator Moss. If you have solved the saturation problem, why do you require 20 to 30 frequencies to handle the limited community covered by low-powered signals?

Mr. McCaddon. Could I refer to our program manager, sir?

Senator Moss. Surely.

Mr. Parsons. SECANT solves the saturation problem by a number of system techniques. Frequency diversification is one technique that is used. We do not use 24 frequencies in our full CAS system and they are used to divide the total population in terms of altitude difference, major altitude difference. But that is only one of the techniques that we use. The most powerful technique used in SECANT is the correlator.

The most powerful is the correlator. There are others as well, range truncation is also used, so in answer to your question there are several techniques used, frequencies are one.

Senator Moss. You are using several techniques besides the number of frequencies. How many frequencies do you use, 24?

Mr. Parsons. Twenty-four frequencies used for the CAS function. If we were asked to solve today's traffic problem we may not have to do that. We don't need all the techniques for today's traffic problem. We are not trying to solve just today's traffic problem but those problems that may come up through the end of the century.

Senator Moss. Well, thank you. Regretfully we are crowded for time and I will forgo any further questions but I appreciate your response to those that I have asked and I do appreciate your testimony, too. It indicates you are working very actively on the general problem that we are concerned with. Thank you.

Senator Cannon. Thank you very much, gentlemen.

The next witness is Mr. Anatole Browde, vice president, communications programs, McDonnell Douglas.

I think we will start and run until we get the 7½-minute warning, and then we will interrupt to go to vote again.

STATEMENT OF ANATOLE BROWDE, VICE PRESIDENT, CNI PROGRAMS, McDONNELL DOUGLAS CORP.; ACCOMPANIED BY ROBERT PERKINSON, ENGINEERING MANAGER ON COLLISION AVOIDANCE

Mr. Browde. I would like to introduce Mr. Robert E. Perkinson, enginering manager on collision avoidance, and also an inventor of the time frequency synchronization technique. He has been working on this problem since 1960.

Mr. Chairman, I have a prepared statement which I would like to abbreviate. I would appreciate it if the full statement could go in.

Senator CANNON. That will be made a part of the record. You may proceed.

Mr. BROWDE. Mr. Chairman, and members of the subcommittee, McDonnell Douglas appreciates the opportunity to discuss with you today the progress of the aviation industry in the field of collision avoidance and to comment on Senate bill S. 2264.

There has been steady progress in industry work on the time/frequency collision avoidance system since MDC flew the EROS in 1964. In the last 2 months, significant new milestones were achieved for our EROS system. The first airline systems were installed in a United Air Lines' 727 commuter aircraft and started flying regularly between Los Angeles and San Francisco on November 23.

Our Micro-CAS for general aviation started flying in our company aircraft in October and will soon join the United tests in San Francisco. The military version—EROS I—has accumulated this month a total of 17,005 flights in our F–4's.

The questions that need to be discussed today are the central ones to the collision avoidance issue:

1. Is the choice of time/frequency a proper one for national and international use?
2. What does the system really cost?
3. What can the Government do to achieve system implementation and widespread use?
4. Should the system be made mandatory as proposed in the Senate bill?

With two midair collisions in the United States, two major landing accidents, and one near-miss between two airliners over Pennsylvania, the months of June and July 1971 demonstrated the need for providing better midair and ground collision avoidance protection for all travelers. In our opinion, rapid introduction of the time/frequency collision avoidance system into the airways system is both essential and urgent.

In Europe also, midair collision avoidance is in the news. On October 7, 1971, the London Daily Telegraph reported that there were 108 near-misses between airliners in airspace over Britain in 1970. In France, the Government has let a contract for a time/frequency collision avoidance concept totally compatible with the U.S. system. In Germany, the International Air Line Pilots Association devoted a major portion of its New-Nav Symposium to this important question.

The action of requiring a system in an aircraft also acts as a powerful stimulus to avionics manufacturers. They start to build equipment, there is competition, and the price goes down.

Through our action here, we can assure that international carriers and government agencies all over the world will move forward to adopt the same compatible system. Since many of these countries do not have adequate traffic control, the time/frequency system can enable them to gain safety benefits for only a small investment. It should be stressed that our own commercial and military aircraft fly in these areas. They need protection there as well as at home. The adoption of the time/frequency system within the United States thus could be of benefit to aviation throughout the world.

With sales of American equipment overseas for collision avoidance and air traffic control, adoption of the system as a U.S. standard would strengthen our export position and could make a contribution towards achieving a favorable balance of trade.

Some more history. The time/frequency system is by no means the first attempt at designing a collision avoidance system. It is, however, the first successful system that is able to separate aircraft of all classes reliably without saturation.

Collision avoidance is one of the most deceptive problems in our aviation field. Many very reputable companies during the late 1950's and early 1960's were sure they had the solutions, built equipment and then were forced to withdraw when their concept, once fully developed and tested, plainly did not work.

I have listed a number of these attempts in appendix A attached.

We, at McDonnell Douglas, had good concepts using infrared and transponder techniques in 1960 and 1961, and had to abandon them when we tested these concepts in depth. However, we did believe time/frequency would work. We invested heavily and in 1965, were flying the system operationally.

We went to the airlines in 1966 and told them: "Here it is—it works—you can buy it."

We were then told the facts of life, that a military system might not be usable for an airline/general aviation environment. We were told that the airlines and the FAA would never buy a system produced by only a single manufacturer. We had to share our knowledge with our competition—Sierra, Bendix, Wilcox—anyone who wanted to attend the open meetings.

The time/frequency adherents were then asked to supply equipment at their own expense for Air Transport Association tests. We all did that and again, invested our money and resources.

Only in 1970, 5 years after our system flew on a daily basis in St. Louis, 1 year after the ATA tests, was the industry satisfied that a system had been configured for all users.

I think everyone will admit then that in terms of development status, time/frequency is far ahead. Does our system then have technical deficiencies, as our opponents claim?

It is the threat logic in the equipment that triggers the alarm by evaluating the information coming into the system. We do not know how people can discuss false alarms without having built, tested, and simulated threat logic. Without this, one really has no collision avoidance system.

I would like to state once and for all that the time-frequency-system is not prone to false alarms.

While the FAA final report has not been released, initial results have been reviewed by qualified operations personnel. Their opinion confirms that the time-frequency collision avoidance system works within the present air traffic control system. Excessive air traffic control interaction just did not occur.

In simulating some 36 hours of peak density Chicago traffic including over 5,000 operations, only 26 climb/descend commands were given, nine of these being traced to either pilot error or a controller spacing aircraft too closely. In other words, in nine instances, the system prevented a potential accident.

One other point is of importance. Does the time-frequency collision avoidance system provide adequate warning time? We tested just how much warning time was required in an extensive simulation. As you know, it is expensive to fly airplanes and sometimes dangerous to set up proper test conditions for collision avoidance work, since you must fly airplanes at each other, sometimes at high speed.

In the ATA tests at Martin-Baltimore, we flew some 220 actual collision-avoidance encounters. In order to multiply our experience significantly, we used a computer to simulate airplanes in flight.

In some of these, we even prevented one of the aircraft from maneuvering. Even in the worst configurations, we found with our published warning times that adequate separation does exist. Not only that, the maneuvers to be executed by these aircraft were found to be gentle, designed not to spill the coffee from your coffee cup.

We come now to the important matter of general aviation equipments. We would like to point out that we have built and are flight testing a complete, fully packaged general aviation collision avoidance system—the Micro-CAS. We are also on record with our pricing for this unit at a $2,500 list price. This is based on a 1,000 unit production run. This is a system that provides protection for the air carrier against a general aviation aircraft and also for one general aviation aircraft against another.

Senator CANNON. We will have to interrupt you, we have to go to vote.

I think we will let you go ahead and conclude your statement with the staff here, and then we will be back just as soon as we can.

Mr. BROWDE. I was discussing the Micro-CAS at a $2,500 list price, based on a 1,000-unit production run. Other companies have discussed possible arrangements with us for producing Micro-CAS and can probably achieve costs lower than $2,500.

In order to check the validity of this, we counted the parts in our Micro-CAS and compared the numbers against the number of parts in the Genave B–4096 Transponder, which retails for about $800. We have about 50 percent more parts in the Micro-CAS.

Prices near $1,200 thus seem supportable once large-scale production starts.

When we hear about systems that are advertised to be much lower in cost than the time/frequency systems, the first question we must ask ourselves is, "What do they do"?

We have tested a simple proximity warning indicator that costs very little. It tells an aircraft that it is in the vicinity of a time/frequency equipped collision avoidance system or beacon within the same altitude band as the other aircraft.

Even so, we worry about giving so little information to a pilot. Because in a crowded traffic environment, he must then look out, determine which is the aircraft that triggered his warning and then figure out which way he should move to escape the threat.

Such a system may be better than nothing. But we question its overall utility even though it might only cost about $600.

Next on our scale of systems is the beacon. This informs other equipped aircraft that they are near a small aircraft and thus depend on the other aircraft to take the evasive maneuver.

McDonnell Douglas could build such a system for $1,600, and it seems reasonable that general aviation avionics manufacturers could produce it for substantially less. However our concern has always been to provide information to both pilots. Thus we prefer systems that insure that each pilot has an unambiguous command telling him what he must do to escape.

In short, we totally reject the concept that time/frequency equipments are any more expensive than comparable competing units.

We would, however, like to call your attention to one major advantage of the time/frequency systems. These systems will do far more than prevent midair collisions, although that would justify their existence all by itself.

The Micro-CAS and the airline/military system both can be used to avoid ground obstacles, if a simple time/frequency beacon is installed at that site. This is being demonstrated today in San Francisco.

They can be used as an airport landing aid. The system reads how far away it is from another ground station, and what its altitude difference is with respect to that station. It will read the range and altitude difference of all other equipped aircraft in the vicinity.

In other words, when one buys time/frequency collision avoidance, one benefits from built-in functions, which normally would require additional avionics equipment in the cockpit.

Much has been made of the requirement for ground stations by the time/frequency system. Any cockpit-to-cockpit system requires ground-based checkout and integrity monitoring. This function is provided by the ground station in addition to its primary time resynchronization role.

Additionally, the resynchronization stations can also act as obstacle avoidance beacons, or as airport approach aids, in places where an ILH system is not available. The 65 U.S. stations shown in the FAA 10-year plan probably require a total investment of less than $13 million, fully installed.

Since 1967, we have generated our technical specifications with full Government participation. NASA, the Air Force, the Navy and the FAA were represented in all CAS/Technical Working Group meetings.

Along every step of the way, we invited the Government to witness our tests, or to participate in them as a full member. The Air Force and the Navy have been fully aware of the role of the EROS I collision avoidance system plays in separating Phantom aircraft in St. Louis.

We, therefore, would reject the claim of those that say there has been insufficient time to evaluate what the system does.

We would urge the FAA to promptly issue the long-promised requests for the ground station implementation study and ground station hardware.

We also urge that the FCC promptly and permanently assign the frequency presently allocated to collision avoidance. This means removing the developmental designation from the band. We submit that the time/frequency system is far beyond the development stage.

We are obviously in favor of S. 2264. However, we share the feeling of others that the FAA currently has the regulatory authority to assure the introduction of collision avoidance. We feel the system should be mandatory in the post-1975 time period.

Our industry surveys show that the equipment could be available for new aircraft delivered after 1973 and that existing aircraft could be retrofitted by 1976.

Most importantly, early official FAA endorsement of the system is required—as is U.S. support of the time/frequency system in international meetings of ICAO starting next spring.

Time/frequency collision avoidance is much more than a dream. The paper concept of 1963 became the flight demonstration program of 1964. The system in daily use in St. Louis since 1965 was the forerunner of our second generation equipment flying under airline conditions in California today.

The system has been ordered by Piedmont Airlines in a most far-sighted and public-spirited move. It exists in flight hardware form for general aviation. It is here—now.

We strongly urge that all responsible parties move forward with resolve and determination to adopt time/frequency collision avoidance—to improve the safety of our crowded airways.

Mr. GINTHER. Does that complete your statement?

Mr. BROWDE. Yes.

Mr. GINTHER. I would like to ask, you are talking about the EROS system on the F-4 Phantoms, was the Marine F-4 involved in the midair in California, so equipped?

Mr. BROWDE. We have a requirement to remove the system before we deliver the airplane to the Government. They are only equipped when they fly in the St. Louis area under test control.

Mr. GINTHER. You mean the U.S. Air Force and Navy do not utilize this equipment?

Mr. BROWDE. They do not utilize it once it leaves St. Louis, right.

Mr. GINTHER. Why is that?

Mr. BROWDE. I think, No. 1, it is a question of economics, No. 2, the overall EROS I system is heavily dependent on ground stations. The EROS II system has gone away from that. Therefore, the utility of EROS I as we fly it in St. Louis, without ground stations, is limited.

This is one of the major advancements we made in going from EROS I to EROS II.

Mr. GINTHER. One of our previous witnesses urged that national standards be developed based on several criteria.

In your judgment, could the United States agree on national standards specifying the time/frequency method using those criteria?

Mr. BROWDE. I think as I heard these criteria, I saw nothing that violated them. We can use all airspace users through 19—through the 2000 year line. This is one of the powerful things about the time/frequency technique. We have the right maneuvers.

I think we would argue that you don't need horizontal maneuvers, there is enough evidence in this particular field for that.

Again, I am trying to remember the criteria as they were listed. We can't think of anything that we could not meet with the time/frequency system.

Mr. GINTHER. Senator Cannon is interested in the cost of the Piedmont system that has recently been installed.

Can you tell us the per unit cost of that system?

Mr. BROWDE. We advertise and have publicly stated than an airline system costs $50,000. We also provide incentives for early purchasers of the system that lower that price.

Mr. GINTHER. Was it your testimony that if the desire or requirement for CAS become widespread that the general aviation component would cost about $2,500 to install?

Mr. BROWDE. No. What we are saying is, if we were to build 1,000 general aviation systems like Micro-CAS today, we could sell them for $2,500. We feel that the history of avionics proves that the price always comes down as more production starts.

The other thing we did—and remember we are operating from a base of a fully developed, built piece of hardware—we counted the components so we could compare them with something that other people like Genave and NARCO build, those that are much more conversant with the general aviation avionics field than we are. So you take a piece of equipment that sells for $800, we in our Micro-CAS have 50 percent more parts. If somebody else might be building that piece of equipment in production, we feel it would be in the $1,200 category.

Now, I can't speak for other companies, but that type of scaling is possible, once you have a hardware design.

Mr. GINTHER. Does McDonnell-Douglass own patent rights to the time-frequency concept?

Mr. BROWDE. We have some patents in the resynchronization technique and the indicator and so on.

We are also fully on record that we will license every single company who wishes to be licensed under these patents, and, furthermore, we have said we will give the Micro-CAS design to any general aviation manufacturer who feels he can produce compatible low-cost equipment.

Mr. GINTHER. But in essence, if the United States was to adopt the time-frequency standard for the U.S. and possibly for international use, it would be an idea owned by McDonnell-Douglas?

Mr. BROWDE. No, sir; Wayne Shear of Bendix has patents in this field. There are some Sierra patents. You see, what happened—I must stress this—the concept that is EROS II was developed by a committee. Some of the committee developed "humps of the camel." But all of us contributed—Bendix and, in the early days, Collins. We all have a few patents here and there.

Bob Perkinson happens to have found the basic scene of resynchronization.

Mr. GINTHER. With that, I think we will recess.

I think Senator Cannon and Senator Moss may have some questions for you, so as soon as they come back, we will resume.

(Recess.)

Senator CANNON. Do I understand that you are talking now in terms of small general aviation aircraft of $2,500 list price for your Micro-CAS?

Mr. BROWDE. Yes, sir.

Senator CANNON. How do you propose, or do you propose that we would get conversion of the aircraft?

Did you relate that to anything in your statement on that point?

Mr. BROWDE. I did not address that point, but let me take the case of the aircraft that we are using now to test small system.

It takes approximately a couple of hours to install this Micro-CAS equipment into a typical Cessna 150 or 172 and that is all that is required.

Senator CANNON. That costs $2,500?

Mr. BROWDE. Yes, sir.

But again I must stress that McDonnell-Douglas is not the most noted producer of general aviation avionics.

Senator CANNON. And the general aviation system would have what in it?

That $2,500 unit?

What capability?

Mr. BROWDE. The full capability to warn a pilot when he is near either another general aviation aircraft, or an airliner and give him escape maneuvers. It will provide for avoidance where there is an obstacle beacon installed, or a ground approach aid.

It has the full spectrum of time/frequency with some exceptions.

It does not propagate time. It cannot act as a data link. It cannot read doppler in the general aviation aircraft.

Senator CANNON. What type escape indicator?

Just an arrow pointing?

Mr. BROWDE. A climb arrow, a descent arrow, a hold altitude bar and advisories that there is an aircraft above or below that is not yet a threat.

Senator CANNON. Do you have any further questions?

Senator MOSS. I might have one or two. I hope I don't repeat what was said before, but I have looked through your testimony, and of course, we heard part of it before we had to leave. I was wondering if you have compared the time frequency system that you described—insofar as complexity is concerned, with the RCA system that we heard about from the last witness?

Mr. BROWDE. We have such studies.

I think the overriding factors are as follows: We use basically a four-frequency cycling. RCA uses as you heard, 24.

We don't rely on bearing measurement, which is a very difficult and costly measurement. But we come down to the very basics that in a traffic environment that is bunched—and all our traffic is bunched, it is not evenly spread through air space—we can work without saturation and when you involve the altitude data exchange and the correlator to exhaustive analysis we always come to the fact there comes a point where there is saturation in the RCA system.

From this standpoint, we feel that actually the complexity of a time frequency system is considerably less than the SECANT system as we know it.

Now, we haven't had the full disclosure of SECANT that you have had of time frequency.

Senator MOSS. How many of these growth features of the time frequency system have been reduced to hardware and flight tested?

Mr. BROWDE. Let me give you an example. We talk of a landing aid. If, today, in our 727 of United Air Lines, you come down at runway 28 left in San Francisco, and you come in too low over the outer marker, you will get a climb arrow, because we have, in effect, a ground obstacle beacon there: The air-to-air station keeping, the indication of where your traffic is, which it is and reading range, and range-rate, we are flying that in our Cessnas with a Micro-CAS system. We have done this with Navy aircraft. We measured bearing with the time frequency system in Navy aircraft in St. Louis today. Every day we use the time frequency outputs from our Phantoms flying overhead to run, in effect, a miniature traffic control system.

The only one that we have not completely reduced to practice is the full spectrum of navigation using that technique. And we think, of course, that that is pretty far downstream.

But we have demonstrated, that if you have three ground stations, you know very accurately where that aircraft is.

Senator Moss. How long would it take you to get into production of the general aviation unit?

Mr. Browde. Approximately 14–18 months. The same time scale as the full airline system.

Senator Moss. I see.

No difference on it.

Mr. Browde. No, sir.

Senator Moss. Well, thank you very much. I appreciate your responses.

Thank you, Mr. Chairman.

Senator Cannon. Thank you, gentlemen.

(The statement follows:)

Statement of Anatole Browde, Vice President, CNI Programs, McDonnell Douglas Electronics Co., McDonnell Douglas Corp.

Mr. Chairman and members of the subcommittee, McDonnell Douglas (MDC) appreciates the opportunity to discuss with you today the progress of the aviation industry in the field of collision avoidance and to comment on Senate Bill S2264 introduced by Senator Moss of Utah.

There has been steady progress in industry work on the time/frequency collision avoidance system since MDC flew the EROS in 1964. In the last two months, significant new milestones were achieved for our EROS system. The first airline systems were installed in a United Air Lines' 727 commuter aircraft and started flying regularly between Los Angeles and San Francisco on November 23. Our Micro-CAS for general aviation started flying in our company aircraft in October and will soon join the United tests in San Francisco. The military version—EROS I—has accumulated this month a total of 17,005 flights in our F4's.

Thus, you can see that we are continuing to make progress in introducing the time/frequency system to the aviation community. We are meeting all of our commitments.

The questions that need to be discussed today are the central ones to the collisions avoidance issue:

1. Is the choice of time/frequency a proper one for national and international use?
2. What does the system really cost?
3. What can the Government do to achieve system implementation and widespread use?
4. Should the system be made mandatory as proposed in the Senate Bill?

At the outset, I would like to state that we agree with the Federal Aviation Administration and the Air Transport Association that the prime responsibility for keeping airplanes apart lies in the ground-based air traffic control system. Yet, in the past few months, we have seen that a backup for air traffic control is needed, one that must operate on a cockpit-to-cockpit basis. With two mid-air collisions in the U.S., two major landing accidents, and one near-miss between two airliners over Pennsylvania, the months of June and July 1971 demonstrated the need for providing better mid-air and ground collision avoidance protection for all travelers. In our opinion, rapid introduction of the time/frequency collision avoidance system into the airways system is both essential and urgent.

Time/frequency collision avoidance implementation was advanced by action of the FAA, the airlines, and private industry sectors. The FAA has endorsed the request for a permanent frequency allocation for collision avoidance now before the FCC. Piedmont Airlines is the first U.S. carrier to order time/frequency collision avoidance. They were able to do so only because an industry-wide, fully coordinated specification, ARINC 587 for the hardware and ANTC 117 for the system, had ben adopted atfer five years of industry committee action and detailed technical work. In November, United Air Lines obtained the first FAA supplementary type certification for a Boeing 727 aircraft using the ARINC 587 system. Bendix, with whom we have worked both cooperatively and competitively, as well as other companies in the U.S., is preparing to build the time/frequency system.

Internationally, the problem of collision avoidance is achieving rare prominence. I have just returned from extensive briefings in the Orient. All segments of Japanese aviation—the airlines, the Japanese Defense Agency, the Japanese Civil Aviation Bureau—are hard at work to see that there will be no repetition of their July 28 collision, one that killed over 160 people. Their adoption of a system to match that of the U.S. is virtually assured when the U.S. goes ahead. Other countries of the Pacific are ready to join in our work, as evidenced by Cathay Pacific Airlines in Hong Kong, who currently chair the Orient Airlines Association Safety Committee, taking the lead to educate all member airlines in the benefits to be achieved from the time/frequency technology. The worldwide spectre of mid-air collisions is perhaps highlighted by the fact that one Pacific international carrier during 1970 experienced four near misses between two of its own airliners.

In Europe also, mid-air collisions avoidance is in the news. On 7 October 1971, the London Daily Telegraph reported that there were 108 near misses between airliners in airspace over Britain in 1970. In France, the government has let a contract for a time/frequency collision avoidance concept totally compatible with the U.S. system. In Germany, the International Air Line Pilots Association devoted a major portion of its New-Navy Symposium to this important question.

Why should we have a U.S. standard? Collision avoidance perforce must be a cooperative system. Overall aviation safety goes up directly with the number of equipped aircraft. Thus the airlines, the military and general aviation all must eventually be equipped with compatible equipment. Therefore, we must provide the power to enforce necessary safety regulations as well as the inducement to buy the system.

The action of requiring a system in an aircraft also acts as a powerful stimulus to avionics manufacturers. They start to build equipment, there is competition, and the price goes down.

Through our action here, we can assure that international carriers and government agencies all over the world will move forward to adopt the same compatible system. Since many of these countries do not have adequate traffic control, the time/frequency system can enable them to gain safety benefits for only a small investment. It should be stressed that our own commercial and military aircraft fly in these areas. They need protection there as well as at home. The adoption of the time/frequency system within the U.S. thus could be of benefit to aviation throughout the world.

With sales of American equipment overseas for collision avoidance and air traffic control, adoption of the system as a U.S. standard would strengthen our export position and could make a contribution toward achieving a favorable balance of trade.

The question that must then be addressed is whether the time/frequency system is a proper choice for implementation. Let me call to your attention the long history of this system. In 1962, MDC started its test program of the first time/frequency components, in 1964, we flew our first full systems and in 1965, EROS I became operational for all of our Phantom flights in St. Louis. In 1967, the industry wrote the first time/frequency collision avoidance specification in open meetings. Many of the companies you see in the room participated in these meetings. We shared our knowledge with others and they, in turn, contributed their expertise. In 1969, the Air Transport Association flew complete systems built by McDonnell Douglas, Bendix, and a team of Sierra Research and Wilcox Electric. These were flown in three piston and two jet aircraft. Through almost two years of industry action, the airline specification ARINC 587 was born, again in open industry meetings. Today, United Air Lines is flying the first EROS prototype units built to that standard.

What I am trying to illustrate is that any system reaching the cockpit takes a long time to develop.

Some more history. The time/frequency system is by no means the first attempt at designing a collision avoidance system. It is, the first *successful* system that is able to separate aircraft of all classes reliably without saturation.

Collision avoidance is one of the most deceptive problems in our aviation field. Many very reputable companies during the late 50's and early 60's were sure they had the solutions, built equipment and then were forced to withdraw when their concept, once fully developed and tested, plainly did not work. I have listed a number of these attempts in Appendix A attached.

Collins in 1958 had many airline orders for a system, but had to refund the airlines' money. Bendix, in 1959 and 1960, developed the ground bounce technique under FAA sponsorship, tested it as a system, and abandoned it. Motorola and Sperry in 1962, each developed an interrogator/responser system which was dropped. Even RCA felt in 1957 that the weather radar might be suitable for collision avoidance and had to abandon that effort. Then there were Aerojet and Honeywell and their infrared systems and many others. More recently, ISC/Telephonics was sponsored by the U.S. Navy at Johnsville, Pennsylvania to develop a transponder system. This, too, had to be dropped. What I am trying to illustrate is that the ability to measure range and range rate between two aircraft is no great achievement—it has been demonstrated by many people many times. Yet, when the time came to build a collision avoidance system, these all fell by the wayside.

We at McDonnell Douglas had good concepts using infrared and transponder techniques in 1960 and 1961, and had to abandon them when we tested these concepts in depth. However, we did believe time/frequency would work. We invested heavily and in 1965, were flying the system operationally. We went to the airlines in 1966 and told them: "Here it is—it works—you can buy it." We were then told the facts of life, that a military system might not be usable for an airline/general aviation environment. We were told that the airlines and the FAA would never buy a system produced by only a single manufacturer. We had to share our knowledge with our competition—Sierra, Bendix, Wilcox—anyone who wanted to atend the open meetings. The time/frequency adherents were then asked to supply equipment at their own expense for Air Transport Association tests. We all did that and again, invested our money and resources. Only in 1970, *five years* after our system flew on a daily basis in St. Louis, one year after the ATA tests, was the industry satisfied that a system had been configured for all users. And it will take another 12 to 18 months to build production hardware.

Any concept has to go through this crucible of scrutiny, simulation and full system hardware tests before one can accept its validity. One difference exists between those early days, when many concepts were funded and died, and today. We now have the time/frequency system available. It is proven. It has been tested. It works. It is economically feasible. Can anyone in this room today say with a clear conscience that we should not use it? That we should start the development cycle over again? That we delay in the hope that a wide-bodied jet will not be involved in a mid-air collision?

The opponents to time/frequency have equipment concepts. One of these, RCA, has not yet been able to show how to exchange altitude information. Their system is heavily based on being able to measure bearing or rate of change of bearing. Yet, they have not built equipment that does this. Nor have they even simulated a threat evaluation logic that would tell a pilot how to use such information. RCA is where many people were in 1962, at a breadboard technology test stage. Other manufacturers feel that systems that are proximity warning indicators today can be extended to encompass the full collision avoidance functions. Yet, again, no hardware has been built to do so. Can we afford to wait five to ten years more to find out whether or not one or another of these concepts works? We do not believe so.

I think everyone will admit then that in terms of development status, time/frequency is far ahead. Does our system then have technical deficiencies, as our opponents claim?

You may have heard much about false alarm rates. The first question that one must ask is what is a false alarm? If, by a false alarm one means giving an alarm when no aircraft is present, then we have never given a false alarm. There comes a time, regardless of what system one has, when one must tell an aircraft that it is too close to another and must ask it to move. As a simple example, an aircraft 1,000 feet above another aircraft may not be dangerous and should not receive an alarm. An aircraft 1,000 feet ahead of another aircraft is indeed dangerous and should be warned, in fact, it should have been warned much in advance of such a situation. It is the threat logic in the equipment that triggers the alarm by evaluating the information coming into the system. We do not know how people can discuss false alarms without having built, tested and simulated threat logic. Without this, one really has no collision avoidance system. It took almost three years of intensive work with full industry and government participation to generate the time/frequency system threat logic. I would like to state once and for all that the time/frequency system is not prone to false alarms. As evidence, I cite FAA's Gordon Jolitz and his Atlanta 1967 traffic analysis. This is further confirmed by Robert Buck, Chief of FAA's Detection Systems Branch (References (a) and (b)). When Mr. Jolitz used our present day threat logic, he found that in 11 hours of Atlantic traffic, only one aircraft pair received a climb/dive command. It should have. It was in a conflict situation. The "do not turn" command was given on 22 occasions in each aircraft pair (1.16% of the time). All other indications were advisories. There are no false alarms. This seems to be confirmed by FAA's 1971 Chicago/O'Hare simulation, using extremely heavy traffic concentrations.

While the FAA final report has not been released, initial results have been reviewed by qualified operations personnel. Their opinion confirms that the time/frequency collision avoidance system works within the present air traffic control system. Excessive air traffic control interaction just did not occur. In simulating some 36 hours of peak density Chicago traffic including over 5,000 operations, only 26 climb/descend commands were given, 9 of these being traced to either pilot error or a controller spacing aircraft too closely. In other words, in 9 instances, the system prevented a potential accident. The time/frequency collision avoidance system did what it was supposed to do—back up the air traffic control system and assure safe separation.

One other point is of importance. Does the time/frequency collision avoidance system provide adequate warning time. We tested just how much warning time was required in an extensive simulation. As you know, it is expensive to fly airplanes and sometimes dangerous to set up proper test conditions for collision avoidance work, since you must fly airplanes at each other, sometimes at high speed. In the ATA tests at Martin-Baltimore, we flew some 220 actual collision avoidance encounters. In order to multiply our experience significantly, we used a computer to simulate airplanes in flight. On a computer one can establish the most dangerous initial conditions, vary such factors as pilot response time, aircraft performance and geometry, and determine whether the two aircraft safely miss each other. We ran over 30,000 cases of climbing, diving, turning aircraft. In some of these, we even prevented one of the aircraft from maneuvering. Even in the worst configurations, we found with our published warning times that adequate separation does exist. Not only that, the maneuvers to be executed by these aircraft were found to be gentle, designed not to spill the coffee from your coffee cup. Incidentally, all of our flight testing, by the ATA in Baltimore and MDC in St. Louis and San Francisco, confirms this.

Let me just briefly treat a few other pertinent technical points, those of escape maneuvers, reliability and military applications. We are on record regarding all of these factors.

Dr. Morrell of Bendix, in his paper presented in the Institute of Navigation (Volume XI, No. 1), as early as 1958 confirmed the fact that vertical maneuvers for collision avoidance were desirable and horizontal maneuvers were not. This conclusion was also confirmed by Collins. The reliability record of our transmitter is being demonstrated to the world in United Air Lines flight test every day. We have not had a single transmitter tube failure in our test program, which started over six months ago. Military vulnerability of the time/frequency signal format was the subject of investigations by the Air Force under classified contracts during 1969 and 1970, and confirmed our system could work in a military environment. The record of development of the time/frequency collision avoidance system is open for your scrutiny. Our equipment is flying in airline use and in general aviation aircraft.

We come now to the important matter of general aviation equipments. We would like to point out that we have built and are flight testing a complete, fully packaged general aviation collision avoidance system—the Micro-CAS. We are also on record with our pricing for this unit at a $2,500 list price. This is based on a 1,000 unit production run. This is a system that provides protection for the air carrier against a general aviation aircraft and also for one general aviation aircraft against another. It provides complete collision avoidance commands in both cockpits. The price includes all distribution markups normally attributable to such equipment. Other companies have discussed possible arrangements with us for producing Micro-CAS and can probably achieve costs lower than $2,500.

In order to check the validity of this, we counted the parts in our Micro-CAS and compared the numbers against the number of parts in the Genave B4096 Transponder, which retails for about $800. We have about 50% more parts in the Micro-CAS. Prices near $1,200 thus seem supportable once large scale production starts. You see, once you have equipment built, you can very accurately estimate how much it costs. Yet, all of us know that before something is built, whether it be a three-bedroom house or a collision avoidance system, a certain degree of optimism exists.

When we hear about systems that are advertised to be much lower in cost than the time/frequency systems, the first question we must ask ourselves is, "What do they do". We have tested a simple Proximity Warning Indicator that costs very little. It tells an aircraft that it is in the vicinity of a time/frequency equipped collision avoidance system or beacon within the same altitude band as the other aircraft. Even so, we worry about giving so little information to a pilot. Because in a crowded traffic environment, he must then look out, determne which is the aircraft that triggered his warning and then figure out which way he should move to escape the threat. Such a system may be better than nothing. Be we question its overall utility even though it might only cost about $600. Next on our scale of systems is the beacon. This informs other equipped aircraft that they are near a small aircraft and thus depends on the other aircraft to take the evasive maneuver. McDonnel Douglas could build such a system for $1,600, and it seems reasonable that general aviation avionics manufacturers could produce it for substantially less. However, our concern has always been to provide information to both pilots. Thus, we prefer systems that insure that each pilot has an unambiguous command telling him what he must do to escape. In short, we totally reject the concept that time/frequency equipments are any more expensive than comparable competing units.

We would, however, like to call your attention to one major advantage of the time/frequency systems. These systems will do far more than prevent mid-air collisions, although that would justify their existence all by itself. The Micro-CAS and the airline/military system both can be used to avoid ground obstacles, if a simple time/frequency beacon is installed at that site. This is being demonstrated today in San Francisco. They can be used as an airport landing aid. The system reads how far away it is from another ground station and what its altitude difference is with respect to that station. It will read the range and altitude difference of all other equipped aricraft in the vicinity.

When a private pilot buys time/frequency collision avoidance, he benefits from built-in functions, which normally would require additional avionics equipment in the cockpit.

Much has been made of the requirement for ground stations by the time/frequency system. Any cockpit-to-cockpit system requires ground-based checkout and integrity monitoring. This function is provided by the ground station in addition to its primary time resynchronization role. Even the VOR's we use today very extensively have 70 ground test installations in the U.S. Additionally, the resynchronization stations can also act as obstacle avoidance beacons, or as airport approach aids, in places where an ILS system is too difficult to install or unwarranted financially. We are demonstrating this in our San Francisco tests. The 65 U.S. stations shown in the FAA ten year plan probably require a total investment of less than thirteen million dollars—fully installed.

The time scale of implementation is a function of the production capability of the various companies involved. We at MDC are able to start airline system deliveries during the Spring of '73, a time that seems appropriate for the first general aviation system deliveries also. Other companies are on record as being able to produce compatible systems in about the same time period.

I have stated that the time/frequency system is available and fully developed. We at McDonnell Douglas do not have a monopoly in this field. You have heard of the other companies that have built equipment. Since 1967, we have generated our technical specifications with full government participation. NASA, the Air Force, the Navy and the FAA were represented in all CAS/Technical Working Group meetings. Along every step of the way, we invited the Government to witness our tests, or to participate in them as a full member. The Air Force and the Navy have been fully aware of the role the EROS I collision avoidance system plays in testing the Phantom aircraft in St. Louis. We, therefore, would reject the claim of those that say there has been insufficient time to evaluate what the system does.

We would urge the FAA to promptly issue the long promised requests for the ground station implementation study and ground station hardware. We further hope that the FAA can meet its commitment and officially advise manufacturers during December of the results of the Chicago/O'Hare traffic simulation and recommend operational procedures for using the system. We also urge that the FCC promptly and permanently assign the frequency presently allocated to collision avoidance. This means removing the developmental designation from the band. We submit that the time/frequency system is far beyond the developmental stage. We, as an industry, have been through two frequency changes and had to redesign our equipment. This is too expensive to continue.

I believe the record of our industry work is sufficiently clear. Eleven years of orderly, careful engineering work, six years of operational use, all done in the open under scrutiny from the FAA, the DOD, and the airlines, have shown that the time/frequency system works and can be built by us as well as other companies.

We are obviously in favor of Senate Bill S2264. However, we share the feeling of others that the FAA currently has the regulatory authority to assure the introduction of collision avoidance. We feel the system should be mandatory in the post 1975 time period.

Our industry surveys show that the equipment could be available for new aircraft delivered after 1973 and that existing aircraft could be retrofitted by 1976. Most importantly, early official FAA endorsement of the system is required—as is U.S. support of the time/frequency system in international meetings of ICAO starting next Spring. Such support will also come from other nations where air safety has become a vital public issue.

Time/frequency collision avoidance is much more than a dream. The paper concept of 1963 became the flight test demonstration program of 1964. The system, in daily use in St. Louis for the protection of our Phantom aircraft since 1965, was the forerunner of our second generation equipment flying under airline conditions in California today. The system has been ordered by Piedmont Airlines in a most far-sighted and public spirited move. It exists in flight hardware form for general aviation. It is here—now. We strongly urge that all responsible parties move forward with resolve and determination to adopt time/frequency collision avoidance—to improve the safety of our crowded airways.

REFERENCES

(a) FAA Technical Note Project No. 241–003–03X, G. Jolitz, Project Manager 4/2/69

(b) CAS/ATC Terminal Compatibility, Robert M. Buck, Chief Detection Systems Branch, FAA 2 May 1969

(c) Preliminary Results Project No. 241–003–03X Simulation and Analysis of ATC/CAS Design November 1968

COLLISION AVOIDANCE CONCEPTS—1956–63[1]

Company	Technique	Status
Collins Radio Inc	2-phase PWI/CAS independent/cooperative.	PWI target date: January 1958 CAS target date: November 1959 price: $6–$7,000. Proposed and marketed 1956, program abandoned 1957.
Aerojet-General	PWI independent. Infrared constant rotating detector, passive radar detector.	Prototypes early 1958. 5 service test models—$400K. Price: $7,500–$10,000. Impossible to develop into automatic CAS. Marketing effort produced no sales. Program abandoned.
RCA	PWI, independent. Standard weather radar with PWI adapter/2-way reflection.	Flight evaluation 1957–60. Price: $10,000 approximately. Unsuccessful.
Minneapolis-Honeywell	PWI, independent. Dual model infrared system.	Proposed to ATA Jan/1958. Ground tested by Naval Ordnance 1962. Apparently abandoned.
Federal Telecommunication Laboratories.	PWI, independent. Interferometric techniques combined with existing airborne radar.	Proposed to ATA Jan/1958. Cost: $10,000. Apparently abandoned.
Ramo Wooldridge	Self contained doppler radar PWI	Study only for Army Signal Corps 1958. No further action.
Bendix Radio	PWI/CAS cooperative. 1-way transmission by direct air-to-air path plus ground bounce signal.	FAA flight tested 1961. Concept unreliable.
Boeing Airplane Co	PWI/cooperative. 2-way reflection radar K-band, nose and tail.	1957–58. No further development.
Decker Aviation Corp	PWI/cooperative. Monochromatic light	1958—No development.
Norden Division of United Aircraft Corp.	PWI/cooperative 2-way reflection transponder. K-band nose and tail radar.	Proposed 1958. No further information.
FAA	December 1960 report to airlines announced 200 PWI/CAS proposals received during the year; few new in concept or feasible for operational use. Hope was abondoned for noncooperative PWI/CAS.	
Sperry Gyroscope Co	PWI/CAS cooperative. K-band radar echo, plus interrogation of transponder.	FAA flight evaluation of flush mounted antenna started in spring, 1961. Contract awarded 1962 for prototype PWI for flight test early 1964; CAS, early 1965. Abandoned.

[1] Reference: Aviation Week Magazine, April 1955—April 1966 Issues.

Senator CANNON. Next is Clyde Parton, vice president and general manager of Honeywell.

STATEMENT OF CLYDE A. PARTON, VICE PRESIDENT AND GENERAL MANAGER OF GOVERNMENT AND AERONAUTICAL PRODUCT DIVISION, HONEYWELL, INC., MINNEAPOLIS, MINN.; ACCOMPANIED BY ROBERT J. FOLLEN, PROJECT ENGINEER, RADAR SYSTEMS; AND RONALD E. ERICKSON, SENIOR MARKETING REPRESENTATIVE, INSTRUMENTS

Mr. PARTON. Thank you, sir.

Mr. Chairman and members of the committee, I appreciate the opportunity of appearing here today to discuss Honeywell's activity relative to the critical problem of prevention of aircraft midair collisions.

I have with me on my left Mr. Robert Follen, project engineer, radar systems, and on my right Mr. Ronald Erickson, senior marketing representative, instruments.

I will be discussing Honeywell's background and current efforts relating to aircraft collision prevention. Following this I would like to review those issues which we feel are critical to the implementation of any air-derived collision prevention system where different segments of the aviation community are involved. Finally, I wish to state Honeywell's recommendations as to the future direction of collision prevention development.

Let me say at the outset that we believe central management through the air traffic control system should have primary responsibility in aircraft separation. We subscribe to the long range plans of the FAA to develop a system that will provide such additional improvements to the air traffic control function as predicting impending traffic conflicts and automating their resolution, flow-control direction in congested traffic situations, and preplanning and sequencing of airport arrivals.

However, several midair collisions in recent months have demonstrated the ineffectiveness of the present ATC equipment. The third generation ATC is nearing implementation and undoubtedly will provide greater assurance of aircraft separation. Notwithstanding this fact, we believe there is an urgent requirement for an air-derived independent system, compatible with the ground-based ATC procedure, for at least two reasons.

First is the desirability of a near-term solution. History tells us that full implementation of the third generation ATC will be several years away, possibly in the 1980's. Additionally, we believe there is a current and long range need to provide an air-derived system which can augment the effectiveness of ground separation control by functioning in an emergency backup mode.

It is also necessary that the technique adopted be in concert with the economic situations of all facets of the aviation community—the commercial fleet, general aviation, and the military services. A large task indeed, but not impossible with appropriate motivation, a commonsense approach to requirements, and the initiation of national direction by an action group.

In the interest of conserving time I will not detail Honeywell's experiences as submitted in our formal presentation.

Suffice it to say, at this time in less than 3 years Honeywell and the Army have implemented successfully an operational pilot warning indicator, tested a modified PWI, which includes relative bearing information, and produced three flightworthy prototypes of a collision-warning system which includes the basic required characteristics needed for an effective anticollision system. These are relative altitude, collision threat evaluation, and relative bearing information if desired.

We believe this demonstrates that today's technology can provide effective air-derived anticollision systems when a need and firm requirements are stipulated.

Honeywell is aware of the significant effort by the various working groups which has established the operational requirements for the commercial segment of the aviation community. Honeywell does not dispute these operational requirements as specified by ARINC characteristic 587 and ANTC–117. Unfortunately, these documents have gone beyond requirement setting in that they have limited the technology to a time/frequency approach only.

We do not agree that the time/frequency technique specified by these documents offers the only feasible approach, nor does it necessarily result in a system which provides both adequate protection for all users and economic feasibility. For example, reasonable state-of-the-art engineering modifications to Honeywell's collision-warning system will satisfy the performance parameters of a collision-avoidance system as stipulated by ANTC–117.

The azimuth information available would make it possible to include horizontal command maneuvers as well as vertical if such were desired. This modular approach with complete compatibility between all versions permits tailoring equipment to a variety of cost/performance needs.

We have projected prices, incorporating necessary command display requirements, for quantities of 5,000 to 10,000 units. We estimate our concept will provide effective systems within a price range of less than $1,000 for general aviation aircraft and less than $10,000 for the more sophisticated complete CAS required by high performance military and commercial jet aircraft. In addition, no expensive ground or airborne synchronizing installations are required.

It has been a popular concept for years that a transponder system, regardless of the signal processing techniques utilized, has an inherent, severe traffic handling limitation because of the two-way communication requirements. The decision to pursue time/frequency techniques for collision avoidance was made many years ago. At that time, transponder techniques were also considered but were rejected as being impractical because of the greater information transfer load.

It has been feared that the systems would saturate under heavy traffic. The decision, at that time, was understandable. The Honeywell transponder collision-warning system presently being evaluated by the Army Electronics Command would also have been considered impractical as little as 5 years ago.

As an example, the traffic densities required of this system necessitate 128 range storage cells per warning sector. This is accomplished with 12 integrated circuit memory units that occupy 2 inches by 5 inches on a single printed circuit card.

Ten years ago—or even 5—the equivalent circuitry to perform this single function would have required approximately 10,000 discrete transistors and would have occupied several cubic feet of volume.

Progress in packaging and modern digital processing techniques have made this possible notwithstanding the related improvement in reliability, size, weight, and cost.

We recognize fully the importance of being able to cope reliably with the traffic projections of the future. At the present time, we are in the midst of a new computer simulation program based on traffic model information furnished by the FAA.

The model simulates the projected flow of air traffic in the Los Angeles basin in the 1980's. The FAA has estimated that there will be as many as 800 aircraft airborne within 70 miles of the Los Angeles airport, and this density is the basis for the model generated.

The 800 aircraft will include low performance VFR and IFR general aviation craft, high performance commercial air carriers, and military aircraft.

In the simulation, each of the 800 aircraft has been assigned a specific location in the basin, a velocity, and a direction of flight, and each aircraft has a Honeywell collision-warning system on board to evaluate collision threats as the aircraft move through the airspace.

The results obtained from the computer simulation will include quantitative information on the traffic-handling capability of the Honeywell system since complete saturation data on each aircraft proceeding through this dynamic simulation can be recorded and analyzed at any instant.

These data will include extraneous noise and multipath inputs. In addition, the velocity vector of each craft can be changed as well as their position in the model.

And analysis of the results of this computer simulation will demonstrate conclusively the capability of a properly designed transponder-type system in a very dense air traffic environment.

Results to date confirm that a beacon transponder system can handle the concentration of aircraft specified by the model. A formal detailed report will be published upon completion of the simulation later this year.

It is encouraging to note that at Fort Rucker, where traffic densities currently run much higher than any civil air terminal, not a single false alarm or saturation effect resulting from multiple aircraft has been reported.

My purpose in testifying before this committee is to emphasize to the committee members that sound alternative solutions to the midair collision problem exist.

Further, these alternatives have substantial advantages in cost, availability, flexibility, and the capability for optimization against the precise application for which they will be used.

We have tried to take an objective look at the midair collision problem and its potential solutions. Notwithstanding the urgency of getting on with some corrective actions, we conclude it would be a colossal mistake to initiate actions at this time that would tend to commit prematurely to a particular type of system concept. We believe that adequate consideration of the following factors is essential to the successful implementation of an air-derived collision-prevention system.

1. Inputs from all segments of aviation are required. The initial Honeywell PWI was tailored for helicopters and the Air Transport Association Time/Frequency CAS was tailored for airline operations. General aviation and the remainder of DOD should be major participants in selecting a concept, particularly since their costs of implementation may be an order of magnitude greater than that of the airlines, for example.

2. The selected concept should be tailored to supplement the ground-based air traffic control while maintaining complete operational compatibility.

3. The concept should be selected on the basis of all the different classes of aircraft that will be involved.

4. With extensively planned aircraft retrofit programs related to AIMS beacons, direct address beacons, microwave landing systems, plus others with DOD, the economic factors of another avionics box become an overwhelming consideration. Users should be required to pay for no more than is necessary to solve the requirement.

RECOMMENDATION

We believe that the efforts of a national group representing all of the aviation community are needed if a viable air-derived collision-prevention program is to evolve. An action group rather than an advisory or coordination group must be established immediately.

Realistic anticollision system requirements based on a determination of where the ATC fails or is weak and what is needed as a supplement to correct the weakness should be developed. Utilizing the efforts to date, we believe this national group could formulate realistic anticollision requirements in 1972, evaluate concepts and hardware in response to these requirements by 1973, and be well along with installation of effective and practical systems for all segments of the aviation community by 1975.

Honeywell would be pleased to participate in this activity, and we are confident that this timetable is well within our capabilities.

Mr. Chairman, this completes our formal statement. However, for the record, I would like to emphasize that the transponder system concept such as we have discussed is not unique to Honeywell. It is our understanding that other companies are pursuing similar non-synchronous transponder concepts.

We believe there should be an evaluation of all competitive products. We need to establish a common standard for nonsynchronous concepts. similar to that which was established for nonsynchronous concepts.

Mr. Chairman, we have with us working simulators of actual operational hardware for our PWI and our collision warning system. If you or other members of the committee would like a demonstration at this time or later, we are at your service at any time.

Mr. Chairman, we appreciate this opportunity to express our views on this important subject.

Senator CANNON. Thank you very much. We won't take the time now to see the demonstration. However, if we have time later this afternoon, we might do that or if not, if you contact our staff people, we will try to work out something.

Senator Moss?

Senator MOSS. Thank you, Mr. Chairman.

I thank you, Mr. Parton, for your very good testimony, and for indicating the work that Honeywell has been doing in this field.

I take it that you believe that we could meet the dates that are set in the bill of S. 2264?

Your testimony says January 1, 1972. You said by 1973 a decision could be made. About what time were you thinking of?

Mr. FOLLEN. I think these needs are perfectly compatible with the type of gear we are proposing.

Senator MOSS. If we took the steps recommended, you think we could meet these dates that are set in the bill?

Mr. FOLLEN. Yes, sir, we do.

Senator MOSS. I believe you estimated that the general aviation unit could be produced for $1,000 or less and that the commercial aviation $10,000 or less, is that correct?

Mr. ERICKSON. Yes; that is right.

Senator MOSS. Fine, thank you.

And after the decision is made, if it is made in January of 1973, you think that production could be mounted thereafter rapidly enough that aircraft could be equipped by 1975?

Mr. FOLLEN. Yes, sir.

Senator MOSS. Thank you very much.

Senator CANNON. Thank you very much, gentlemen.

The next witness is Mr. Douglas A. Decker, commissioner, Utah Aeronautics Board, Salt Lake City.

Senator MOSS. I am very glad to have Mr. Decker here, coming from Utah and being on our aeronautics board. We appreciate your coming back here to testify.

STATEMENT OF DOUGLAS A. DECKER, COMMISSIONER, UTAH AERONAUTICS BOARD, SALT LAKE CITY, UTAH

Mr. DECKER. Thank you, Mr. Chairman, Mr. Moss.

The Division of Aeronautics of the State of Utah would like to congratulate you gentlemen on calling this hearing to investigate proper methods of reducing air traffic collisions.

As you know, we lost many Utahans in a midair collision and many of the were very close to us in the division of aeronautics as I know, Mr. Moss, so we are very deeply grieved by this midair collision.

We believe that there is a great need for investigation of the problems of collision avoidance. The purpose of this statement is to request that all phases of the implementation of the collision avoidance system be carefully scanned.

Utah is a rural State and as such relies heavily on the general aviation fleet and its over 5,000 pilots to provide transportation to many parts of the State.

We therefore respectively request that the economic impact of a collision avoidance system be also carefully evaluated.

Gentlemen, I would now like to make just a couple of brief comments of my own personal opinion and not necessarily the opinion of the Utah Division of Aeronautics.

I am a member of the general aviation fleet, being an owner of a single-engine airplane, and I do not come to this hearing as an expert on collision avoidance systems.

I am a single-, multi-engine, instrument, and commercially rated pilot.

I personally believe that the legislation to force mandatory requirements on general aviation have to be very, very carefully weighed.

I would like to point out one item which I really do not think will come out of this testimony, because you are talking to vendors trying to propose CAS systems. I have talked to a few of the inventors, and the limitation of the 12,500-pound limit that is placed on the proposed legislation should be reviewed.

There are many aircraft in the aviation fleet throughout the United States that are higher—that exceed that limitation of 12,500 pounds. Some of these aircraft cost $25,000 or $35,000.

To require a unit that costs $50,000 I think you can see would be economically damaging to that particular segment.

Secondly, I would like to just say that the history of general aviation in participation in Government programs has been very great. The transponder is one example that general aviation has supported, and right now, the majority of general aviation planes on a voluntary basis have installed this equipment on their aircraft without Government regulation.

That is all I have, gentlemen.

Senator CANNON. Senator Moss?

Senator MOSS. Thank you, Mr. Decker.

If we didn't use the weight standard in dividing between collision avoidance system and PWI, is there any other standard that you would recommend?

Mr. DECKER. Yes.

I would think that in talking to some of the gentlemen of the equipment suppliers, and I think they are more qualified than I am here, but I think that speed and altitude might be one of the requirements.

Senator MOSS. You would prefer to work out some formula rather than simply weight.

Mr. DECKER. Yes, sir.

Senator MOSS. Now, it has been estimated by various companies working in this area that costs for a general-aviation plane would be around $1,000, some a little higher, possibly some a little lower. Is that something that seems to you to be excessive for general aviation?

Mr. DECKER. Well, I would just say that the $1,000 figure in dollars and cents is not excessive. I believe, though, that that cost would be lower than $1,000 if a few of the general-aviation manufacturers got behind it and started development and work.

But this would take time. This is why I get back to the point that a mandatory requirement—these people are not going to have the time to do the research and development to make an inexpensive unit.

Right now there are transponders on the market for $400. They used to be $1,200 to $2,000. They have them down to a very reasonable price. But it has taken time.

Senator MOSS. You are saying then you think perhaps these dates are too short, the length of time is too short, or would you eliminate altogether any deadline?

Mr. DECKER. Well, that is not really for my judgment. I would just as soon not say. I don't have an opinion on that.

Senator MOSS. I see. You have made mention of the fact that there was a midair collision in which we lost so many Utah citizens and friends. I know this weighs on you as much as it does me and also on anybody else that is interested in aviation or humanity.

So, I am sure you are anxious to get to the goal that we are seeking, and what you are telling us is that you are putting up warning flags along the way in the event the bill is forced too fast, so that we must be careful of the cost factors because it might eliminate some of the general aviation?

Mr. DECKER. That is right. If I might point out one other thing: If it were implemented on the airlines and with the implementation of the FAA's terminal control area which prohibits general aviation in many ways of getting near larger airport facilities, then the system would still be operable among all the airline planes one to each other.

I might also point out that I believe that one implementation that could be made immediately is to require military aircraft operating on a VFR flight plan in high density areas, to be required to contact the appropriate air traffic controller in that area when he is coming into that area. The pilots of these sophisticated airplanes have a terrific management problem in flying these airplanes.

I do not think that with their high cockpit duties that they are scanning the skies as they should. Therefore, a requirement to contact the appropriate radar facilities and announce their arrival could have possibly prevented that accident in California.

The FAA informed me yesterday, in Mr. Shaffer's office, that they were encouraging all military aircraft to operate in the IFR instrument flight rule mode, and this, of course, will assist in this problem also.

Senator Moss. In notification?

Mr. Decker. Yes.

Senator Moss. Thank you, and thank you, Mr. Chairman.

Senator Cannon. Of course, my observation in respect to your remark on that very unfortunate accident is that none of these instruments can be substituted for good judgment, no matter what you do, and I think that that was as much a factor in that unfortunate accident that you are concerned with as anything else.

So you can instrument them. All you are going to do is if they don't follow the regulations, the pilots, or use good judgment, you are going to have the hazard to deal with.

Mr. Decker. That is exactly right.

Senator Cannon. Thank you very much.

STATEMENT OF HERBERT J. FRANK, PRESIDENT, AEROSONIC CORP., CLEARWATER, FLA.

Mr. Frank. Mr. Chairman, Senator Moss, I am going to be very brief. I am a small company, so I don't have very much to say.

Senator Cannon. I thought that worked in reverse usually.

Mr. Frank. I am Herbert J. Frank, president of the Aerosonic Corp., a company that has been manufacturing aircraft instruments and working since 1964 on simple, inexpensive, anticollision devices for the light aircraft.

It is my opinion, as a pilot, a manufacturer, and certainly an advocate of aviation, that every airplane must be equipped, with some form of anticollision or warning system to tell each aircraft that there are other types of aircraft operating within its area.

It is also my personal opinion that part of the aviation industry today has survived in spite of the FAA. I know that as many as 10 years ago devices were available to the aviation world in the form of proximity or anticollision devices, that would have saved hundred of lives, but we find in our FAA that everybody is looking for perfection and nobody is interested in halfway fix. I do not believe there is such a thing as perfection, but I do believe that halfway fixes would and still can, save hundreds of lives through devices that would prevent midair collision.

The state of the art today is such that devices are available for under $500 per aircraft, and I personally feel that such a cost must be held in order to make it economically feasible for all aircraft to be equipped with such a device.

Companies such as mine, who are pilot oriented, have developed such devices, flown with such devices, and one such device is available today. I feel, as do many pilots, that these devices would be of great assistance to anyone flying an airplane.

I must bring, however, to the committee's attention two things that I think are greatly important to this program:

1. In order to maintain and keep the price below $500, some company or independent agency must become involved with the sale and the disposition of these items to eliminate the typical 100- and 200-percent markup that accompanies such devices when finally bought by the public.

I am sure that manufacturers can become involved in the manufacture and production of such items, but I believe that if distribution was set through normal channels these devices would run from $1,000 to $1,500 apiece.

2. I would like to call to the attention of the chairman and the Senator, that the Japanese have so decimated our industry today that I am making a plea before the Senate and you, gentlemen, to be sure that your program is "Buy American" 100 percent in order that the program can keep the manufacturers in business rather than letting the Japanese and Far East nations completely wreck our aircraft avionics and instrument manufacturing business.

I am also of the opinion, as a manufacturer, that such a program can be completed on or before the year 1975, provided that somehow the FAA is not made the program manager of such a program. But industry, along with the FAA, along with pilot associations, are able to get together on a set requirement. I would like to reemphasize the fact that anticollision and proximity warnings are a must, if our aviation program is to continue in the United States, and that the state of the art as it stands today could supply the aviation industry with such devices.

I want to thank this committee for allowing me to appear before you to permit at least one pilot and manufacturer to speak on behalf of such action.

Thank you very much.

Senator CANNON. We appreciate your being here. Thank you.

Senator MOSS. Thank you, Mr. Frank, I appreciate your testimony, too.

What is the device you say is being flown today that gives at least half a fix?

Mr. FRANK. We have a device that tells altitude of other aircraft and gives your altitude to the other aircraft. Under those circumstances, if two airplanes are not at the same altitude they can't hit each other. That is the simplicity of the whole device.

Senator MOSS. I see.

Thank you very much.

Senator CANNON. Thank you, sir.

Next is Mr. George Rock, product line manager, Loral Electronics Systems, New York City.

Mr. Rock.

STATEMENT OF GEORGE C. ROCK, PRODUCT LINE MANAGER, AIRCRAFT SYSTEMS, LORAL ELECTRONICS SYSTEMS, BRONX, N.Y.

Mr. Rock. Thank you, sir.

Mr. Chairman, members of the committee, I have to apologize for not having a lengthy presentation. I have a simple slide presentation. Unfortunately, the ambient conditions of the room may make it difficult for you to see it.

My complete statement is contained in the published document that I submitted prior to this meeting.

May I have the lights off, please.

Thank you.

SLIDE 1.—AIRCRAFT COLLISION PREVENTION—ALPHABET SOUP

Everyone agrees that aircraft collision prevention is a problem. We are confronted, however, with a multiplicity of proposals to solve the problem. We need a clear picture of how good these proposals really are.

SLIDE 2.—COLLISION AVOIDANCE SYSTEMS

Operate in VFR and IFR.
Detect intruders.
Evaluate threats.
Determine avoidance action.
Execute commands.
Have high cost of ownership.
Offer limited protection to majority of airspace users.

The solutions generally fall into two categories, collision avoidance systems or CAS, which by its nature is costly and offers only limited benefits to general aviation.

SLIDE 3.—MICRO-CAS

Priced beyond reach of general aviation.
Requires airline or ground CAS environment.
Micro CAS does not quite make it either.

SLIDE 4.—PROXIMITY WARNING INDICATORS (PWI)

Operate in VFR.
Alert pilot.
Assist visual scan.
Show direction of intruders.
Have low cost of ownership.
Serve majority of airspace users.

The alternative solution falls generally under the heading of pilot or proximity warning indicators or PWI. This class of device is designed to fit the pocketbooks of the majority of the aerospace users.

SLIDE 5.—MOST MID-AIR COLLISIONS OCCUR

In daylight.
Under good visual (VFR) conditions.

Below 5,000 feet.
Near uncontrolled airports.
Between general aviation aircraft.

PWI operates best under the conditions most likely to produce midair collisions. One might pause to ask why this concern about the problems of general aviation.

SLIDE 6.—BY 1985 GENERAL AVIATION WILL:

Fly 57 million hours/year.
Account for 40 percent of all IFR itinerant operations.
Contribute $7 billion to the gross national product.
Carry more passengers intercity than scheduled airlines.
Contribute substantially to regional development.

A look at the FAA's evaluation of this group provides the answer.

SLIDE 7.—GENERAL AVIATION

Is important in national economic development.
Is growing rapidly.
Is most vulnerable to midair collisions.
Cannot afford CAS.
Needs collision prevention now.

General aviation, which is making an ever-increasing contribution to the Nation's economic growth, is most susceptible to midair collisions. Unfortunately, the various CAS proposals have not offered adequate solutions to this growing problem.

SLIDE 8.—CAS IMPLEMENTATION—1980 OR BEYOND?

Five–seven years to equip airline fleet.
Five–seven years to install ground stations.
Selection of best system will delay decision date.

Should a CAS, meeting the requirements of all aerospace users, be developed it would not become fully operational until the 1980's.

SLIDE 9.—IN THE MEANTIME

Air traffic control procedures.
Pilot training programs.
Improved aircraft conspicuity and proximity warning systems . . . can limit the increase in midair collisions during the next decade.

The situation, however, is not exactly hopeless. Interim if not complete solutions that address the needs of most aerospace users have been suggested by the National Transportation Safety Board, the Department of Transportation, and even the FAA.

SLIDE 10.—THE HIGH-INTENSITY XENON STROBE LIGHT

Provides best conspicuity enhancement.
Is widely recommended by Government and industry aviation groups.

Enjoys substantial popularity among general aviation users.

Can be used with optical PWI.

Can be purchased and installed for less than $150.

The most universally recommended means by Government and industry for conspicuity enhancement has been the high-intensity Xenon strobe light. That this is an effective device is attested to by the great acceptance it enjoys among general aviation users.

Surveys in the past 2 years indicate that between 30 and 50 percent of the active general aviation aircraft are equipped with strobe lights.

SLIDE 11.—PHOTO OF AIRCRAFT WING TIP SHOWING STROBE LIGHT INSTALLATION

Senator CANNON. What is the cost of that installation you just showed?

Mr. ROCK. I don't know, sir. We are not in the strobe business. But I will get to the point of my presentation in a moment.

Senator CANNON. All right.

SLIDE 12.—PHOTO OF STROBE LIGHT MOUNTED ON U.S. ARMY TH-13 HELICOPTER

Mr. ROCK. The U.S. Army has found that the high-intensity strobe light enhances the conspicuity of Army aircraft.

SLIDE 13.—DISTANT AIRCRAFT ARE TOUGH TO SEE—UNLESS YOU KNOW WHERE TO LOOK

In order for a PWI to do its job it must point the direction of the intruding aircraft. The preliminary FAA systems characteristic contains this requirement.

SLIDE 14.—VISUAL DETECTABILITY OF AIRCRAFT INFORMATION SUPPLIED BY PWI

	Percent detection
Warning, bearing and elevation	75.0
Warning and bearing only	50.0
Warning only	3.5

A study conducted by Sperry for the FAA supports this conclusion.

SLIDE 15.—THE IDEAL PWI SHOULD

Be self-contained and noncooperative.

Require no special radio frequency.

Provide intruder direction and altitude or elevation discrimination.

Be lightweight, low powered, and easily installed.

Not affect the aircraft's airworthiness or appearance.

Retail for less than $1,000.

The characteristics of a PWI, that will meet the needs of most general aviation users, have by now been well established.

SLIDE 16.—THE OPTICAL (INFRARED) PWI IS THE ONLY SYSTEM CAPABLE OF

Displaying intruder direction with sufficient accuracy.

Providing adequate range for worst case general aviation closing speeds.

A low order of false alarms.

Meeting the size, weight, and power limitations of the smallest general aviation aircraft.

Of the many PWI approaches proposed and/or tested, the optical technique offers many advantages not inherent in alternative solutions.

SLIDE 17.—THE OPTICAL (INFRARED) PWI

Does not affect the aircraft's airworthiness or appearance.

Operates with Xenon strobe beacons.

Does not rely on critical radio frequencies.

Retails for less than $1,000.

The cosmetic, aerodynamic, and structural integrity of general aviation aircraft is of great importance to the manufacturer, the owner, and the technician charged with the responsibility of installing proximity warning instruments.

SLIDE 18.—ILLUSTRATION OF TYPICAL PWI SENSOR WING TIP INSTALLATION

Thus the wing tip installation, illustrated, has universal appeal.

SLIDE 19.—PHOTO OF APPROVED RED STROBE BEACON MOUNTED ON AIRCRAFT TAIL

The most often repeated objection to white strobe lights as replacements for the prescribed anticollision beacon is that they cause annoying back scatter from clouds and aircraft structure. Back scatter induced by a red Xenon strobe light is no worse than that induced by the current standard rotating red beacon. The red "strobe" however is a vastly superior infrared source for PWI purposes, as hundreds of flight test hours have amply demonstrated. At least two red strobe beacons are on the market that can be purchased and installed for less than $150.

Now, with your permission I have a short film clip that demonstrates how such an optical infrared PWI works. This is a film of an actual flight test.

(Film presentation.)

Here we have the target aircraft, and in a moment you will see the strobe beacon flashing. The second one is the one equipped with the PWI.

Incidentally, the target airplane has a dual strobe installation. The one in the vertical stabilizer is a red beacon. The one in the belly is a white beacon.

The target airplane in this instance is at about the 1 o'clock position relative to the equipped aircraft. The indicator, as you can see, does display the approximate bearing of the target airplane.

In a moment the intruder will cross over the nose of the protected airplane and we will see the indication in another sector.

Senator CANNON. I hope the system works better than the projector.

Mr. ROCK. Unfortunately, the ambient light conditions here are not conducive to this particular projector.

We have him indicated in the 8 o'clock position. Again we see him in about the 1 to 2 o'clock position. Now he is again at the 8 o'clock.

Here you can see the target.

The range, incidentally, in this demonstration was between 1 and 2 miles at the maximum range.

Here we have the target moving from 1 o'clock to 2 o'clock and that is the end of the film.

SLIDE 20—WE URGE THE FAA TO:

Immediately publicize a CAS program timetable.

Immediately publicize a PWI program timetable.

Amend FAR 91–33 to require the installation of red or white Xenon strobe lights on all aircraft for day and night operations.

Acknowledge the acceptability of optical PWI's.

In conclusion, it is urged that the Federal Aviation Administration:

Immediately publicize a realistic timetable for the implementation of a collision avoidance system, with a full disclosure of all the factors affecting this timetable.

Immediately publicize a realistic timetable for the completion of their proposed PWI research and development effort and the generation of a final national standard. It should be emphasized that the suggested PWI retail price be kept under $1,000.

Amend FAR 91.33 to immediately require the installation of a high intensity xenon strobe light on all aircraft for day and night operation. To reduce the problem of back-scatter, a red xenon beacon, meeting the previous anticollision beacon standard, provides a satisfactory source for optical PWI purposes and should be installed on those aircraft where back-scatter may be bothersome.

Immediately and unequivocally state that optical PWI's are well within the state of the art and are capable of meeting present and foreseeable PWI system characteristics. State also that at least one such system has been demonstrated to meet the present PWI system characteristics and is considered completely acceptable.

Thank you very much.

Senator CANNON. Thank you, Mr. Rock, for your fine presentation.

Senator Moss?

Senator MOSS. Thank you, sir.

Does the screen part in the aircraft system that you exhibited, show altitude as well as direction?

Mr. ROCK. No, sir. We use an elevation technique. The angular elevation of the other aircraft is limited by the optics system to plus or minus 10 degrees over and below the horizon which means that we can eliminate the false alarms produced by aircraft above 10 degrees and below 10 degrees.

Senator MOSS. I see. So this wouldn't be effective unless the aircraft were flying level, that is if it were coming in at an angle it wouldn't be picked up until it was too late?

Mr. ROCK. The intruding or the——

Senator MOSS. Intruding airplane, yes.

Mr. ROCK. If you look at the geometries of various collisions encounters an encounter at the effective range of this system would be detected within the plus or minus 10 degree elevation limits.

Senator MOSS. How expensive is the system that you have shown?

Mr. ROCK. We planned to have a system available that we will market, that is with the distribution and other costs involved, for less than $1,000.

Senator MOSS. Could you go into production on that in a relatively short time?

Mr. ROCK. Yes, sir. Within a year.

Senator MOSS. Thank you, Mr. Rock.

Senator CANNON. Thank you.

Mr. ROCK. Thank you.

(The statement follows:)

STATEMENT OF GEORGE G. ROCK, PRODUCT LINE MANAGER, GENERAL AVIATION

A LOW-COST SOLUTION TO THE PROBLEM OF GENERAL AVIATION MID-AIR COLLISIONS

The current PWI/CAS picture is influenced by a number of factors. Great concern regarding the likelihood of mid-air collisions exists throughout the Department of Transportation, the FAA, DOD, Congress, various aviation lobby groups, and among those who own and/or fly airplanes. Industry response to this concern has been substantial.

Paradoxially, potential users are confused and uncertain as to their options. This is due principally to the multiplicity of conflicting claims, by proponents of various systems, that each offers adequate protection to all users of the airspace, at prices ranging from $50 to $50,000. Nowhere, however, is there a comparative shopping list that states the features of each system, the degree of protection each offers, the names of the offerors, the complexity of each option, and the cost to the user of these options. Nor can anyone put his finger on when it's all going to happen.

The General Aviation user is in the worst "bind" of all. As we shall see, he is the one most immediately in danger of a mid-air collision, and this potential for a catastrophic encounter is rapidly increasing. Furthermore, he is the one least able to afford the risk of investment in equipment that may be of only marginal utility or that is likely to become obsolete overnight. He is already confronted with this problem with the Radar Beacon Transponder and navigation radios.

At present and for the foreseeable future, two general and non-competing classes of devices have been conceived to meet the requirements of various airspace users. The most widely publicized is the Collision Avoidance System, or CAS concept. The other is the Proximity Warning Indicator, or PWI. The PWI differs from CAS in two very fundamental and important areas. The PWI's only function is to alert and to assist the pilot in *visually* detecting the potential collision threat. Threat evaluation and appropriate avoidance action rely upon the pilot's judgment. CAS, on the other hand, has the much more difficult tasks of analyzing potential collisions, discriminating between threats and non-threats, determining the appropriate escape maneuver (vertical escape), and presenting the information to the pilot, or automatic pilot, for execution. The complexity of the CAS function suggests the second fundamental difference. that of cost

PWI is basically an aid to the pilot to see and avoid other aircraft and is required to operate only in Visual Flight Rules (VFR) weather conditions. CAS, on the other hand, must function under all weather conditions. Ideally, a unified system is needed, embracing the functions of both PWI and CAS. Numerous proposals have been advanced for CAS-compatible (time/frequency) Proximity Warning Indicators and limited function Micro CAS.

McDonnell-Douglas has developed a system targeted for sale to General Aviation at $2500. Unfortunately, this price is far too high to attract most General Aviation aircraft owners. Additionally, Micro CAS, unlike full CAS, functions continuously in the Interrogate-Transponder mode and relies for its operation upon the proximity of either ground or airborne (airline CAS) synchronization stations. Without one or the other within 98 nautical miles or line-of-sight range (whichever is the shorter distance), the system falls out of synchronization within minutes and ceases to function properly. Since two Micro CAS-equipped aircraft must rely on a third party, so to speak, to start their systems operating properly and to keep them working, in the absence of re-synchronization, neither aircraft is protected from the other. There is some question, incidentally, as to how many aircraft can be accommodated in the Interrogate-Transponder or CAS backup mode. The Air Transport Association's CAS specification[1] states that ". . . the backup mode is limited (in certain physical combinations of aircraft encounters) to encounters involving two aircraft." Furthermore, the system offers no protection from non-CAS equipped aircraft and is therefore of questionable value in the environment where protection is most needed, that is, in the vicinity of approximately 700 joint use airports and over 6500 other public use airports not included in the 22 terminal control areas now planned (5 are in operation).

Clearly then, until such time as there are sufficient synchronizing stations (ground and airborne), Micro CAS will offer no real solution to this very great problem confronting the private aircraft user.

Because of the equipment cost, CAS can be purchased only by the most affluent airspace user. Thus, the major trunk and regional carriers and a few corporate operators are those most likely to afford the equipment. Paradoxically, these users, who can best afford to protect themselves from each other, are the least to run into each other. This fact becomes obvious when one considers that, for reasons of economy, these users operate at high altitude in positive control airspace, i.e., under radar guidance by air traffic control at all times, in good and bad weather. Their separation is thus assured by the Air Traffic Control System.

Although sponsored by the airlines through the Air Transport Association (ATA), CAS is meeting opposition from the airlines as well. Equipment cost is a factor. To assure complete redundancy, each airline would require two independent CAS sets. The costs of equipment, spares and installation are estimated to exceed $150,000 per aircraft. This investment has to be weighed against the degree of protection obtained.

With some notable exceptions, the vast majority of mid-air collisions and near collisions involving airlines have occurred below 10,000 feet altitude, in or near an airport terminal area, and between an airliner and a small private plane. Major terminal areas, on the other hand, are becoming more restricted to uncontrolled air traffic under recently implemented and planned air traffic rules and procedures, such as the Terminal Control Area concept in which all aircraft must be under positive control. All these factors make the return on investment questionable.

Persons within the airline industry have stated that, before all airline aircraft are CAS equipped, it will take from 5 to 7 years from the decision date to proceed. Airline economics and General Aviation's inability to participate can well delay that decision date indefinitely. Should all the airlines become so equipped, the system still would not be fully operational, since even these Collision Avoidance Systems can become unsynchronized. They, in turn, require ground stations to provide re-synchronization. Since no ground stations presently exist and must be developed, the required process of compatitive bidding, the selection of an R&D supplier, the development, operational test, production bidding, contractor selection, and production and installation of fully operational stations will likely take from 5 to 7 years. The foregoing assumes, incidentally, that one of several candidate collision avoidance systems will have been selected and a national/international standard agreed upon. The time scale for a fully operational CAS environment can well extend into the 1980's.

It has been suggested that, in a full CAS environment, Micro CAS synchronization could be provided by overflying airlines. However, when one considers that by 1980 some 4,000 airline aircraft will be in operation, with perhaps half of them airborne during peak hours, there will be one airliner for each 1500 square miles. Of course, this estimate is over-simplified, but it does not take much imagination to appreciate that in many areas an airliner will not be present to provide the necessary synchronization.

Meanwhile, regional and local service carriers, air taxis, corporate operators, and others unable to afford a full CAS installation are more likely to operate

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[1] Air Transport Association, ANTC Report No. 117, Section B–4a.

in a mixed environment with small private aircraft at uncontrolled airports; therefore these suffer the greatest risk of collision. In fact, aircraft traffic density tends to increase outside of, but in the vicinity of, hub airports having operational Terminal Control Areas (TCA), thus increasing the exposure of this group to mid-air collisions. As of December 1970, there were 389 airports with control towers, out of 7371 publicly-owned or publicly-used privately-owned airports. Of these, 786 offer scheduled airline service. The remainder are used by air taxi, corporate and other private operators.

As noted by Mr. John H. Shaffer, the FAA Administrator, in a recent article in "Professional Pilot" magazine, American industry is migrating to rural areas outside of the 22 major urban complexes. Accessibility by air is a prime requisite in new plant site selection. Some 400 cities with populations of from 25,000 to 100,000 are without any kind of direct air service. Yet the trend of industry is toward these areas. On the other hand, faced by the lack of profitability of many short haul point-to-point routes, the scheduled airlines are moving away from these areas and are concentrating on the major hubs with ever larger aircraft. The increasing transportation vacuum is being filled by General Aviation. Thus, the growing requirements of business for rapid, responsive transportation is creating an ever increasing demand for private aircraft of all sizes and types by large and small companies alike.

The FAA, by its own reckoning, estimates that by 1985 there will be 285,000 General Aviation aircraft. They will:

Fly 57 million hours annually.

Account for 40% of all IFR itinerant operations.

Contribute 7 billion dollars to the gross national product. (This does not include the indirect contribution and increased productivity of the companies they will serve.)

Carry more passengers inter-city than the scheduled airlines.

Contribute substantially to regional development.

Thus, instead of getting better, the problem is going to get worse, as the demand increases for more aircraft and more people learn to fly. In the New York area, General Aviation airports are already reaching a point of saturation from student and transient traffic, especially on weekends when the weather is good. VFR holding is common outside of the Teterboro, New Jersey Control Zone, and long takeoff and landing delays are the rule rather than the exception on such weekends. A pilot plays a sinister game of tag with other aircraft holding at the "Alpine Tower" at less than 980 feet above ground, all the airspace that remains between the floor of the New York Terminal Control Area at that location and the top of the Palisades. This hazardous situation is repeated in many areas around the country. Its potential for an increasing number of mid-air collisions between General Aviation airplanes is acknowledged by the National Transportation Safety Board, the FAA and the Office of Safety and Consumer Affairs within the Department of Transportation. Several reports have recently been published on the subject.

Among the many recommendations most often repeated for relieving this problem are: conspicuity enhancement, new traffic pattern entry procedures, training programs for pilots to improve visual scanning techniques, and Proximity Warning Indicators. Probably the most effective device for conspicuity enhancement to appear in a long time is the high intensity xenon strobe light. This evaluation appears to be widely held. The National Transportation Safety Board, in its Report of Proceedings[2] into the midair collision problem, strongly recommends that strobe lights be made mandatory. The report states, in part, "Such lights are benefical not only from the standpoint of their direct conspicuity, but also from their use in conjunction with Pilot Warning Indicators (PWI)." Documenting industry and government support for white strobe lights, the report includes statements from the following organizations: The National Pilots Association, Aircraft Owners and Pilots Association, National Business Aircraft Association, Airline Pilots Association, Allied Pilots Association, Air Traffic Control Association, National Association, of Air Traffic Control Specialists, Federal Aviation Administration, Department of Defense, and National Aeronautics and Space Administration.

That strobe lights enjoy substantial popularity is amply demonstrated by the results of surveys[3] made in 1970 of aircraft owners and chief pilots during three of the most popular General Aviation gatherings, the Reading Air Show,

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[2] Report of Proceedings of the National Transportation Safety Board into the Mid-Air Collision Problem, Report No. NTSB–AAS–70–2, November 4 through 10, 1969.

the NBAA Convention, and the AOPA Plantation Party. The percentage of strobe equipped aircraft ran from 32% at the AOPA Plantation Party to 56% at the NBAA Convention. In August 1971, a physical count of aircraft at Teterboro Airport revealed that 44% were strobe equipped.

The U.S. Army, in a recent report,[4] concludes that strobes materially enhance the daytime conspicuity of Army helicopters, especially against a ground background.

In view of strong industry/government support, the popularity of strobes among General Aviation aircraft owners, and the dramatic results achieved by the U.S. Army with high intensity xenon strobe lights, it is very difficult to understand the action (or inaction) of the FAA in this area. The recent amendment to FAR 91.33 falls very wide of the mark. In effect, the amendment makes no meaningful change to the anti-collision lighting standards, as far as most aircraft are concerned.

Various Proximity Warning Indicators (PWI) have been demonstrated, tested and proposed, and one, at least, has been marketed. The FAA, in conjunction with COPAG (the Collision Prevention Advisory Group, which is composed of representatives from government agencies and selected Civil Aviation associations, including three of the strongest advocates of strobe lights), has generated a preliminary PWI system characteristic. A paramount requirement is to determine and display the direction of threat aircraft. Thus, warning-only systems are immediately disqualified.

It should be noted that at least one manufacturer has learned the folly of attempting to market a warning-only-type PWI (no relative bearing or relative altitude discrimination) based on the passive transponder principle. Excessive false alarms resulted in extreme irritation and distraction for the pilot, causing him, in most instances, to turn the device off. Obviously, this completely defeats its intended purpose. After initial enthusiastic acceptance of the device, sales rapidly declined to a trickle. Cost, incidentally, was not a factor, since the device retailed for $395, well within the price range of most marketing estimates for PWI.

PWI's can be classified according to whether they use light or radio waves to transmit information. In general, those relying on radio waves would compete with other critical services in already overcrowded radio bands. One proposed PWI system, however, would make use of signals being generated by radar transponders already installed in most commercial and military aircraft and in some 40% of the General Aviation fleet. This technique would not require a special frequency assignment.

Undoubtedly, such a device can be developed. The requirement for relative bearing, however, and the attendant size and complexity of the antenna and related electronics, make it doubtful that a resonably priced PWI would result.

Some obvious operational limitations are inherent in this concept also. Since it is a passive listening device, it must operate in an Air Traffic Control Radar Beacon environment. This condition is met only within line-of-sight range of ground-based, en route, and terminal secondary radars. When one considers the nature of mid-air collisions, as summarized in a report by the National Transportation Safety Board,[5] and the availability of the requisite secondary radars, the shortcomings become apparent.

The report states, "In every 1968 mid-air collision accident, a General Aviation aircraft was involved. In three cases, an air carrier was involved with a General Aviation aircraft. In one case, a military aircraft was involved with a General Aviation aircraft. In the remaining 34 instances (89%), the collisions were between two General Aviation aircraft. . . ." Most of the 1968 mid-air collision accidents occurred at or near an *uncontrolled* airport, below 5000 feet, in Visual Flight Rules (VFR) weather, during the summer months, and on a weekend. The traffic in the airspace involved in the 1968 mid-air collision accidents was not congested, and the closure rate between the aircraft involved was well below the cruise speed of the aircraft involved.

A report prepared by the Airline Pilots Association extends the analysis to include the five-year period from 1964 through 1968. The conclusions of the NTSB report are confirmed on every essential point. These are: *mid-air collisions*

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[3] Loral Electronic Systems. PWI Marketing Survey, 1970.

[4] The Use of High Intensity Xenon Lights to Enhance U.S. Army Aircraft Day/Night Conspicuity. U.S. AERL Report No. 7113. January 1971.

[5] Mid-Air Collisions in U.S. Civil Aviation—1968, A Special Accident Prevention Study, National Transportation Safety Board, July 1969.

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predominantly involve two General Aviation aircraft, in daytime VFR weather, at low altitudes, at or near uncontrolled airports.

It was mentioned that there are some 389 tower controlled airports. Present FAA plans are to increase this number to 525 by 1981. However, there are over 7,000 publicly-owned or publicly-used privately-owned airports. Terminal Beacon Radar service is provided at slightly more than half of the *controlled* facilities, or approximately 3% of the total. This is hardly a suitable environment for a Radar Beacon PWI System.

The ideal PWI for General Aviation would be one that: is self-contained; is non-cooperative; requires no special radio frequency; provides the other aircraft's relative bearing, altitude or elevation; draws little power; is light in weight; is easily installed; does not affect the aesthetic, aerodynamic or structural integrity of the aircraft in which it is installed; provides a useful range of at least one mile; has a low order of false alarms; and is priced to sell under $1,000. Of all the candidate systems; the Infra-Red Optical Approach offers the best compromise. Since it relies on infra-red radiation generated by high intensity xenon strobe lights, it does not compete for critical radio frequency space. It provides relative bearing with the required accuracy, elevation discrimination is readily achieved, ranges between one and two miles at a low false alarm rate have been consistently demonstrated, and the compact lightweight optical sensors fit conveniently within aircraft wingtips. Thus the cosmetic, aerodynamic and structural integrity of the aircraft remain intact. Power and over-all weight are low, and it can easily achieve a *retail* price of under $1,000. In short, the Optical PWI technique meets or exceeds all of the FAA PWI system characteristics.

Its principal shortcoming lies in the fact that all aircraft do not have xenon strobe lights. For less than $150, suitable strobe lights for PWI purposes can be purchased and installed as direct replacements for the present anti-collision beacon. Their reliability exceeds that of the rotating beacon, and maintenance costs are low.

The high-intensity xenon strobe light is regarded almost universally as a superior aircraft light. Although its daytime visibility (especially under bright sky conditions) is considered marginal by some, it has been consistently demonstrated that the Optical PWI can detect these lights under those very conditions. Many times the lights were marginally visible although the intruding aircraft itself was easily seen.

Some have argued that strobes generate disturbing back-scatter from clouds and aircraft structure. This is true in some instances, especially in the case of a low-wing airplane with a strobe mounted on the vertical stabilizer. Such is the with the Cherokee "Six" used in the development of the Loral Optical PWI. The problem was solved, however, when the white lens was replaced by a red lens. That same "red" strobe, when mounted on another ("target") aircraft, provided most of the data that enabled the successful development of the Infra-Red PWI technique. Equal performance has been achieved with both red and white strobe lights. The red strobe reduces back-scatter from both sources to acceptable levels, comparable to those of the standard rotating anti-collision beacon when operating in clouds; this is attested to by the many undisturbed (by the strobe) hours flown at night and in weather in the Loral Cherokee Six. It is worth noting that the same type strobe with a white lens was used by the Transportation Systems Center of the Department of Transportation in their recently completed test of Optical PWI's.

In conclusion, it is urged that the Federal Aviation Administration:

Immediately publicize a realistic timetable for the implementation of a collision avoidance system, with a full disclosure of all the factors affecting this timetable.

Immediately publicize the benefits and shortcomings of the time/frequency CAS and related systems, for all users.

Immediately publicize the benefits and shortcomings of the various approaches to PWI, including a realistic assessment of the ability of each system to meet the PWI system characteristics in all operational environments. It should be emphasized that the suggested retail price should be under $1,000.

Immediately publicize, clearly and unequivocally, a realistic timetable for the completion of their proposed PWI research and development effort and the generation of a final national standard. Comparison of this effort with past programs of equal complexity, such as the Radar Beacon Transponder, should be made public.

Amend FAR 91.33 to immediately require the installation of a high intensity xenon strobe light on all aircraft for day and night operation. To reduce the problem of back-scatter, a red xenon beacon, meeting the previous anti-collision beacon standard, provides a satisfactory source for Optical PWI purposes and should be installed on those aircraft where back-scatter may be bothersome.

Immediately and unequivocally state that optical PWI's are well within the state-of-the-art and are capable of meeting present and foreseeable PWI system characteristics. State also that at least one such system has been demonstrated to meet the present PWI system characteristics and is considered completely acceptable.

Senator CANNON. Next witness, Mr. Steven Sample, deputy director for programs, Illinois Board of Higher Education.

STATEMENT OF STEVEN D. SAMPLE, DEPUTY DIRECTOR FOR PROGRAMS, ILLINOIS BOARD OF HIGHER EDUCATION, CHICAGO, ILL.

Mr. SAMPLE. Mr. Chairman, I would like to summarize my testimony using illustrated posters, if that is all right.

Senator CANNON. All right.

Mr. SAMPLE. I am Steven Sample and, as shown on the witness list, I am with the Illinois Board of Higher Education. I am also on leave from Purdue University where I am an associate professor of electrical engineering.

I am testifying on behalf of myself and two colleagues concerning our efforts to develop a low-cost directional pilot warning instrument.

One of my colleagues, Mr. Thomas Duncan, is vice president for engineering of a large domestic appliance firm in Indiana. My other colleague, Mr. Paul Scheuer, is a research engineer with the same firm that employes Mr. Duncan.

Our interest in problems of collision avoidance arose generally from Mr. Duncan's experiences as an aircraft owner and pilot.

(Poster shown.)

Mr. SAMPLE. This is an artist's illustration of a photograph taken from the cockpit of Mr. Duncan's plane that shows another plane a quarter mile distant.

If the other plane were traveling toward the plane from which the view is taken, a collision would occur within 3 seconds.

It has been experiences of this sort, coupled with the experiences reported by others, that have led us to try to develop a system which will be an extension of the pilot's senses, warning him of all aircraft in his vicinity and giving him an approximate indication of the bearing and range of such other aircraft.

We have established seven criteria which we feel that any effective pilot warning instrument must meet.

First, we agree with many of the other witnesses that in order to be effective, all aircraft must be equipped with the system of a compatible subsystem.

Second, it must be low cost in order to make it attractive to general aviation.

Third, it must be all-weather, and in particular, as the previous board illustrated, it must work under the worst weather conditions, because it is our opinion that under these conditions the greatest danger of collision occurs.

Fourth, it must be capable of detecting multiple intruders, displaying the presence of same, while not becoming confused by multiple intruders at the same range.

Fifth, it must indicate the range and relative bearing of an intruder. We feel the relative bearing is very important.

Sixth, it should turn on automatically.

And, finally, it should be self-calibrating in order to remove the need for frequent and expensive attention by highly skilled technicians, which would be an intolerable burden for aircraft that are normally based in remote areas of the country.

Our system is predicated upon each aircraft being equipped with a small transmitter and receiver. Every plane would periodically transmit a short burst of radio energy, and would listen for the pulses transmitted by other aircraft during the relatively long periods of time between its own transmissions.

(Poster shown.)

Mr. SAMPLE. Illustrated here you see the propagating pulses from the aircraft at the center of the drawing. These transmissions are illustrated at the bottom of the board by a series of pulses separated by long quiet periods.

Thus, if any aircraft came within the sphere of detection of the aircraft in question, the intruder would receive the pulses from this aircraft, and likewise the aircraft in question would receive the pulses from the intruder.

Now, the salient question is how does one insure that two aircraft are not transmitting at the same time, thus causing each other to be blind to each other's presence?

(Poster shown.)

Mr. SAMPLE. We propose to achieve what we feel is a comfortable margin of safety against simultaneous transmission through the use of a quasi random time-sharing technique.

Rather than trying to synchronize the transmissions by some elaborate ground-based system, we propose that the transmissions be inherently asynchronous.

As a consequence, in most cases there would be no overlap, as illustrated here. However, in the unikely event that two planes should transmit simultaneously at a particular instant (and for the particular example described in our printed testimony the chances against such an occurrence are 5,000 to 1), the odds become overwhelming that they will not be transmitting simultaneously during the next second thereafter, so that a spurious simultaneous transmission would be followed almost certainly by nonsimultaneous transmission.

The other principal feature of our system is its directional characteristics. Many of the previous witnesses addressed themselves to the bearing question here today. Generally, determining bearing with a radio direction finder is an expensive process, and it generally requires a number of sophisticated, carefully calibrated analog circuits.

We propose to determine bearing in a way we feel is more compatible with the pilot's senses, namely, to determine the bearing only within some discrete number of sectors, similar to the optical system described by the previous witness.

(Poster shown.)

Mr. SAMPLE. As shown here. we would have a sectored display, similar to that shown in the previous testimony, mounted in the cockpit of the airplane. The particular case here illustrates an intruder in the 2 o'clock sector.

In addition to giving the approximate bearing of an intruder, we would also give an approximate indication of the range of the intruder by varying the length of time that each sector light was lit for each received pulse from an intruder.

Thus, a distant intruder would cause the light to blink very briefly; as he came closer, the sector light would stay on for longer periods of time.

(Poster shown.)

Mr. SAMPLE. On this board we illustrate how the system would work for three aircraft in the same vicinity.

Notice there is no problem in displaying multiple intruders.

There are two special features for which our system can be easily adapted and which we would propose as options.

The first has to do with altitude discrimination, namely, the rejection of signals from aircraft that are considerably above or below the receiving aircraft in question.

(Poster shown.)

Mr. SAMPLE. In the example here with four aircraft, the airliner at 23,000 feet would process no signals from the three aircraft at considerably lower altitudes, because each plane's pulse would be encoded or carry the information of its altitude. It would be compared with the altitude of the receiving aircraft.

In the situation shown in the lower part of the picture, the center craft at 6,000 feet would detect the presence of both the smaller ones at 5,500 and the large one at 7,000 feet. The 7,000 and 5,500-feet craft, since they are separated by more than a thousand feet, would not detect each other's presence.

(Poster shown.)

Mr. SAMPLE. Our system lends itself to downed aircraft warning, that is, in the event of an emergency landing by a plane, that plane's pulses would be encoded to trigger a downed aircraft warning light in the center of the display of any other aircraft in the vicinity.

Moreover, the directional characteristics of our system would aid other aircraft in locating that aircraft.

(Poster shown.)

Mr. SAMPLE. On this final board, we show a block diagram of our system. It is at this point that I would like to talk about the low cost that we think can be readily achieved.

I spoke before about the necessity for closely calibrated, expensive circuits in normal direction-finding systems. However, with our system, because we are content to determine the direction of an intruder within a discrete number of sectors, (six in the example given here), the direction-finding equipment becomes very simple to implement using high-density, integrated digital logic circuits.

In particular, for the volumes expected for any useful implementation of a PWI, these custom integrated logic circuits would be very, very low in cost.

In addition, the fact that the direction finder is implemented using digital circuits facilities digital encoding and decoding of the signal for the purposes of altitude discrimination and downed aircraft warning.

That concludes my presentation.

I will be happy at this time to answer any questions.

I might also say that I certainly appreciate the opportunity to testify today.

Senator CANNON. Are you talking about a theoretical system or have you developed one, have you tested one, or what?

Where do you stand?

Mr. SAMPLE. I would say our system is, for the most part, a paper concept. The development to date has been principally in the design area. It has been strictly without capital backing of a corporation or the university or the Government.

Senator CANNON. Have you talked to manufacturers about the possibility of production of a model?

Mr. SAMPLE. Yes; we have talked to a few.

Senator CANNON. What type of costs do they talk about?

Mr. SAMPLE. Assuming that one does not include the cost of the reporting altimeter, and assuming a volume of a few thousand units a year, we feel confident that we can achieve a market cost of under $500.

Senator CANNON. Do you propose or will you go ahead now and have somebody build a flight test model and see how it flies?

Mr. SAMPLE. Yes; we are looking in that direction. But I don't want to imply that we have any firm agreement to that effect.

Senator CANNON. Senator Moss.

Senator MOSS. There is nothing very sophisticated about this that would delay getting into production provided this was approved, is that right?

Mr. SAMPLE. No, sir; technologically, it is very simple and straightforward.

Senator MOSS. Thank you, Mr. Sample, that was a good presentation.

Senator CANNON. Thank you, sir.

(The attachment to the statement follows:)

A Low-Cost Directional Pilot Warning Instrument

THOMAS W. DUNCAN, STEVEN B. SAMPLE, AND PAUL R. SCHEUER

ABSTRACT

In response to the need for a reliable, all-weather system to warn pilots of other aircraft in their vicinity, a low-cost directional pilot warning instrument has been conceived. In order to be completely effective, this system would require participation by all aircraft. However, it would be inexpensive enough that private aircraft pilots could readily afford it, and it would offer these pilots the same degree of protection as pilots of larger aircraft. The operation of this system depends on each plane periodically transmitting a radio signal for a short period of time, and then listening for the signals from other planes during the relatively long periods of time between its own transmissions. Each plane would be equipped with a discrete direction-finding receiver, and a panel indicator which would tell the pilot where to look for other aircraft in his vicinity. The system would also provide the pilot with an approximate indication of the range of other aircraft, and, when used with reporting altimeter, would exclude signals from aircraft which were not at his general altitude. Finally, the system would provide specially encoded signals which would aid in identifying and locating downed aircraft.

INTRODUCTION

Is some type of universal airborne anti-collision system *really* needed, or would the expense of such a system simply restrict the growth of general aviation without substantially reducing the chances of mid-air collisions?

At first glance there does not seem to be any compelling need for such a system. In fact, to a ground-based observer, it might well appear that any mid-air collision must be due to gross negligence on the part of one or both of the pilots. This is because an observer on the ground is first made aware of the presence of aircraft through engine noise. Since the ears are reasonably good direction-finders, they enable him to determine the direction in which to look for aircraft in his vicinity. On a clear day, silhouetted against the bright sky a plane can be readily observed from the ground for two and a half miles in either direction. Thus, if an aircraft were passing overhead at 3000 feet and at a speed of 150 mph, a stationary observer could leisurely track it for two minutes as it moved through his field of vision.

However, from the cockpit of an airplane, the visual acquisition and tracking of other aircraft is considerably more difficult than from the ground. Near collisions can easily occur even under the best conditions, as illustrated by the following scenario.

The noise of your engine drowns out any other outside noise. There was another plane in the traffic pattern as you took off and you saw it, but you couldn't hear it. You can see fairly well out the side windows (7 miles visibility reported), but over the nose of the plane toward the sun you can see only the haze layer, which reaches up to about eight thousand feet today. You can't pick out a landmark on the horizon to guide you, but your directional gyro is very accurate and you can watch it to stay on course. Besides, you are homing on an omni station at your destination. and all you need to do is keep the needle centered. You look at your engine gauges to be sure everything is all right. It's a little bumpy and you have to check the directional gyro and omni needle several times a minute to stay on course. The fuel gauge for the left tank shows it's time to change tanks. The altimeter tells you that you have gained 200 feet in this bumpy air. Better get back down to 3000. Keep looking around for other aircraft. There's one a couple of miles off your left wing. Where? You can't see him right now. He's just this side of that woods. Now he's turning and you can see the light reflecting off his wings as he banks. Keep an eye on him. The one that was so easy to see from the ground a while ago is approaching you head on. He is still five miles away, but in sixty seconds he will be right on your nose. You don't even know he's there, but as you scan the horizon you see the small dot of the fuselage and the thin line of the wing not more than a mile ahead in that bright haze between you and the sun. You have almost twelve seconds to evade him. Those wooded hills on the horizon behind you made a perfect camouflage and he didn't see you until you rolled into your turn. Why is your face so white? After all, you didn't hit him.

Anyone who has flown very much has had the frightening experience of having a plane suddenly appear at close range. Unless a plane is above an observer or very near, it is not silhouetted against the sky, but appears against the background of various colored fields, woods or buildings. A pilot cannot hear the sounds of other aircraft as an alerting signal. The motion of his own plane tends to minimize the appearance of motion in another plane unless it is close or changes direction abruptly. In bad weather the visibility is extremely poor, thus precluding an early visual warning of the presence of another aircraft. Even in non-instrument flight there are a number of instruments that must be monitored frequently to maintain altitude, heading, and fuel and engine safety. In unfamiliar territory the pilot must periodically check maps in order to maintain constant knowledge of his position. At best his attention is divided between the cockpit and scanning for other aircraft.

In light of all these competing demands upon the pilot's attention, and considering the increase in air traffic density over the past decade, it appears that some sort of instrument is definitely needed to assist the pilot in avoiding collisions with other aircraft. The question is, what type of instrument represents the best compromise among such factors as cost, bulk, ease of operation, and effectiveness?

THE PROPOSED SYSTEM

Basic Characteristics

The following are believed to be the minimum criteria for acceptable performance of an effective pilot warning instrument (PWI).

1. All aircraft must be equipped with the instrument.
2. The cost must be low enough to make installation on all aircraft a reasonable requirement.
3. The instrument must function under all weather conditions.
4. It must indicate to the pilot when other aircraft are in the vicinity, and it must not become confused by the presence of more than one intruder.
5. It must indicate to the pilot the position of other aircraft relative to his own.
6. It must turn on automatically when the aircraft attains flying speed so that it cannot be left inoperative by error.
7. It must have self-testing and self-calibrating capabilities.

If an anti-collision system is adopted which does not require the participation of *all* aircraft, then any aircraft not equipped with the system is a potential threat to those that are, especially if the pilots of the equipped aircraft have become highly dependent on their anti-collision instruments to warn them of intruders into their airspace. Thus, criteria numbers (1) and (2) are closely linked together. It is foolish to expect that any system costing tens of thousands of dollars, installed on a few commercial and military aircraft, can by itself be a solution to a problem that exists for every craft that flies. An overall solution necessarily lies in a system costing less than a thousand dollars which can readily be installed on all aircraft. This important requirement is satisfied by the pilot warning instrument described in this paper.

Criterion number (3) refers to the necessity of operating under all weather conditions. Strobe lights, rotating beacons, or brilliant paint colors are easily obscured by clouds, mist, and rain. On the other hand, radio waves are completely unaffected by various weather conditions, and thus these waves were chosen as the signalling medium for the present system.

Operation of the System

In its simplest form, the present system requires that there be a small transmitter and receiver mounted on every aircraft, with all transmitters and receivers operating at the same fixed frequency. Each aircraft periodically transmits a very brief signal, and then listens for the signals from other aircraft during the relatively long periods of time between its own transmissions. In order to guard against the possibility of two aircraft in the same area transmitting at the same time, the transmission repetition rates are governed by a system of quasi-random time sharing.

The receiver on each aircraft is actually a radio direction-finder, capable of determining the relative bearing (i.e., horizontal direction) of incoming radio waves. However, unlike conventional direction-finders that attempt to pinpoint the bearing of a radio source, the receiver in the present system locates the source within one of a number of discrete horizontal sectors.

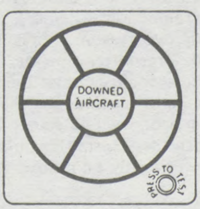

Fig. 1. Six-segment panel indicator.

The sector information from the receiver is used to drive a segmented indicator on the control panel of the aircraft. Fig. 1 shows a six-segment indicator in which each segment corresponds to a sixty-degree sector of the azimuth. Fig. 2 illustrates an aircraft instrument panel with this same indicator mounted in the upper center part of the panel. The lighted segment of the indicator shown in Fig. 2 denotes an intruder in the 2 o'clock sector (i.e., in the sector lying between 30° and 90° clockwise from the nose of the aircraft). Each time the intruder aircraft transmits its signal, the two o'clock segment of the indicator is illuminated. If the intruder is relatively far

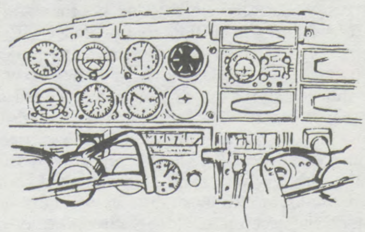

Fig. 2. Directional PWI indicator mounted on an instrument panel.

away, the segment flashes only briefly. However, as the distance between the observing aircraft and the intruder decreases, the segment light stays on for an increasing length of time after each transmission from the intruder.

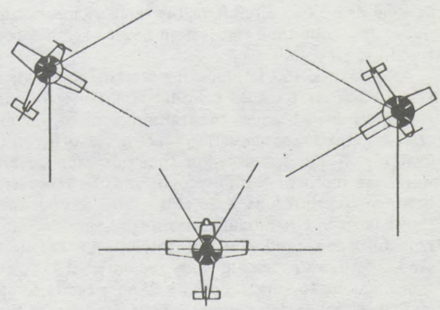

Fig. 3. Three aircraft in the same vicinity.

Fig. 3 illustrates the case of three aircraft in the same vicinity. The panel indicator in each aircraft shows the presence of two intruders. However, it should be noted that the relative bearings of the intruders vary from craft to craft.

If an aircraft is forced to land under emergency conditions, its transmitter automatically begins to send a distress signal. This signal, when received by any other aircraft in the vicinity, activates the *downed aircraft* light in the center of the receiving aircraft's panel indicator (see Fig. 1). Thus, the pilot of the receiving aircraft is alerted to the emergency, and can use the directional capability of his pilot warning instrument to help locate the downed craft.

The situation might readily occur where two aircraft are relatively close to each other, but sufficiently separated in altitude that no danger of collision exists. In order to prevent the panel indicator of each craft from displaying the presence of the other, the transmissions of each would be encoded by a reporting altimeter. The receiver in each aircraft would then compare the altitude information carried by incoming signals with the altitude reported by the altimeter at the receiver. Thus, signals which originated from aircraft at altitudes substantially above or below that of the receiver could be automatically rejected before reaching the panel indicator.

TECHNICAL CONSIDERATIONS

Quasi-Random Time Sharing

The directional pilot warning instrument proposed here does not involve one plane interrogating another and then waiting for a response. Thus, the problems that might arise when two intruders respond simultaneously to an interrogation are eliminated. In fact, as long as no two aircraft in the same vicinity transmit at the same time the system never becomes confused.

As indicated in the preceding section, the chances that two aircraft would transmit simultaneously are extremely low, because the transmissions of one aircraft are quasi-random with respect to the other. For example, if the transmission time for each aircraft were one tenth of a millisecond, and if the interval between transmissions were about one second, then the chances of two aircraft transmitting simultaneously in any one second would be only one in five thousand. Moreover, by allowing the interval between transmissions to vary randomly from aircraft to aircraft over, say, a ten percent range, the chances that two aircraft would transmit simultaneously for two seconds in a row could be only one in five million.

Thus, while it is remotely possible that the proposed system might become confused for one second, the chances that it would remain confused for any significant length of time are essentially zero.

Discrete Direction Finding

The antenna complement for the pilot warning instrument described here comprises several loops and a single dipole, in much the same configuration as would be found in a conventional airborne automatic direction-finding system (ADF). However, unlike a conventional system, the direction-finder of the present system simply correlates the phases of the loop-antenna signals (or combinations of such signals) with that of the dipole, in order to generate a discrete number of binary signals. These binary signals are then processed by a simple digital logic circuit, in order to yield the discrete sector information. In general, the system resolves two sectors for every distinct binary signal derived from the loop antennas.

The principal advantage of this system over conventional ADF equipment is that it avoids the need for matched amplifiers and analog comparator circuits. As a consequence, calibration problems are practically eliminated. In addition, the system can be implemented using inexpensive integrated digital logic circuits.

Range Detection and Display

In the present pilot warning instrument, range is determined on the basis of signal strength. The transmitting antenna is a dipole (the same dipole which is used in the receiving system described above), and is assumed to be omni-directional in the plane of the aircraft. Each transmitter and receiver is calibrated for the particular aircraft in which it is installed.

The single calibrated amplifier in the receiver (driven by the dipole antenna) rejects signals below a predetermined level, thus preventing aircraft beyond the corresponding maximum range from activating the panel indicator. Signals above the minimum level drive proportional memory circuits, which in turn determine the length of time each segment of the panel indicator is to be illuminated.

This range detection scheme lends itself to self-calibration for two reasons: first, because both the amplifier and transmitter operate at a single fixed frequency; and second, because the method of range display does not demand great accuracy. Thus, through the use of level detectors and calibrated attenuators, both the transmitter output and amplifier gain can be continually monitored and automatically adjusted.

Signal Encoding

There are several ways in which the transmitted signal might be usefully encoded. Two of these, namely, the distress signal and the reporting altimeter information, have been briefly discussed above. The beginning part of each transmission might also carry a special code which would enable the receiving circuits, thus insuring the rejection of spurious signals at the same frequency.

It should be pointed out that both the encoding and the decoding of the transmissions could be readily performed by a simple extension of the integrated logic circuit used to determine bearing. In addition, integrated digital logic could be used to determine whether the altitude of an intruder was substantially above or below the altitude of the receiver.

Controls

An overall block diagram of the directional pilot warning instrument is shown in Fig. 4. The air speed switch turns the instrument on as soon as the aircraft reaches flying speed, thereby insuring that *all* aircraft in flight and *only* aircraft in flight will be transmitting.

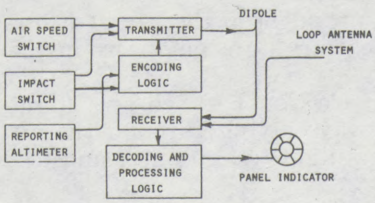

Fig. 4. Block diagram of the directional PWI.

The impact switch overrides the airspeed switch, and activates the special distress code in the event the aircraft crashes. In addition the impact switch increases the transmitter power to its maximum level, thereby maximizing the area over which the distress signal can be detected by other aircraft. The impact switch can also be operated by hand in case of an emergency landing that does not result in severe impact.

A "press-to-test" button is shown on the panel indicator illustrated in Fig. 1. Depressing this button activates all the lights in the panel indicator, and, by means of a small light in the button itself, assures the pilot that his transmitter and receiver are in working order.

SUMMARY AND CONCLUSIONS

The authors feel that some type of universal airborne anti-collision system is indeed needed, and that the system proposed here meets that need by fulfilling the seven criteria listed earlier. The first two criteria – universal implementation and low cost – are satisfied because the system offers all types of aircraft a substantial degree of protection against mid-air collisions, while being sufficiently inexpensive to be attractive to the general aviation pilot. A major factor in achieving this low cost is the use of a discrete direction finding technique utilizing inexpensive integrated logic circuits. Through the use of radio waves as the signaling medium, the system automatically meets the third criterion, namely, unlimited weather operation. Because the system utilizes quasi-random time sharing, it does not become confused in the presence of heavy air traffic, and thus it satisfies criterion number four. The requirements of criterion number five – indication of intruder position – are met by the discrete direction finder coupled with the segmented panel indicator. An air pressure switch automatically turns the system on, thus providing the fail-safe feature called for in criterion number six. And finally, since the use of analog electronic circuits is held to an absolute minimum, the system lends itself to self-testing and automatic calibration, thus fulfilling criterion number seven.

In addition to meeting these seven basic criteria, the directional pilot warning instrument described here has a number of special features that make it particularly attractive to both commercial and general aviation.

First, an aircraft that was forced to make an emergency landing would have the capability of transmitting a distress signal to any other aircraft in the vicinity. This "downed aircraft" feature would greatly reduce the time required to locate an aircraft in distress.

Second, the operation of the system is greatly improved by the use of a reporting altimeter which codes the transmitted signals in such a way that only aircraft flying at the same general altitude will detect each other's signals. This feature causes the system to display the presence of only those aircraft which would be considered hazardous, while rejecting signals from aircraft at altitudes substantially above or below that of the receiving aircraft.

Third, in addition to warning the pilot of the presence and relative bearing of an intruding aircraft, the panel indicator provides an estimate of the range of the intruder by varying the length of time that the appropriate segment of the indicator is illuminated.

All in all, it is our conclusion that the directional pilot warning instrument described here offers an excellent compromise among such competing factors as cost, bulk, ease of operation and effectiveness.

Senator CANNON. Next is Mr. Errol Johnstad, president of Flight Engineers' International Association.

STATEMENT OF ERROL L. JOHNSTAD, PRESIDENT, FLIGHT ENGINEERS' INTERNATIONAL ASSOCIATION, WASHINGTON, D.C.

Mr. JOHNSTAD. Good afternoon, sir.

Senator MOSS. Mr. Johnstad, good afternoon.

Mr. JOHNSTAD. I am Errol Johnstad, president of the Flight Engineers' International Association representing flight engineers in the United States and 12 other nations.

For the 5½ years prior to my recent election I served as a flight engineer on Pan American World Airways, flying through the air corridors into West Berlin. I had been a flight test engineer and test pilot with the McDonnell Douglas Corp.

Vis-a-vis air traffic control, Berlin is unique. Picture the face of a 20-mile radius clock. This is the Berlin control zone. Tempelhof Airport is near the center, Gatow Airport at 9 o'clock near the edge of the zone, Tegel Airport is slightly closer in at 10 o'clock.

And the East Germans have Schonefeld Airport near the 4 o'clock perimeter position on our clock. At the 8, 9, and 10 o'clock positions, air corridor fingers extend out from our clock join the airspace of West Germany.

Within this area, all traffic is IFR, all traffic operates at similar airspeeds, all traffic is under positive radar control, and with the exception of the limited movements at Schonefeld, which are flying a prescribed arrival and departure routing, all aircraft are under the control of the Allied Powers Air Safety Center.

Note that there is no general aviation traffic and the military transports and civilian air carriers are bridled with positive radar control. In his sterile environment, one would expect the near-miss incident to be a nonentity. Not so.

I was a flight engineer on a HAM/BER flight cleared to hold in the control zone at 10,000 feet. The Tempelhof runway was closed temporarily and aircraft were being pumped in through the air corridors and efficiently stacked about the control zone, until one aircraft arrive at or reported at a fix different from what the controller had planned.

Controllers then began identifying all aircraft and during this intense communications period we were given radar vectors out of the holding pattern. We broke out of the overcast, still at 10,000 feet, flying head on into an Air Force C–130 at 500 yards. We both took evasive maneuvering.

A computerized control center would have seen this incident in the making and provided warning. But so too would have an airborne collision avoidance system.

Two aircraft on intersecting runway takeoff roll at Hamburg enjoyed a tower estimated 30 meter (100 feet) near-miss. A collision avoidance system would have alerted the aircrews.

Three aircraft in tandem descending through clouds and limited visibility. The controller was getting behind the ball game and the second aircraft, the one in which I was a crewmember, overran the first and we pulled over to the right.

As we started our turn to the right, we were surprised by aircraft No. 3 as he came whizzing by our right side. The controller still had not given any heading changes for aircrafts 2 and 3. Someday an aircraft data-link coupled computerized control center could prevent this. Today, a collision avoidance system would give the necessary warning.

When I left the McDonnell flight test department in 1966, I had just completed the airborne flight testing of EROS—elimination range zero system. I had just completed the initial demonstration flights for the Air Transport Association and several airlines. In 1966, the system worked.

I flew an F–4 Phantom against our company EROS equipped Lockheed Jet Star at all altitudes. Our overtake speeds varied from a few knots to in excess of mach 2. The system worked.

Six years later a collision avoidance system is not yet in service operation. With each threatening situation of which I have heard or witnessed in the last 6 years, I ask, how long will it take?

I know that it takes time to evaluate systems, to standardize systems, to provide manufacturing lead time. I know too, that time must be allowed for procrastination. After 6 years we have had enough of the latter. Let us now establish a timetable.

The flight engineers do not support a particular collision avoidance system. Because of my close association with one of these systems, I would personally disqualify myself from making such a choice.

The FEIA expects continued progress in the FAA implementation of the discrete addressable beacon system and of automated radar tracking systems, but we strongly urge keeping the men in the middle informed by an airborne collision avoidance system indicator in the cockpit.

Men are always the vital monitor link in even the most automated of systems.

The Flight Engineers' International Association is interested in collision avoidance because our experience is all firsthand knowledge. We support legislation which will put a timetable on getting collision avoidance equipment into the field.

We support S. 2264.

Senator CANNON. Thank you very much for a fine statement. After listening to that, I can see why you are no longer in Berlin. I wouldn't be either. Thanks very much.

The next witness is Mr. David H. Scott.

STATEMENT OF DAVID H. SCOTT, WASHINGTON REPRESENTATIVE, EXPERIMENTAL AIRCRAFT ASSOCIATION, WASHINGTON, D.C.

Mr. SCOTT. I am David H. Scott. I am the Washington representative of the Experimental Aircraft Association. I have filed a formal statement with your distinguished committee, and to save time, may I verbally summarize the points that I feel are important in that statement.

To my knowledge, I don't think there is anyone in aviation that is not a supporter of a collision avoidance system or PWI device as soon as possible. Not only technically but to get it in use and to use it effectively.

We certainly support the intent of a CAS or PWI device. We hope it will come through proved merit rather than through rules or congressional legislation that would require it on every aircraft.

We think that in the last year there have been two instances of congressional pressure on the FAA to put forth programs that have not proved to be wise. One is the airport certification rule, and the other one is the emergency locator transmitter legislation, and we think in both of those instances there has been great weaknesses in the legislation.

We would like to see a PWI or CAS system developed that is an integral part of an advanced ATC system. In other words, we don't necessarily feel that the solution is just to create another black box that will be carried around as a more or less independent part of collision avoidance systems or a PWI.

We would like to see something that is an integral part of an advanced air traffic system and preferably something that gets away from secondary radar as the primary means of target identification.

Of the systems that we have heard about, the Eros 2 seems to have great promise; and although we are certainly in no position to recommend it, from what we can gather it seems to have the greatest potential of ones that we have heard about so far.

May I say something a little bit about the size of the amateur-built aircraft movement? Most people don't seem to realize that this is a growing activity. At the moment there are approximately 7,000 aircraft under construction by amateur builders. To put that figure into perspective, that is roughly about the same number of aircraft that the factories will produce in the year 1971.

To further refine that figure of 7,000 factory-produced aircraft, 30 or 35 percent will be shipped for export, which means that far less than 7,000 aircraft will be entering the domestic civil aircraft system from the factories during 1971.

Please do not misunderstand me. I do not say that we are going to put 7,000 amateur-built aircraft into the skies in 1971. It will take somewhere between 1 to 10 years to build these aircraft. But I wish to impress upon your committee that this is a sizable number of our aircraft fleet and it is growing.

These aircraft are very unsophisticated. They are used for sport and recreation purposes. They are not used to fly across country, generally speaking. They fly at low altitudes, at very low speeds. Most of them average between 40 to 75 hours a year of operation. Other times they are removed from service because the owners want to modify them.

My point in going into this detail is to point out that if you make it mandatory for all aircraft to have PWI or CAS systems, you are going to penalize very severely a rather sizable group of civil aircraft.

I notice that the committee is very much interested in costs. I would like to submit a few figures on the cost of amateur-built aircraft.

Many of these aircraft are being built for an initial outlay of $700 to $800 total. Therefore, if you ask them to install a $500 to $1,000 black box of some sort, this is a very crippling penalty.

I think my formal statement, Mr. Chairman, goes into considerably more detail, but I realize the time is limited here, and these are the most essential points of my statement, and may I thank you for having this opportunity to appear here this afternoon.

Senator CANNON. Thank you very much for giving us your views.

Senator Moss?

Senator MOSS. Thank you, Mr. Chairman.

Do you understand it that you don't believe there ought to be a time frame put on this or any kind of requirement as to a start?

Mr. SCOTT. I would modify that by saying if you want to put a time frame for certain aircraft for use in the air traffic control system, we would have no objection to that. It is just that I feel when you say all aircraft—for example, this emergency locator requirement means that racing or aerobatic aircraft, you have to have these, and that is ridiculous.

I would like to see exceptions. Aircraft not used in the ATC, used only for local flying or that of such limited performance capabilities, maybe less than 125 knots or whatever figure you might choose.

Senator MOSS. You wouldn't eliminate general aviation, just the specialized types?

Mr. SCOTT. Yes, sir; that's correct.

Senator MOSS. Thank you.

Thank you, Mr. Chairman.

Senator CANNON. I may say that emergency locator beacon legislation never did come before this committee. That legislation was tacked on as a rider to another bill as an amendment.

Thank you very much.

(The statement follows:)

STATEMENT OF DAVID H. SCOTT, THE EXPERIMENTAL AIRCRAFT ASSOCIATION

Mr. Chairman, my name is David H. Scott, and I appear here as the Washington Representative of the Experimental Aircraft Association. This is an organization comprising 32,000 members who are primarily interested in the development of light aircraft for sport and recreational uses. We are identified mostly as amateur aircraft builders, and restorers of classic and antique aircraft. We are also pilots and owners of factory built aircraft and therefore are interested in all phases of civil aviation development.

The Experimental Aircraft Association has both positive and negative comments to make on S. 2264 requiring Collision Avoidance Systems or Proximity Warning Indicators on all civil aircraft.

On the positive side we endorse and suport any effort to develop an airborne collision warning device that is practical and workable at a reasonable price. We believe there is universal agreement in the aviation industry to achieve this goal. And it may be that the industry and FAA does require outside pressure to move ahead rapidly in this field. At least the FAA should indicate to industry that if practical CAS and PWI devices are developed it will move rapidly to employ them in the ATC system.

On the negative side we question whether it is desirable to force the adoption of a technical device on the industry through legislative action. There have been two instances in the past year where Congress has legislated in the technical field with unfortunate results. One was the requirement for airport certification which has had to be postponed because of its impractical requirements. The other is the Emergency Locator Transmitter legislation which will create many problems for the FAA, search and rescue organizations and for individual aircraft owners. Generally speaking the FAA should be encouraged to make their own rules when it comes to technical aviation problems. On the other hand the FAA has been so slow and sterile in adopting new ideas for air traffic control and in other areas that we can well appreciate the impatience of Congress to force the FAA to move ahead rapidly in the field of aviation safety. The aviation industry has always responded promptly to the adoption of any new devices that will improve safety or efficiency. The government did not have to push the widespread use of VOR navigation receivers and VHF communications equipment. These were adopted quickly because of their proven value. Transponders are selling well for those who have the need for them.

If the industry is successful in developing a practical PWI or CAS we be'ieve that it should become a part of the ATC system. Our present Air Traffic Control System is based on ground control of traffic by controllers using radar as the tool for target identification. It is generally agreed that this present system cannot be successfully expanded to handle the air traffic needs of the future without more automation. We believe that one of the weaknesses of the present FAA thinking in ATC control is the continued reliance on radar. There are perhaps better ways to automate ATC through more extended use of inertial navigation, time/frequency systems, or possibly satellites for target identification. If aircraft were equipped with PWI devices in conjunction with previously above mentioned systems it would be possible to return navigation decisions to the cockpit with ground controllers on'y monitoring the flow of traffic. The present "custom" system of handling individual aircraft cannot be expanded to meet the needs of the 1980's and beyond.

Although we support an all out industry effort to develop a practical PWI device we know of no technical breakthrough that encourages the hope that we can have such a device that does not require cooperative equipment in other aircraft, that tells the pilot in which direction to look and can be sold at a reasonable price.

In the meantime there are a number of things that can be done to reduce the collision hazard. As long as speeds are kept low—less than 150 knots—the visibilities are 3 miles or better, the see and be seen concept of collision avoidance works very well. There is a problem around busy non-controlled airports where by far most of the mid-airs are occurring. We can improve traffic patterns around non-tower airports and the FAA has a proposed new rule on that now. Better traffic pattern markings and wind direction indicators would help also. Area navigation will assist in relieving the near miss problem around VOR navigation facilities. Better training of pilots through improved scanning techniques also holds some promise for improvement.

May we conclude our statement by saying something about costs. Cost is a very important factor for sport and general aviation. One of the reasons for the popularity of the homebuilt aircraft movement is that it enables individuals to build a safe and acceptable simple aircraft at minimal cost. We have homebuilders who are constructing aircraft for as low as $700 and $1000. More elaborate multiplace aircraft including amphibians are being built for under $5000. This contrasts with $10,000 as the cost of a new properly equipped factory built two place aircraft. There are about 7000 homebuilt aircraft under construction at the present time. This is equal to the number of factory built aircraft that will be delivered in 1971. And some 35% to 40% of these are for export. We do not say that 7000 homebuilt aircraft will join the civil aircraft fleet in 1971. These aircraft are in various stages of construction and will take from one to five years to complete. The point is that homebuilt aircraft are being built in respectable numbers at reasonable cost. Therefore the cost of $2500 or even $500 for a PWI for homebuilt aircraft is quite unrealistic.

To every aircraft owner the big problem is how to spend his dollars in order to get the most safety or efficiency. He should always be allowed the freedom to set his own priorities. If he has $1000 to spend will this bring him more safety in better instruments, an autopilot, better navigation or communication radios, a transponder, or Distance Measuring Equipment? These are the choices he must make taking into consideration the use of the aircraft. If he is forced to buy equipment such as Emergency Locator Transmitters, Proximity Warning Indicators, or Collision Avoidance Systems this may degrade his safety because he cannot buy other items that would make his aircraft safer for the type of operation he contemplates.

The problem of collision avoidance is surely a highly complex one. We hope we have pointed out some of the complicated factors here that will help your distinguished committee to make some recommendations concerning the ultimate disposition of S. 2264.

Senator CANNON. Next is John Bean, chairman of the board, National Business Aircraft Association.

STATEMENT OF JOHN B. BEAN, CHAIRMAN OF THE BOARD, NATIONAL BUSINESS AIRCRAFT ASSOCIATION, INC., WASHINGTON, D.C.; ACCOMPANIED BY FRED McINTOSH, MANAGER OF TECHNICAL SERVICES; AND JOHN WINANT, PRESIDENT

Mr. BEAN. Mr. Chairman, my name is John Bean, chairman of the board of the National Business Aircraft Association, and on my left is Mr. Fred McIntosh, the manager of our technical services, and on my right is Mr. John Winant, president of the association.

The National Business Aircraft Association represents 851 companies utilizing approximately 2,200 aircraft in the everyday conduct of their business enterprises. These aircraft are used for the transportation of personnel and cargo and are flown by professional crews who are full-time pilots.

The equipment ranges from single and light twin-engined aircraft used for pipeline patrol to the most modern turbine-powered aircraft available. Operating environments cover all of the airspace, altitudes, and airports normally used by commercial carriers, plus the large number of airports and routes not covered by the scheduled airlines.

We mention this to stress to the committee that we are equally concerned with the controlled high-speed, high-altitude environment as we are with the low-level, low-speed airport areas where the National Transportation Safety Board reports that most midair collisions occur.

NBAA's continued concern for flying safety is evidenced by participation in FAA's Collision Prevention Advisory Group (COPAG), FAA's Flight Information Advisory Committee (FIAC) and local and regional air traffic control advisory committees.

Additionally, NBAA has been privileged to assist the NTSB by providing specific expertise in the operational and maintenance areas of certain aircraft accident investigations.

Our 8-year experience in working for collision avoidance equipment shows that many people are unclear on the basic definitions that directly relate to the need of the environment. Collision avoidance systems (CAS) provide the pilot with an avoidance maneuver. He need never see the intruder and at high closure speeds probably will not.

At 1,200 mile per hour closure speeds, CAS equipment must function at extended ranges of 40 to 50 miles, in all kinds of weather, and to be truly effective must provide maneuver information to both aircraft.

Adequate testimony will be presented by other groups on the technical complexity and the obvious cost of providing such a capability. Cost alone may restrict CAS availability to a limited number of aircraft, probably not more than unto itself. They are only additional tools available to the pilots and must be used to supplement air traffic control procedures, flight rules, and traffic separation standards. There are those who would have you believe otherwise, but we urge you not to be misled.

NBAA prefers to remain outside of the technical area. Our expertise lies in the real-world of aircraft safety of operations and economics. We have resisted what we would call premature establishment of a "national standard" for any CAS or PWI system at this time.

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In spite of the professional work that the airlines have accomplished in evaluating the available techniques, deciding on time-frequency, and following through to flight-test proving trials, the fact remains that the T/F systems as presently developed cannot in our opinion include sufficient numbers of aircraft to warrant its designation as a national standard, at least not at this time.

Taking such a position is not an easy one for NBAA when 80 percent of our members' aircraft are flying daily on the same flight tracks at the same altitudes and over the same relative distances as the air carrier aircraft. Most, if not all of ours, will install the CAS equipment when and if it becomes available.

But up there, they are under FAA's positive control procedures and the records show that the accidents are not 3,000 to 5,000 in the next 10 years.

A proximity warning indicator, on the other hand, is designed and required for an entirely different mode of operation. In its simplest form a PWI would tell a pilot that another aircraft is within a given distance of him. Obviously, a PWI is designed for a relatively low-speed environment, and therefore low altitude. Further, the range requirement can be considerably less—not more than 5 miles and probably under 3 miles.

We stress that these two environments are already with us. They are created by the aircraft, FAA's air traffic control and the nature of the system. The needs of the two areas are very different except for one important commonality—the higher performance aircraft have to climb and descend through the lower speed strata of aircraft when taking off and landing.

We emphasize these fundamental issues because NBAA has no ax to grind but safety. We have no equipment or technology to sell. Our efforts have confirmed that if you do not get the smaller aircraft into the anticollision system, you will not achieve the goal that brings us here today. Complexity, with its attendant higher cost, is the biggest detriment at the present time.

Neither CAS or PWI, of themselves, will guarantee that accidents will not happen. Neither CAS or PWI is an answer occurring in that environment. Indeed, the law forbids you to enter these areas without an operable transponder.

We respectfully suggest that the subcommittee could perform a major service to the public and aviation safety by vo'cing its report in forms of priority programs for the FAA and the industry.

As will be, or perhaps has been, pointed out by other speakers, there are several technical means available for warning and avoidance systems. Each has its relative advantages and disadvantges. We urge the committee not enter into technical evaluation, but rather exercise its congressional prerogative of offering guidance to the Federal Aviation Administration which is charged under the Federal Aviation Act with the safety of the airways.

We suggest that the FAA has to a degree relinquished its proper role of leadership in the areas of collision avoidance. After much study, the FAA had determined to let a research and development contract to develop and compare ways and means of collision avoidance (CAS).

Acting for a large part on the recommendation of the COPAG FAA/Industry group, the FAA chose to support the air carriers effort being marshalled by the Air Transport Association.

It should be publicly acknowledged that NBAA supported this move by the ATA feeling that private industry could move more quickly toward a well-defined goal. This, of course, has proved to be true and the companies and ATA are to be complimented.

The FAA, however, also, chose to concentrate on supporting the ATA effort and for all practical purposes, stopped any further evaluation of other possible techniques, including PWI research.

It should be further acknowledged that FAA was operating then under a much more restrictive R. & D. budget with heavy demands being made by other important air traffic control projects.

At that time, knowledgeable industry began to feel that FAA had made the unannounced decision that time-frequency technology had been accepted by the Government and it would be relatively useless to invest private funds in research or the development of other proposals.

The record will show, however, that some companies persisted as did some major governmental agencies, namely the U.S. Army and Navy, and indeed, the inclusion of a $19 million in public FAA budget planning documents for ground stations for time-frequency CAS did nothing to allay industry's fears.

Finally, in 1970, representatives of 80 percent of the pilots flying 90 percent of the aircraft in the United States gathered and developed operational requirements for a proximity warning indicator.

Representatives of the Air Line Pilots Association, Aircraft Owner and Pilots Association and NBAA met with FAA. Using FAA-contract produced data, they developed PWI requirements and presented them to the FAA, and National Transportation Safety Board, with a request that action be expedited on calling for proposals from industry.

Although programed, the FAA's request for proposal has been delayed until the latest projected date is 90 days from now. It is extremely difficult not to feel that without this industry initative, PWI would be still further behind.

Speakers have or will address themselves to possible compatibility for the CAS to perform the PWI function by use of a "micro" system or small unit in the general aviation aircraft.

This, without question, would be the ultimate and would be immediately "blessed" by other aviation factions. Intensive development and flight test work must produce an economical box that will both alert the large aircraft to the presence of the smaller one, but in addition it must protect the two smaller aircraft from each other.

To be effective, the system used must have as large a number of aircraft as possible to participate. The small single-engined aircraft must not only participate with the large jet, but must also participate with the many more smaller and lower-speed aircraft around it.

To date, that capability has not been forthcoming primarily due to cost. Even at $1,000 per installation, we are speaking of 10 percent or more of the total cost of some aircraft.

We feel that this problem can be overcome, but more importantly, it must be solved before Federal law casts in concrete the technique or system. It is not yet time for a national standard. We are not degrading the excellent work done under the guidance of our friends in the airline industry. They felt they had a serious requirement, they took forthright steps to solve it, and backed their convictions with their own money.

However, it must be rembered that the basic requirement against which the air carriers developed their system and which led to its present configuration is tailored for air carrier operations.

They have made a commendable effort to scale and extend the system to include other aircraft, but the basic system is designed around ground stations and intricate time-base technology. It is not a total requirement developed against the total background of air traffic control system with its mix of aircraft monitored by ground based radars and controllers. Such a total system requirement has never been developed by the Department of Transportation.

History has shown that eventually an aircraft operator must "buy a ticket" to be permitted to use our limited air space.

Transponders and flight clearances are two common examples. Two-way radio and minimum flight instruments could be added to the list. We are not saying this is wrong, but each one is attached to a national standard. Each one has a price tag. We are not at this point considering the price tag for collision avoidance.

It would indeed be proper for the subcommittee to recommend that the FAA be required to objectively review this important area and expend funds to determine the proper system to be phased into the airspace system.

The testimony before this committee shows, if nothing else, that there are major differences of technical opinion on how this important task can be accomplished. Perhaps it is not too late to take a page out of the military R. & D. book: A clear statement of requirements, proposals followed by selected contracts producing hardware suitable for test backed by a high priority.

Senator Moss. May I interrupt you, I will go ahead and vote and you finish your statement with the staff.

Mr. Bean. Thank you.

It is NBAA's opinion that two groups of hardware will probably evolve: One, a system capable of providing CAS data for all-weather high-speed operations, and two, a CAS/PWI system capable of 5 miles or less range in the lower altitudes.

There is little doubt that the CAS will have to be a compatible system. Meanwhile, evidence is piling up that even a reasonable PWI will require equipment to be installed in both the protected and the intruder aircraft.

Whatever system is ultimately evolved, the smaller aircraft must be protected from the larger aircraft. We see both CAS and PWI equipment installed in the larger, complex and faster aircraft. Ideally, the PWI function would be an extension of the primary CAS system.

There are other indicators that FAA's primary concern is on CAS. Recently the minimum standards for aircraft anticollision lighting were substantially increased which will require primarily condenser-discharge or "strobe" type lighting.

The FAA, for reasons not completely explained, chose to ignore industry and user requests that this opportunity be seized upon to require minimum infrared content in the strobe lighting. This, in spite of the fact, that PWI devices utilizing strobe-generated infrared are currently on the market. The cost of this addition would have been minor.

We know that the administration and the FAA are properly concerned about expenditures of public funds to secure the "most for the most people," but we respectfully remind the committee that nearly 50 percent of the people and a large proportion of the goods moved in air commerce are moved by other than commercial carriers. We suggest that safety priorities should be reviewed by the committee and provided for guidance of the affected agencies.

In summary, NBAA believes that FAA did, perhaps unknowingly, surrender its statutory leadership in this area of aviation safety. It is not too late for them to move rapidly back to the forefront in developing anticollision and warning devices. This can only be done if the administration will accept collision warning and avoidance as a form of national goal.

It was not accident that the Air Transport Association finally took the lead and solved their problem to the best of their ability and credit. The technology is here, the moneys are available through the trust fund, and past reasons for delayed actions do not appear to be valid.

Therefore, it is recommended that the committee go on record as finding:

1. That the technology exists to provide backup collision avoidance and pilot warning capabilities;
2. That their timely development must be given the priority needed in order to accomplish the task;
3. This priority must give due consideration to the other contributing methods of traffic separation, such as use of transponders, terminal control areas, and corridors;
4. That FAA be urged to immediately institute a development and test program with knowledgeable industry for both the CAS and PWI functions. Target dates should be tightly set commensurate with the priority established. Hardware should be developed and tested. Only in this manner can the technical differences outlined in these hearings be properly evaluated against cost-benefits for aviation safety;
5. Such a system must include the mutual protection capability for small as well as large, complex aircraft when necessarily mixed in the lower airspace;
6. That the pursuance of these important goals is properly a Federal function and the expenditure of public funds for its solution is in the public interest.

And in closing, may we refer the committee's able staff to the report of the National Transportation Safety Board's hearings of November 1969 on the same question as a source of important guidance on this vital subject.

Mr. GINTHER. Thank you, gentlemen.

I must say there has been an interesting flirtation with the aviation trust fund today despite the efforts of the committee and the Congress to close the door.

I have no questions, I think we shall recess until the members of the committee return and perhaps they will have questions.

(Recess.)

Senator MOSS (presiding). If you will be seated, we will resume.

Senator Cannon will be here as soon as he has voted this second time since last we were both here.

We are now at Mr. Bean. Mr. Bean, have you finished your prepared statement?

Mr. BEAN. Yes, sir.

Senator Moss. I understood you had a response you wanted to make to some questions that were earlier asked; is that correct?

Mr. BEAN. Mr. McIntosh did.

Mr. McINTOSH. Senator Moss, I did. I believe several questions were asked by yourself and I believe Senator Baker of how the cost for a box could be realistically brought down. I felt I would take the liberty of explaining the method that has been used and I should preface this by saying that not all electronic manufacturers subscribe to this method.

General aviation in the sense used today has been for airplanes flying below 15,000 or 12,000 feet, the environmental requirements for an electronic box, the ability to survive temperatures of minus 65 degrees is not required; therefore you can use different components. Ofttimes you can use even fewer components.

This in itself results in a lower cost. By not having to meet very high environmental standards, that is.

Add to this the capability that brought the general aviation transponder into being in which the U.S. Government underwrote the research and development and the early construction of that transponder. They spread the costs over a longer period of time with that manufacturer who was represented here today, returning a portion of his sales cost back to the Federal Treasury over a given period of time. In that way the costs of the transponders was in fact brought down and by then the other knowledgeable companies who specialized in general aviation hardware had come into the act. Competition and sheer numbers then continued to push the cost down to where you now have a general aviation transponder in the $400 to $500 bracket.

I didn't think that that was adequately answered to either Senator Baker and for yourself, and for what it is worth, may I put it in the record?

Senator Moss. Thank you. I am glad to have that explanation. Thank you very much.

I will turn the meeting back to Senator Cannon.

Senator CANNON (presiding). Thank you very much, gentlemen. We appreciate your testimony.

Next, Mr. Walter Jensen, vice president, operations, Air Transport Association.

May I say I deliberately left you to the last so you would have an opportunity to hear everyone who had been before so you could comment, Mr. Jensen.

STATEMENT OF WALTER JENSEN. VICE PRESIDENT, OPERATIONS, AIR TRANSPORT ASSOCIATION, WASHINGTON, D.C.; ACCOMPANIED BY FRANK C. WHITE, ASSOCIATE DIRECTOR, INFORMATIONS SYSTEMS AND AVIONICS

Mr. JENSEN. Thank you, Mr. Chairman, and I will do so.

I am Walter A. Jensen, vice president, operations, Air Transport Association, representing the scheduled airlines of the United States.

You have my prepared text, and in accordance with your opening remarks, I assume it will be inserted in the record.

Senator CANNON. That is correct.

Mr. JENSEN. I have a statement, a summary that will not track with the words in our main text.

It seems apparent to me that as I read S. 2264 that the broad, overall objective of this bill is to improve aviation safety—in particular, to reduce the possibility of midair collisions—by requiring the use of airborne anticollision devices at the earliest practical time.

We agree with this objective. In fact, for the last 16 years it has been our objective. Over these years Frank White has devoted a major portion of his time and energy to this objective; and the airlines, although not in the research and development business, have spent several millions of dollars in pursuit of this objective.

Great progress has been made, particularly in the last 2 or 3 years as a result of these efforts and the excellent work done by McDonnell Douglas, Bendix Avionics, Sierra Research, and Wilcox Electric.

Specifications for a collision avoidance system have been written, hardware has been built and successfully flight-tested.

This collision avoidance system utilizing the time-frequency technology is clearly in a much more advanced stage of development than any other collision avoidance system. But a number of additional steps must be taken to bring it into widespread use.

First, an official selection must be made regarding the type of collision avoidance system to be put in use. The FAA is the logical agency to make this selection, and we, of course, think that the time-frequency CAS is the logical choice.

Second, the FAA needs to determine whether the time-frequency CAS in its present form is fully compatible with the air traffic control system. The testing has been completed and the results should be available soon. No major problems are anticipated, but relatively minor adjustments to the equipment or procedures for its use may be required. Since the collision avoidance system is a backup to the ATC system, these two systems must be compatible.

Third, more work is needed to insure that a time-frequency CAS is produced for general aviation at a reasonable price. There are good indications that reliable equipment can be produced to sell in the $1,500 to $2,500 price range.

Fourth, a decision has to be made as to when the use of CAS will become mandatory. The increased protection from collision provided by CAS is directly proportional to the number of aircraft equipped, and, unfortunately, past experience indicates that rulemaking is required to expedite the widespread use of equipment such as this.

There are additional points covered in my prepared text, but these points just mentioned are probably the most significant.

Because sound decisions on these matters require a rather extensive knowledge of CAS technology, we are of the opinion that the FAA should make them.

Specifically with reference to S. 2264, we believe that the establishment of a mandatory date for the use of CAS and PWI should be a matter of FAA rulemaking and not an action of the Congress. For that reason we think it would be unwise to pass S. 2264.

We respectfully suggest that the role of Congress would better be to monitor FAA's actions in this regard to insure that they move as promptly as conditions permit. In our view, they have been doing a good job and are as anxious to minimize the risk of midair collisions as this committee is and as we are.

Now, three points that have come up during today's discussion.

One, I am sure if I did not volunteer, you would ask me what we though collision avoidance systems would cost the airlines. I am sure your also would realize that there are a number of variables that are as yet undefined. How much a production run would be involved, how many equipments would be required for each airplane, over what period of time, what the installation costs are, and a number of things.

To the best of our knowledge, to try and anticipate these variables, it looks like it might cost the U.S. airlines something like $250 million for the installation of CAS equipment. However, this might come down if these variables change, down to as low as $150 million. Something in that range.

Second, I would like to comment on the relationship of PWI and CAS. First, from an airline standpoint, I think that we owe it to our passengers at the speeds we travel and with the traffic situation that exists persently, to avoid collision by something more positive than looking out the window.

PWI by definition is a device for giving the pilot an indication of where traffic is, and having him look out the window, see it, and figure out what to do about it.

From an airline standpoint—and I am not speaking for general aviation and I shouldn't—we think we need to have something of a CAS nature that will work in weather conditions where you can't see out the window and look and see what to do about the other traffic, and to give an avoidance maneuver to the pilot so that we are sure that the two airplanes are going to do the right thing in relation to each other.

We can't leave it to pilot judgment in each of the airplanes hoping they will take evasive maneuvers that will be compatible and will avoid the collision.

The time frequency CAS takes this into account and gives the maneuvers which are related to each other and will protect against that situation.

PWI, if it is used, must be in our view compatible with CAS if we are to use CAS. In other words, we can't have a CAS system in our airplanes and then have PWI in some airplanes. That could cause a potential conflict because of what I just mentioned where the CAS tells the pilot what to do to avoid a collision and yet the PWI leaves it to pilot judgment as to what to do to avoid the collision.

You can see there is a potential conflict between the two if this is not clearly thought out in advance. They must be compatible.

With regard to dates, mandatory dates, you have asked several of the witnesses whether or not the dates in the proposed bill are realistic. There is a bit of confusion about what the dates really say.

If one assumes that the dates are intended to say in the bill that by January 1, 1973 a decision will be made on the standards to be utilized and the equipment would then be installed and operating in the airplanes by January 1, 1975, I would have to say that that doesn't allow enough time between the setting of the standards and the full implementation.

The manufacturers would have to await the decision which you would put in the bill as being January 1 of 1973 before we really went to work to develop their production runs and the time that would take, plus the time it takes to implement even on an expedited basis, equipment of this nature in airline aircraft and in other aircraft for that matter, would require more than 2 years' interval, even on the best of our intent to try and get this in.

I think our actions speak for themselves in our intent to try to get on with this job.

Those are the thoughts that occur to me in view of the testimony so far and I stand ready to answer any questions I am able to.

Senator CANNON. Don't you think the more complicated CAS system is really going to do the job in the area of your biggest hazard, which is in close around the airport, below 10,000 feet, and say 30 or 40 miles from the airport, where you have a lot of small airplanes that—that the cost of that system to that airplane owner is as someone said earlier going to be 10 percent of the entire cost of the airplane?

Mr. JENSEN. The answer to that question as I see it would have to be that it will not do the job unless the other aircraft is equipped. Unless the price is such that you can reasonably expect general aviation aircraft to be equipped.

Now, I would go on to say that the worst possible collision in the eyes of the airline industry is to have two airplanes owned by the same airline collide. Fortunately that has never happened. The next worst situation that you can envision is to have two airlines collide. That has happened. The situation then going down the scale, colliding with a general aviation aircraft while tragic, is not of the same consequence and loss of life as the airline to airline collision. We must make an effort to try and prevent at all costs the airline to airline type of collision.

Senator CANNON. You listed the greatest hazards there in order of importance and yet if you were to list the greatest frequency or the greatest opportunity for collision you would go just the reverse.

Mr. JENSEN. That is correct.

Senator CANNON. You would have to reverse the scale completely.

Mr. JENSEN. And I might also point out in view of the comments today about high density areas, that when one looks at the records of midair collisions, whether airline to airline or airline to general aviation or airline to military, that a rather significant percentage of these midair collisions have not occurred where you would expect them to. They have not occurred in Chicago, or Los Angeles, and Miami and so forth. They are in lesser dense areas than one might expect as far as traffic density producing midair collisions. I grant you there have been midairs in the New York area but not in terms of what you think in terms of density.

Senator MOSS. I point out one exception, one we referred to earlier, Air West was coming out of Los Angeles Airport when it collided with a Phantom jet.

Mr. JENSEN. I agree, Senator Moss, but much of the attention often is focused on what is considered to be the high density terminal area. Most of the considerations of these areas didn't go out as far as where that midair took place.

Senator MOSS. I notice that you approve very much of the objective of this S. 2264, that we have on the table, but you do think that there shouldn't be any date set in here and as I remember you said that the Congress ought to monitor the FAA to see that it expedited its rule-making. That is what motivated this bill. We are monitoring and monitoring and monitoring and not getting the expedition.

Mr. JENSEN. I think today's testimony indicates the complexity of trying to figure out a good date for mandatory carriage of anticollision devices. It is as bad to make that date too loose as it is to make it too tight. Either one is unrealistic.

There are an enormous number of considerations that must be weighed in order to make that date right. I would think that the FAA has the time and the manpower to study that matter completely provided you look over their shoulder and make sure that they are doing it as quickly as it ought to be done and that they are doing it realistically and accurately.

You have many methods of insuring that FAA complies with your desires by means other than the passage of a statute.

Senator MOSS. Well, I acknowledge your point. You shouldn't have a statute if it can be done in a simpler and better tailored manner. But of course the FAA will be coming before the subcommittee to testify and maybe this will serve one of the purposes of having them say how or in what kind of a time frame they think they can move and also whether they would prefer not to have a fixed date set down in the bill.

Mr. JENSEN. Actually, Senator, I might say it is my own observation that I would like to see them make a decision prior to January 1, 1973 as to what ought to be done.

Senator MOSS. Very good. Maybe it is too loose as you say.

Well, I appreciate your testimony, and the problems you have pointed out are obviously complex, and not a simple matter to be readily enacted. But what you have told us today and also the response of other witnesses have made a good record.

Mr. JENSEN. Thank you.

Senator CANNON. Thank you very much, Mr. Jensen. We appreciate your both being here.

Mr. JENSEN. Thank you.

(The statement and attachments follow:)

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

My name is Walter A. Jensen. I am vice president, Operations, of the Air Transport Association of America, an organization of the scheduled airlines of the United States.

The Air Transport Association appreciates the opportunity to comment on Senate Bill S. 2264, because the early implementation of an effective collision avoidance system is of major concern to the airlines. The Air Transport Association and a number of its member airlines pioneered the Collision Avoidance System (CAS) effort and recognize its urgent need. In September 1955, almost a year before the Grand Canyon midair collision, the scheduled airlines established a goal of providing a collision avoidance system for their aircraft. After more than a decade and a half of work we are on the threshold of implementation. A chronology of this work is appended to this testimony as attachment A.

Before I become too deeply involved in discussing the problem of CAS implementation, I would like to spend a few moments in defining the terms CAS and PWI as we believe there may be some confusion as to what each is and does. Since ATA coined these two terms, in 1959, we would like to be sure that they are understood as we intend them to be.

A PWI is a *P*ilot *W*arning *I*ndicator. It scans the airspace around the airspace around the aircraft searching for other aircraft. Once it locates another aircraft, it warns the pilot and indicates where he should concentrate his vision to find the other aircraft. A PWI places a fair amount of workload on the pilot by requiring him to visually locate the other aircraft, determine if it presents a collision threat, and select the avoiding maneuver. Thus the PWI is essentially an aid to seeing other aircraft.

CAS however, means *C*ollision *A*voidance *S*ystem; it not only detects other aircraft but it also automatically determines whether a detected aircraft presents a collision threat and, if so, indicates to the pilot the proper avoiding maneuver. It works as well in the clouds as in clear air. In our opinion it is a far better solution than PWI in that it assures split second decision and *complementary* avoiding maneuvers which PWI leaves to human reactions and frailties.

With this as background, I would now like to discuss some of the critical factors in implementing a CAS program.

First of all, a single system should be selected by the FAA for implementation. The Air Transport Association is convinced that a system using the time/frequency technology is the only fully developed system, essentially ready for implementation. A brief, summary description of the time/frequency Collision Avoidance System is provided at attachment B.

Secondly, an implementation program for this system, like any new system in the Air Traffic Control environment, requires action by many segments of aviation, including the U. S. Government; not only are airline airborne equipment programs involved, but many other, more time consuming and far reaching decisions and programs are necessary. These include: World-wide system standards (to be developed and adopted by the International Civil Aviation Organization); ground station design and implementation by FAA; FAA analysis and real time simulation of the CAS system interaction with the ATC system so that the CAS can be adjusted as necessary; development of competitive, low cost general aviation CAS equipment; installation of airborne equipment in general aviation and military aircraft; regulatory action by the FAA; and the most appropriate timing for intermeshing of all these items.

The approval of the FAA is required to permit operational utilization of the CAS system in the Air Traffic Control environment. To provide certain essential information on the acceptability of the CAS system when operating in the ATC environment, a real time simulation of CAS/ATC interaction has been underway at the FAA's National Aviation Facilities Experimental Center. Since CAS is a back-up to the ATC system, it must not interfere with that primary means of controlling aircraft. This NAFEC simulation, analysis of results, and publication of the findings has been scheduled by FAA for completion this year.

Assuming that the simulation does not reveal any insolvable problems of CAS and ATC system interaction, the airlines would expect an FAA approval, possibly late this year; to utilize the Time/Frequency CAS system. The results of the simulation may indicate a need to adjust CAS design; so finalization of production hardware must await completion of this phase.

The Collision Avoidance System will require some ground stations to provide calibration signals for the airborne CAS. The first of these ground stations for the time/frequency CAS is currently scheduled by FAA for procurement using FY–1972 monies; this contract will provide for six units which should be operational in 1974.

The Collision Avoidance System we have selected will become truly effective only when the majority of the airspace users are equipped. This is because it is a cooperative system. This means that the extent of protection to the equipped aircraft is directly proportional to the number of other aircraft that are also CAS equipped—military and general aviation as well as air carriers. Past experience has shown that not all the users of the nation's airspace will equip their aircraft with a safety device unless it is required by the Federal Government. We do not believe that this requirement should be in the form of an additional statutory requirement, such as that proposed by Senate Bill E. 2264, but should be established through the administrative rule-making process, by the FAA, the agency vested with the responsibility for air safety. Accordingly, we consider the overriding question is *when* can a regulation making installation of CAS mandatory be feasibly promulgated by FAA. That date will be the consequence of a series of decisions which must be made in order to assure an effective collision avoidance system. I would like to discuss some of the factors that must be considered in establishing that date.

With regard to installation of operational CAS equipment in airline aircraft, competitivve production equipment is expected to be available late next year. One manufacturer, the McDonnell Douglas Company, is now testing pre-production airborne CAS units in their own aircraft. Although three other manufacturers, Bendix Avionics, Ft. Lauderdale, Florida; Sierra Research, Buffalo, New York; and Wilcox Electric, Kansas City, Missouri, also participated in the airline funded flight test program by providing developmental equipment, to date none of them has completed a pre-production model. These manufacturers have indicated that an airline pre-production model could be available in about 14 months from now. Production equipment would require a minimum of four additional months.

For a CAS to be ready for application on anything approaching a mandatory basis, competitive manufacture of the equipment must be available for all categories of users, particularly general aviation aircraft, at a cost that is not prohibitive. We believe that the price of CAS equipment for mandatory use in designated, critical airspace, should not exceed the $1500 to $2500 price range for general aviation aircraft. McDonnell Douglas already has a general aviation version CAS unit about ready to fly and has indicated that it will market in this price range. This is an authoritative estimate by a competent and highly respected source. We would like to see other, competitive sources before the government considers making time/frequency CAS mandatory. With the objective of reducing the cost of general aviation CAS equipment, we have urged the FAA to fund the competitive production of such equipment. If such funding is promptly provided, the first units of equipment suitable for installing in general aviation aircraft could be available as early as 1973.

The cost of the more sophisticated airline equipment will run as high as $100,000 per aircraft with a dual installation. The main reason for the high cost of time/frequency CAS in airline aircraft is that these units have the burden of propagating the CAS master time that is the basic requirement for the time/frequency system. All other aircraft are "passed" this master time automatically, which permits them to utilize less expensive time/frequency CAS equipment.

Piedmont Airlines, on June 22, 1971, advised McDonnell Douglas of its intent to purchase EROS II Time/Frequency Collision Avoidance equipment for its Boeing 737 aircraft fleet, subject to FAA approval. Under this arrangement, production equipment is expected to be delivered to Piedmont between January and April 1973. United Air Lines has arranged for delivery of two of the McDonnell Douglas units to investigate the operational and engineering problems as related to installation of CAS into Boeing 727 aircraft and this equipment has now been delivered.

In addition to requiring installation of CAS in aircraft having a maximum certificated weight of 12,500 pounds or more, Senate Bill S. 2264 proposes equipping aircraft grossing less than 12,500 pounds with a Pilot Warning Indicator (PWI), perhaps with the thought that this would provide a less expensive way to proceed for such smaller aircraft.

We believe that time/frequency technology can provide not only CAS but probably, in addition, a satisfactory PWI. We say "probably" since the requirements for a PWI have never been authoritatively stated. Much remains to be learned as to what should be required of a PWI. How well must it measure the location of the other aircraft to advise the pilot where to look? Obviously the more emphasis that is placed on accuracy, the higher will be the cost. We have serious doubts that a PWI of the type now being developed can provide sufficient warning time to prevent a collision with a high performance aircraft.

The Army has a PWI operating in helicopters flying at Fort Rucker. This environment is obviously one of very low closure rates. The PWI now being used by the Army will not, in our view, be adequate for fixed wing aircraft operating in the civil environment either enroute or in terminal areas. Only time will tell, since no one knows for sure today what is really needed. We have judgment, estimates, and intuition.—but little more. We support the development of a PWI but it *must* be one that is compatible with the time/frequency CAS so that a single system can be carried by all users to fulfill both CAS and PWI requirements and safety will not be derogated.

We believe the proposal on PWT of S. 2264 is weak in that it does not address this problem of CAS and PWI compatibility. It is difficult to see how a CAS, which advises the pilot the correct avoiding maneuver, and a PWI, which leaves to the pilot the selection of the avoiding maneuver, can be operationally compatible. In congested airspace, with more than two aircraft nearby, a pilot has no way to know, when looking out the window of his aircraft, if the aircraft he sees nearby is the one that his PWI has advised him to maneuver to avoid. The concept of PWI, although attractive since it appears to offer the possibility to lower cost equipment than CAS, remains to be developed and integrated with a CAS which has already been developed. Permitting the development of a PWI that is not compatible with the time/frequency CAS would only be assuring the good likelihood that at some future date there would be a mid-air collision involving a PWI equipped aircraft and a CAS equipped aircraft. "See-and-be-seen" is a very tenuous method of separating aircraft, attempting to improve it by adding a PWI sounds attractive but remains to be demonstrated as an effective method of airborne collision prevention for civil aircraft.

SUMMARY

1. The time/frequency CAS has been developed over a period of nearly a decade and is the only system ready for implementation now.

2. To be effective, CAS must be cooperative. Installations will not occur on a voluntary basis in all aircraft, thus regulatory action by FAA will be required to assure that all users are equipped. We do not believe a statutory requirement is necessary as proposed in S. 2264, but the administrative rule-making process should be utilized. FAA should be the agency to issue such regulation.

3. A PWI has not been developed conceptually. If it is permitted, it should be required to be fully compatible, technically and operationally, with CAS. If its installation is not controlled by FAA, safety would be derogated as CAS separated aircraft could collide with PWI equipped aircraft.

4. CAS should not be made mandatory until competitively manufactured equipment is available for all classes of users. Competitively manufactured time/frequency CAS equipment for airline use is expected to be ready by early 1973. If the development of general aviation equipment can be sponsored, possibly by the FAA, it too could be available during 1973. No other system is near this stage of development and availability.

In conclusion, we believe that considering the complexities involved, that implementation of CAS is moving forward as rapidly as possible. The airlines will continue, as they have for the past decade, to be the leaders in pressing for the installation of airborne collision avoidance devices, not only in airline aircraft, but all other aircraft that share the airspace. It must be remembered that once the decision is made to require the carriage of CAS by the various categories of users of the airspace, experience has taught us that we cannot expect a large majority to install these complicated airborne devices in their aircraft in less than 5 to 7 years. Therefore, we are urging the FAA to state its intention now to make CAS mandatory at some future time, as we believe it is necessary to state this intention if we are to keep the program moving forward.

I appreciate the opportunity to offer these comments.

Attachments:

A. Chronology of the Airline Search For a Collision Avoidance System.

B. ATA Fact Sheet—Collision Avoidance System Fundamentals.

Attachment A

CHRONOLOGY OF THE AIRLINE SEARCH FOR A COLLISION AVOIDANCE SYSTEM

1955: At a joint meeting of the Institute of Radio Engineers and Radio Technical Commission for Aeronautics, ATA requested industry to propose, or produce, a collision avoidance system (CAS). Airline analysis of CAS problem and "inventor's chart" was also circulated among hundreds of inventors, engineers and manufacturers. No response received.

1956: Mid-air collision over the Grand Canyon stimulated interest, resulted in a flood of ideas to ATA.

In July, 1956. ATA sponsored a symposium in Washington, D.C., bringing together experts, engineers and inventors to compare airline requirements against then-current technology.

As an outgrowth of that symposium, Collins Radio, in September, 1956, submitted the first formal proposal to the airlines for a non-cooperative pilot warning indicator (PWI) system, which they believed could later by developed into a CAS. Two million dollars' worth of airline orders were placed with Collins. But in the development work that followed, Collins discovered that normal aircraft movements in flight prevented their airborne doppler radar from making reliable collision prediction, or could create erroneous predictions in a significant percentage of cases. This eliminated the CAS feature of the Collision proposal. So the proposal was withdrawn while Collins continued its analytical work which has been carried on to this day.

1958: Development of the Tau concept (Tau is range divided by range-rate) by Bendix Radio's Dr. J. S. Morrell, following their publication in the mid-50's of the first accurate description of the fundamental physics of the airborne collision avoidance problem.

1959: The ATA Collision Avoidance Committee (formed in 1956) continued to monitor and encourage CAS investigations until 1959, when FAA created its Collision Prevention Advisory Group (COPAG). Thereafter, ATA took part in CAS work as a member of COPAG.

1960: Collision between two fighter aircraft being tested by their manufacturer, McDonnell Aircraft Corporation, sparked an all-out effort by McDonnell to develop a CAS for use in their flight test area.

1962: In July, 1962, the FAA's Airborne CAS symposium, held in Washington, D.C., gave the first industry-wide briefing on the state of CAS investigations, and received widespread support from all segments of aviation. Bendix Radio described a CAS based on the Tau concept and using one-way ranging, with the ground-bounce technique. With ATA encouragement, Collins Radio outlined a method for testing by computer simulation the features of any proposed CAS technique. This was a major contribution since it offered for the first time a quick and minimum-cost method of choosing the most promising techniques from among a wide variety of theoretical concepts.

1963: In the fall of 1963. FAA gave Collins a contract to study CAS techniques by simulation.

1965: A report of the Collins study was forwarded to FAA in mid-1965. In essence, Collins told FAA that the simple time-frequency system is the most promising, that it works quite well for the enroute case, but has some limitations in the terminal area—where aircraft are most likely to be maneuvering in flight.

At an ATA meeting in April, 1965, Collins reported on the results of its studies and McDonnell Aircraft showed the equipment they planned to use in their flight test operation later that year. The airlines were sufficiently impressed with McDonnell's system to invite their experts to brief the Airlines Operations Conference in September, 1965. After this briefing, the Conference charged the ATA Air Traffic Control (ATC) Committee with monitoring the development of collision avoidance systems and their relationships with the air traffic control system.

1966: Intensive review of the application of time and frequency techniques to CAS by ATA staff and ATC Committee. Four manufacturers—McDonnell, National, TRG, and Collins—briefed ATC Committee.

October, 1956.—ATA issued expanded statement of airline policy on CAS, with detailed listing of functional requirements for a CAS meeting airline needs. Document circulated widely throughout industry and government, particulary to electronics manufacturers with experience in time and frequency techniques.

December, 1966.—ATC Committee of ATA formed CAS Technical Working Group, to study technical details of proposed CAS concepts and prepare draft technical description of system that will meet airline requirements.

1967: First meeting of CAS Technical Working Group in January, 1967, for three days. Group continued regular monthly meetings thereafter (sometimes twice a month) for a total of 37 meeting days between January 1 and June 30, 1967.

June 14, 1967.—ATA asked FAA to have the necessary frequencies designated for CAS.

Technical description of a CAS that will meet airline requirements completed June 30 and distributed to industry, government and airlines early in July.

July 12, 1967.— ATA asks FAA to use system technical description:

to test, by simulation, the interaction of CAS and ATC in order to verify that operation of such a CAS will not adversely affect ATC,

as a starting point for developing a national common system for airborne collision avoidance systems. FAA asked to give early attention to insuring compatibility of civil and military use of CAS techniques.

to begin the efforts that will ultimately be needed to secure international agreement on a common international system for airborne CAS.

1967: *December 14, 1967.*—ATA Board of Directors approve comprehensive evaluation of prototype CAS hardware, with budget of $150,000 for 1968 portion of the two-year test program.

1968: *January, 1968.*—Airline evaluation of CAS cockpit displays begins. Four airlines using Link flight simulators to gather information on pilot and airframe reaction time, using different CAS display devices.

July 26, 1968.—ATA selected Martin-Marietta, of Baltimore, Md. to perform flight tests of CAS prototype hardware build for airline evaluation by Bendix Avioncis, McDonnell Doug.as and a Sierra Research-Wilcox Electric team.

October, 1968.—The Operations Conference of the ATA (Vice presidents of Operations of member airlines) urged FAA to expedite the real time digital simu ation of CAS/ATC interaction since interaction between the CAS and the FAA ATC system was expected and should be minimized by appropriate modifications in either CAS and ATC system design.

1969.—Beginning in August and continuing through mid November, CAS equipment accumulated 317.2 hours of flight during the Martin-Marietta flight test program divided as follows:

McDonnell Douglas 209.9 (82 flights).

Bendix Avionics 97.4 (30 flights).

Sierra-Wilcox 28.8 (12 flights).

64,000 epochs of data were recorded on magnetic tape and/or photo panel film permitting CAS message comparison for 128,000 data points. An additional 24,500 epochs of data exchanged between ground and air and air to ground yielding 49,000 data points.

In its report final (Volume I Section VII) to ATA under the $1.85 million cost plus fixed fee contract, Martin-Marietta concluded as fo'lows:

The overall result of the flight test program was the proof that the time-frequency CAS was effective in:

Detecting the presence of an intruder

Evaluating the collision hazard

Selecting the appropriate, mutually compensating evasive maneuvers

Commanding these maneuvers in time to allow aircraft to achieve safe vertical separation before reaching the potential collision point.

Satisfactory CAS performance was achieved with all combinations of different manufacturer's equipment. The intermixing of systems did not influence the accuracy.

The time-frequency technique proved to be an effective means of implementing aircraft-to-aircraft interchange of accurate range, range rate and altitude data.

The combined tolerances of the CAS systems affected the collision warning accuracy by displaying the CAS climb/dive command within five seconds of the desired zone boundary 90% of the time and within ten seconds of the zone boundary 100% of the time.

Signal multipath and externally generated interference did not prevent the satisfactory accomplishment of CAS data interchange in all test environments.

1970: *June, 1970.*—The ATA Board of Directors noted with deep satisfaction the successful completion of the airline flight test program and requested:

FAA endorsement of the CAS system and approval for its use by any aircraft operator.

Obtaining assurance from FAA that it will plan for the procurement and maintenance of the requisite ground stations to support the wide-spread use of the CAS, particularly by low cost systems for use by general aviation aircraft.

Obtain FAA support for promoting the CAS as an FAA standard and for adoption by ICAO.

Continuing encouragement and fostering the development of low cost compatible systems suited for general aviation use.

July, 1970.—Approval of airline characteristic ARINC 587 for Time/Frequency CAS.

1971: *June, 1971.*—The FAA, at its National Aeronautical Facilities Experimental Center, began the rea' time digital simulation of CAS/ATC interaction.

McDonnel Douglas began flight evaluation of its pre-production ARINC 587 airline CAS equipment.

Attachment B

FACT SHEET—COLLISION AVOIDANCE SYSTEM FUNDAMENTALS

What is it?

A collision avoidance system (CAS) is an airborne device that detects potential collision threats from other aircraft, analyzes them and identifies which are actual threats. For these threats, the CAS determines the evasive maneuver required to avoid collision, and commands this maneuver in time to remove the threat.

Information needed

Information on the altitude, range, and range-rate of the intruding aircraft is needed in order to detect and analyze a potential collision threat.

The CAS computer in the protected aircraft needs the intruder's altitude, so it can be compared with the altitude of the protected aircraft. Range is the distance from the protected aircraft to the intruding aircraft. Range-rates is the rate at which this range is changing.

How information is obtained

Each aircraft transmits a short burst of information in digital form. This message contains the aircraft's altitude and other information about it's time-keeping capabilities. Accurate time-keeping is essential to the CAS because the system relies on measurement of time difference from the start of transmission by one aircraft to the receipt of that transmission by another aircraft to determine the range between these two aircraft. Time-keeping accuracy to within one-quarter of a millionth of a second is assured by atomic clocks at ground stations (and in some aircraft) and a constant correction of less accurate airborne clocks by signals from more accurate time sources—either ground or airborne.

The aircraft transmissions resemble a count-down—each number spoken by a different person. Only one aircraft transmits at a time, with a'l other aircraft listening. One complete sequence of aircraft reporting lasts three seconds and is known as an epoch. Each epoch is divided into 2000 time slots of 1500 microseconds in length. An aircraft making its transmission of altitude and other data, does so in a vacant time slot. The travel time of a transmission can be determined by the receiving aircraft's computer once time of receipt is known because the beginning time of each slot is fixed by the system and known to the computer. Thus, the accuracy of time-keeping directly affects the accuracy with which the range of the intruding aircraft is determined.

The actual frequency used to transmit the short burst of digital information is kept precisely and is also known to the airborne computers. Hence, the apparent shift in frequency observed at the receiving aircraft is a measure of the range-rate—just as the doppler shift in pitch of a train whistle is a measure of the speed with which it is approaching or departing.

This use of very accurate measurements of differences in precisely-kept time and frequency is known as the time-frequency technique. By adopting this technique for the CAS, it has been possible to provide all the required information with a one-way transmission. Elimination of the need for a two-way exchange makes possible accommodating the greatest number of participating aircraft with the minimum essential number of scarce radio frequencies.

How threat is determined

The simplest way to visualize the CAS is to think of a balloon extending around the protected aircraft. When another CAS-equipped aircraft intrudes into this balloon, each airplane's CAS provides its pilot with a command to make an evasive maneuver. Actually, this is an over-simplification, because in reality there are different-sized protective balloons for each phase of flight—e.g., level cruise, climbing, or descending. For an aircraft in level flight, for example, the protective balloon extends 700 feet above and below that plane's altitude. If the plane were climbing or descending, the protective balloon could extend as much as 3500 feet above or below the plane's altitude.

To determine the collision threat, a CAS computer divides the range of an intruder by its range-rate. This gives the time until a collision would occur if no evasive manuever were made. Known to CAS engineers as Tau, this time is the basis for the determination of evasive maneuvers.

Since new range and range-rate information is received every three seconds, the computer aboard the protected aircraft makes what amounts to a continuous succession of Tau calculations. When Tau reaches a predetermined minimum safe value, the CAS commands the appropriate evasive maneuver. Great care has been used in selecting this minimum safe time interval. It must be long enough to preclude the need for abrupt evasive maneuvers yet not so long that it calls for too many maneuvers. The evasive maneuver required by CAS is actually more gentle than an average jet takeoff.

For two aircraft in level cruise, the command to maneuver is given thirty seconds before a collision would occur. This thirty seconds warning time holds for two SST's as well as for two propeller-driven aircraft: the difference is that the faster aircraft are farther apart when they receive the warning. Thus, two SST's, approaching head-on at a combined closing rate of 3600 mph would be 30 miles apart when the command to maneuver is given, while two piston-powered aircraft closing at 360 mph would be 3 miles apart when they receive the command to maneuver. For subsonic jets, the distance would be 10 miles, with a combined closing speed of 1200 mph.

What the pilot gets

The pilot of a CAS-equipped aircraft gets both visual and aural signals. These signals provide the common commands:

Fly up (intruder is approaching, below your altitude).

Fly down (intruder is approaching, above your altitude).

Do not climb (there is an aircraft above you).

Do not descend (there is an aircraft below you).

Some CAS designs have featured an alert warning that calls the pilot's attention to the fact that he will soon receive a command to make an evasive maneuver. Another form of alert provided in the CAS is one that tells the pilot not to climb or descend at a rate exceeding a specified number of feet per minute.

Senator CANNON. The hearings will be recessed, subject to the call of the Chair.

Our next witnesses will be the governmental witnesses, and we are not certain of the exact date, at the moment, when they will be available.

(Whereupon, at 4:53 p.m., the hearing was recessed, subject to the call of the Chair.)

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COLLISION AVOIDANCE AND PILOT WARNING INDICATOR SYSTEMS

TUESDAY, FEBRUARY 29, 1972

U.S. SENATE,
COMMITTEE ON COMMERCE,
SUBCOMMITTEE ON AVIATION,
Washington, D.C.

The subcommittee met at 11 a.m. in room 5110, New Senate Office Building, Hon. Howard W. Cannon (chairman) presiding.

Present: Senators Cannon, Moss, Spong, and Pearson.

OPENING STATEMENT BY SENATOR CANNON

Senator CANNON. The hearings will come to order.

Today's hearing is a continuation of a subcommittee inquiry began on December 1 last year into the subject of midair collisions and the study of Government and industry efforts to reduce the risk of such occurrences in the future. Particularly, we are hearing testimony on legislation introduced by the distinguished Senator from Utah, S. 2264, which would require the development and universal installation of an airborne collision avoidance system within the next 5 years.

In December, the committee heard from a variety of industry witnesses who explained the various technological and associated hardware developments which have recently been achieved. The committee heard described a variety of airborne systems relating to collision avoidance, which are being developed or have been developed by private industry.

Today we will concentrate on questioning the Government agencies involved to ascertain whether the Government itself is moving forward with sufficient urgency in attempting to find better methods and systems for separating aircraft.

In addition to the Government witnesses, the subcommittee will hear Mr. Dan C. Ross, president of Ross Telecommunications Engineering Corp., who did not have an opportunity to testify in December.

In addition, the committee has received a revised statement from the Air Line Pilots Association, which has been submitted as a supplement to its testimony in December. The revised statement will be made a part of the subcommittee record.

(The statement follows:)

STATEMENT OF JOHN J. O'DONNELL, PRESIDENT, AIR LINE PILOTS ASSOCIATION, INTERNATIONAL

Mr. Chairman, the 31,000 pilots and 15,000 flight attendants of the Air Line Pilots Association appreciate this opportunity for me to submit a statement in their behalf on the subject of collision avoidance. They feel very deeply that the lives of their passenegrs are at stake on this issue and are grateful that your committee shares their concern.

It is ironic in this era of space flight that there should be a controversy about collision avoidance systems. We have the technical know-how to produce systems that well keep aircraft from running into each other. We have the governmental organization that can organize the research and development of the hardware. We have a number of manufacturers ready to make the equipment.

What we do not have is action on the part of the Federal Aviation Administration—action in the form of live, competitive testing of the known concepts and action in the form of a decision on some basic parameters to challenge the scientists to come up with the best, least expensive system.

Each time our flight crews take off they are playing a kind of Russian roulette. They are carefully controlled from the moment they leave the gate until they shut down at the destination. But the skies are full of uncontrolled aircraft and our pilots never know when one of them will suddenly appear directly in their flight path. Neither are they convinced that the FAA system that is controlling them is totally reliable because they have experienced too many ATC system failures and have been victims of human error, power shutdowns, and electronic aberrations.

Therefore, airline pilots are asking for an on-board collision avoidance system that will back up the ground-controlled system and give all aircraft some measure of self-protection which they do not have now. They will go along with planned improvements that the FAA plans to implement to update the control system on the ground. They are in favor of automation that will relieve the ground controller from excessive workload. They recognize the necessity for making a sound, practical decision in regard to which technical concept to adopt.

But what airline pilots do not accept is the deliberate footdragging by a government agency charged with safety in the air. They do not understand why collision avoidance has such an apparently low priority on the FAA's list of things that need doing. And they do not understand why the FAA Administrator consistently plays down the urgency of developing workable hardware that will enable the pilot to know when a midair collision is possible and imminent.

There is an old aviation saying that "the pilot is the first to arrive at the scene of an accident." This grim humor also applies in the case of the midair collision, which is considered by air space users to be the No. 1 operational hazard and the most neglected in aviation today. This fact explains why the Air Line Pilots Association continues to work so long and diligently towards the development and implementation of some form of collision prevention means to minimize this continued hazard which has cost so many lives and loss of property over the years.

Long before the ALPA Collision Avoidance Systems Committee was established in 1966, the Association was participating in meetings at which the midair collision problem was aired. In fact, ALPA provided the FAA with a set of proposed operational specifications in 1959, through the FAA Collision Prevention Advisory Group (COPAG).

Throughout all this period. we have stressed the need for an independent backup to the ATC system. ALPA feels that we must rely primarily on the ATC system to provide separation between aircraft, as well as a regulated flow of traffic from ramp to ramp. We agree that the large investment by the taxpayers for this complex system should be utilized to the greatest extent possible. In addition, we feel that a part of the capability and responsibility for the safe separation and flow of aircraft should be assumed by a ground-based system. It is essential, however, that the pilot be provided with the capability and responsibility for providing separation for his own aircraft when the ground-based system fails, and by the record it does and will continue to fail.

In recent months, the FAA has stated on several occasions that the new automation technologies they are planning will obviate the necessity for airborne anti-collision equipment. The news media on several occasions has called attention to FAA's reluctance to expedite implementation of collision avoidance systems as illustrated by the following Seattle Post-Intelligencer quotation:

"The Federal Aviation Administration, in effect, has given in-flight collision-avoidance systems (CAS) the cold shoulder. Only recently, FAA Chief John Shaffer said CAS won't be necessary once the agency complete its nationwide automatic air traffic control system—probably sometime in the early 1980's."

We must point out that at least 15 years and most likely 20 years will be required to completely install an improved ATC system—which is still subject to failure. One might ask, what collision protection will be available in the next

15 to 20 years unless implementation of an effective collision avoidance/proximity warning system is commenced as soon at possible in all airplanes. This will prevent the horrendous collisions with their terrible loss of lives and the near collisions which are continuing at a frightening rate.

These statements are based upon the anticipated capability of an ATC computer system that will detect a potential conflict between aircraft and subsequently resolve the conflict by giving the controller a suggested change in the flight path or altitudes(s) of the concerned aircraft.

The Air Line Pilots Association has no quarrel with this type of progress. It is obvious, however, that by concentrating all of the capability of the "black boxes" that control the system. From past history, we are only too well aware that very simple equipment failures can seriously affect the operation of aircraft almost to the extent that a catastrophic failure can. The FAA should be asked "What happens to all the airborne aircraft in the system when the ground-based system fails, as it undoubtedly will?" It is mainly for this reason that ALPA is pressing, and will continue to press, for an airborne Collision Avoidance System, so that protection against the midair collision is continually available to the pilot. Another reason is the existence of the IFR/VFR traffic mix, as well as the hazard of the "lost" VFR flight. Furthermore, we feel strongly that Intermittent Positive Control based, in part, on the availability of CAS, will enable the ground-based ATC system to cope with the greatly increased traffic density expected in the 1980's.

Beginning in 1964, the aviation industry urged the CAA/FAA to act immediately to get on with research and development to enable the implementation of some form of collision avoidance system. Specifications were provided and various technologies were explored. Following the introduction of a time-frequency technique by the McDonnell Aircraft Co., the FAA began work on the development of a collision avoidance system for civil aircraft using the same technology. When the Air Transport Association of America issued a requirement for a time-frequency CAS, the FAA withdrew their Engineering requirement and completed their activity in this area. It would seem to be in the public interest to ask the FAA, "Why was this important activity stopped when the ATA effort was directed only towards the airline aircraft problem?" While it is realized that a midair collision between two airliners is an extremely serious catastrophe, midair collisions are more frequent between airliners and general aviation aircraft and between two general aviation aircraft. Initially, the ATA development activity was not intended to handle these latter cases. One might well ask, "Why did the FAA not intensify their efforts towards the solution of the midair collision problem encountered by airline and general aviation aircraft?"

It has been generally conceded that the airspace in which the greatest potential for a midair collision exists is in the terminal area of almost any airport. The Air Line Pilots Association along with other users of the airspace have been deeply concerned with this problem for many years and in 1969 proposed that a safety corridor be established for selected busy airports. In this case the ATA and the FAA got together and strongly opposed it by sponsoring the Terminal Control Area concept, which has caused a lengthy delay in the implementation of segregation if IFR and VFR flights. In a recent report by a special area navigation subcommittee of the airlines, however, it was indicated that they recommended the use of corridors virtually the same as the one they repudiated earlier. We still endorse very strongly the corridor concept as a procedural method of preventing collisions in most terminal areas. For many years ALPA has been on record that the "see-and-be-seen" or "see-and-avoid" philosophy cannot be relied upon in today's air traffic environment. The FAA might be requested to answer the question: "What is their real objection to the corridor concept, when virtually all airspace users recommend it?"

In previous statements to the House Subcommittee of the Committee on Government Operations in August 1971, and to your committee on December 1, 1971, the Association emphasized the urgent need for a low cost collision avoidance means. Up to this point in this presentation, we have commented only on collision avoidance systems, which are generally considered to be complex and costly. Because of these factors, it is likely that they will be installed only on airline aircraft and some of the more expensive corporate aircraft. The general aviation fleet, comprising some 225,000 aircraft by 1980, will also require protection against midair collisions. This is where ALPA's interest in having this huge general aviation fleet equipped with a low-cost collision avoidance system becomes stronger, since any small general-aviation aircraft is capable of knocking a jumbo jet out of the sky.

The major factor preventing the early equipping of general aviation aircraft with ccollision avoidance hardware is the cost of such equipment. It is our feeling that the Government must develop a plan to assist the owners of small aircraft to finance the purchase of suitable equipment. This might be accomplished by some form of tax relief or significant reductions in insurance and licensing costs. Another approach might be for the Government to purchase the equipment and have the aircraft owner pay for it in installments over a number of years. It might also be leased by the manufacturer to the owner.

NASA has provided a limited effort in the collision avoidance problem area, while the FAA has concerned itself with countless studies of the many facets of the PWI problem. While this impractical theoretical approach has been taking place, the U.S. Army has demonstrated very clearly what can be done if the desire is present. Prior to 1968, the Army experienced many midair collisions between their helicopters operating at a training base at Fort Rucker, Ala. In 1968, the Army issued a Request for Proposals for a collision warning device for helicopters. A contract for 222 units was awarded in June 1969 with deliveries starting in December 1969. At the end of 1971, these units had accumulated more than a half million flight hours without a single midair collision. Thus they have accomplished in three years what civil aviation industry has been seeking for eighteen years and, unless a greater effort is made to expedite the process, this objective still appears to be at least eight to ten years away. The FAA should be required to account for this inexcusable delay. On the part of the Association, we are at a complete loss to account for the lack of research and development of an economically viable collision avoidance system.

It is conceded that, at long last, there does appear to be some hope of action sometime in the future. It is understood that FAA anticipates awarding four contracts by the end of FY 72; however, two of these are for further studies. The FAA should explain "Why are there not adequate contracts for the purchase and installation of flyable hardware to obtain qualitative and quantitative data?"

One extremely vital issue which has not yet been accomplished is the publication of specifications to which collision avoidance hardware can be manufactured and installed in aircraft for flight evaluation. While it is understood that an interagency group has only recently been established to determine the position of the Government on the technology they will endorse or approve as National Standard, it appears that considerable time will elapse before tangible results are available. This group should therefore be strongly urged to expedite this decision and recommendations and the FAA should be provided with the funds and manpower with which to accomplish this action. At present, we are told that the lack of manpower within the FAA is the main factor that is delaying any meaningful action. We urge the members of this Committee therefore to take whatever action is necessary to have the FAA provide sufficient talent and move expeditiously towards the implementation of an adequate collision prevention system for all aircraft that operate in the ATC system.

In its continuing pressure for action to implement a nationwide system of collision prevention devices, the Air Line Pilots Association does not endorse any specific technology, system or manufacturer, but is vitally concerned in the public interest that the approved National Standard will provide the required protection.

We want to caution those who will make the decision that it does no good if the concept decided upon is not acceptable to the entire aviation community. For example, Piedmont Airlines recently purchased collision avoidance equipment for its fleet of 36 aircraft. They are to be commended for breaking the ice in this battle to keep their passengers and crews alive. But despite their good intentions, the only aircraft their pilots will avoid are other Piedmont aircraft. They could still have collisions with aircraft of other airlines, military aircraft or general aviation planes.

While we are awaiting the development of a National Standard for collision avoidance means, there is a readily available collision prevention device that should be installed on every aircraft in the system immediately. That is the aircraft strobe light. One does not have to be a pilot to recognize the safety advantages that such lights provide. ALPA has petitioned the FAA to make the use of aircraft strobe lights mandatory. The answer was to delay the decision by issuing a rule which permitted the use of a white "anticollision" light, as well as the red light previously required. In the meantime the FAA is completing further evaluation and study of the strobe light, despite the overwhelming evidence of its great superiority over any other light. The very few problems associated with its use in clouds, for example, could be resolved without difficulty if it were given the necessary backing. Such Xenon strobe lights can be installed on light aircraft for little more than $100. The FAA could be asked, "Why has there not been more effort expended towards the mandatory requirement for the use of aircraft strobe lights, especially since they have been in constant use for more than 15 years?"

Mr. Chairman, the time is long past due for aggressive, positive action on this serious problem of midair collisions. The Air Line Pilots Association has patiently waited for the FAA to take action for far too many years. We are no longer patient. The lives of the millions of passangers we carry are at stake in this matter. We earnestly seek your counsel, support and assistance in getting the Federal Aviation Administration to seek a viable solution to this rapidly growing menace. Your committee is the court of last resort for us. We are confident that you will succeed in getting the ponderous machinery of the FAA to move in the proper direction.

Senator CANNON. Our first witness will be the Honorable John H. Reed, Chairman, National Transportation Safety Board; followed by Mr. Kenneth M. Smith, Deputy Administrator, Federal Aviation Administration; and by the Honorable Phillip N. Whittaker, Assistant Secretary, Department of the Air Force.

STATEMENT OF HON. JOHN H. REED, CHAIRMAN, NATIONAL TRANSPORTATION SAFETY BOARD, WASHINGTON, D.C.; ACCOMPANIED BY CHARLES O. MILLER, DIRECTOR, BUREAU OF AVIATION SAFETY

Mr. REED. Good morning, Mr. Chairman, members of the Committee. I wish to thank you for inviting the National Transportation Safety Board to testify on S. 2264, pertaining to collision avoidance and pilot warning systems and the general problem of midair collisions.

Accompanying me this morning is Mr. Charles O. Miller, the Director of our Bureau of Aviation Safety.

The Safety Board concurs in the position of the FAA that action on S. 2264 should be deferred. I would like to point out that there appear to exist already sufficient legislative authority to accomplish the purposes set forth in the bill.

With respect to the problem of midair collisions, the Safety Board has been continuously aware of the need to identify and implement practical and economically feasible solutions. One of the first major aircraft accident investigations conducted by the Safety Board involved the midair collision which occurred in the vicinity of Urbana, Ohio, on March 9, 1967. From that time forward, we have been most concerned with this problem, and we remain concerned, both with accidents involving air carrier aircraft, which tend to get the greatest publicity, and those more numerous collisions involving general-aviation aircraft.

There are really two distinct problem areas with respect to the midair collision accident problem. Our data indicates that most collisions between general aviation aircraft occur in clear weather in the immediate vicinity, or in the landing pattern, of an uncontrolled airport. This type of collision accounted for 63 percent of the total midair collisions during a recent 3-year study period, 1968 through 1970.

The second problem area is the midair collision which involves an air carrier aircraft is under air traffic control ta the time of the col-density terminal area, controlled airport or airway. Very often, the air carrier aircraft is under air traffic control at the time of the collision. Although a far less frequent occurrence, this type of collision accounts for the largest percentage of the midair-related fatalities.

We believe that in reviewing the possible solutions for reducing the probability of midair collisions, your committee may wish to treat each of these types of collisions separately.

Although the midair-collision situation has remained relatively unimproved and continues to be a major hazard in aviation, there has been an improvement in the rate of midair collisions; that is, fewer midair collisions per hour of exposure. During the 10-year period 1960 through 1970, there were 279 midair collisions involving U.S.-registered aircraft. More than half of these, 144, were fatal, resulting in 684 fatalities.

The Safety Board has recognized the total scope of this hazard and has increased its efforts to pinpoint the causes.

In 1968 we conducted a special safety study of midair collisions which occurred in the United States. This study of 38 collisions involved 76 aircraft. And 71 fatalities, all occupants of general-aviation aircraft, occurred in 24 of those 38 midair collisions. Our 1968 study analyzed these midair collisions in a case-by-case review with respect to the environment in which they occurred, the kinds and phases of operations being conducted, the experience of the pilots involved, and other relevant factors. As a result of this study, we made several recommendations addressed to the aviation community and, in addition, recommended that the Federal Aviation Administration undertake 14 specific activities which we believed would help prevent and, hopefully, eliminate the types of midair collisions cited in the report.

Attached to my statement is a copy of that 1968 study and a summary of the responses we received from the FAA in regard to our recommendations.

Early in November 1969, several weeks after a fatal collision of an air carrier aircraft and a general aviation aircraft near Indianapolis, Ind., the Safety Board convened a public hearing on the midair collision problem. During the 5 days of this hearing, we heard testimony from spokesmen representing all segments of the aviation industry, and we received statements from many other interested persons.

This public hearing and study resulted in 11 additional recommendations which the Board made to the Federal Aviation Administration. A copy of the proceedings of that hearing into the midair collision problem, and a summary of the responses we received from the FAA relative to the recommendations we made, are also attached to my statement.

Our accident data reveals that there were 27 midair collision accidents and four incidents during 1969, and 37 accidents and one incident during 1970. In 1971, there were 37 midair collisions.

These mishaps follow essentially the same pattern as those in prior years. There were, however, more fatalities in 1969 as a result of midair collisions involving air carrier aircraft.

As in the 1968 data, most of the 1969–70 midair collision accidents occurred at or near an uncontrolled airport at altitudes below 1,000 feet, in visual flight rules (VFR) weather, during daylight, and on weekends.

Using 1968–70 midair collision data, we analyzed, hypothetically, the effectiveness of existing and proposed midair collision prevention methods. This analysis was conducted in an attempt to evaluate the effectiveness of the see-and-avoid concept and other techniques or hardware being utilized or proposed for midair collision avoidance.

Safety Board data on actual midair collisions indicates that most of the accidents occur outside high-density areas. Therefore, one can conclude that whereas the potential for collision is theoretically greater in high-density areas due to the large numbers of aircraft involved, the air traffic control processes, both ground-based and airborne, have done a good job. This improved performance is due in part to the increased awareness by all concerned in the high-density areas.

In studying the effectiveness of existing and proposed midair collision prevention methods, 11 assessment parameters were created, each representing a different accident prevention concept. For example, improved ATC systems, improved see-and-be-seen procedures, compulsory use of transponders, standard traffic patterns, and passive radar reflectors are a few of the concept areas delineated.

If they were judged to hold reasonable accident prevention promise for a particular accident, that accident was classified accordingly.

The conclusion we reached, based upon the actual accident experience as well as the threat identified by near midair collision data, is simply that there is no single, remedial approach, including CAS equipment, that holds the potential for eliminating the midair collision hazard. Collision avoidance equipment, such as the McDonnell Douglas EROS or Micro CAS; the Honeywell YG–1054; the RCA SECANT; and Texas Instruments' weather IDAS simply, by itself, will not solve the problem today. However, we recommend that the testing of these systems be continued and expedited.

Our studies of the midair collision problem indicates there should be rapid action in the following specific areas:

1. Segregate traffic by the establishment of high-performance arrival/departure corridors and increase use of the ATC system.

2. Improve ATC radar coverage as well as increase radar reflectivity of aircraft operating in the high-density terminal area. Mandatory use of transponders and radar reflectors must be considered.

3. A vigorous education program to alert pilots to the dangers of midair collisions and in collision avoidance procedures which include, but are not restricted to, proper pattern entry and departure, aircraft spacing techniques, and proper cockpit procedures. This could be accomplished by the preparation of instructional material for use in student pilot instruction and in the preparation of a series of informative data bulletins to be distributed to licensed pilots.

4. Continue the emphasis on implementation of a requirement for all aircraft to be radio equipped and to adhere to mandatory position reports to be made in the vicinity of uncontrolled airport areas. The need continues for a published standard traffic pattern at all airports.

5. Continue the development of a pilot warning indicator which could be compatible with CAS and which would be cost-feasible to the general aviation pilot.

We believe that these recommendations will prevent midair collisions in the present aviation transportation system. However, as the aviation transportation system becomes more complex and automated, industry and Government should be prepared to implement a compatible collision avoidance system.

Thank you again for this opportunity to testify. I will be happy to answer any questions you may have.

Senator CANNON. Thank you very much, Mr. Reed.

You suggest that the FAA act to "segregate traffic by the establishment of high-performance arrival/departure corridors and increased use of the ATC system."

Do you believe that the establishment of five terminal control areas by February 1972 adequately meets this recommendation?

Mr. REED. Mr. Chairman, we feel that this is a real major step forward, but we don't feel it is the entire answer to the problem.

Senator CANNON. Is the TCA concept an adequate alternative to climb and descent corridors?

Mr. REED. We believe the TCA concept is excellent for the major hubs and that climb and descent corridors work fine at the lower density airports.

Senator CANNON. Do you think that that system should be put into effect at all terminal areas in which air carrier operations occur?

Mr. REED. We would say, Mr. Chairman, that the TCA's should be installed where there is a heavy volume of traffic. But for areas that do not have as large a volume, the climb and descent corridors would suffice.

Senator CANNON. Where would you draw the line, at what volume of traffic?

Mr. REED. It is pretty difficult to give a specific answer to that. However, we think the major hub areas would be well served with the TCA concept and that airports with lesser air carrier traffic we could use the corridor system.

Senator CANNON. You also suggest "increased use of the ATC system."

Would you explain just exactly what you mean by that, and would you suggest that all traffic, IFR and VFR, be under positive control when operating in air carrier terminal areas?

Mr. REED. We would say that you couldn't put all traffic under positive control, but more could be done than is being done now.

Senator CANNON. Well, that is not a very definitive answer.

Mr. REED. Mr. Chairman, with your permission, I would like to call upon Mr. Miller who works every day in this field and ask him to expand on it.

Senator CANNON. All right.

Mr. MILLER. Senator, I think the problem is one of capability of the ATC system to handle it. I think we have all flown into areas where we would like to get a radar advisory or other type of radar service, and the volume of activity at present simply wouldn't allow it. I believe the comment that the chairman has made here goes to this point. We would like to see the use of ATC system increased but we also recognize the inherent limit of the ATC system as a function of the total volume present.

Senator CANNON. Then, to the second part of my question, would you suggest that all traffic, IFR and VFR, be under positive control when operating in air carrier terminal areas?

Mr. MILLER. I believe that is basically what is going on in the TCA's today, except in one sense. Take Los Angeles, for example. You have a VFR corridor going right through the TCA for all practical purposes.

Senator CANNON. That is only at five locations?

Mr. MILLER. Yes, sir. Let's say if you adopted a TCA system as it is in existence today in five areas, you are setting up a program where for all practical purposes the traffic in that area is under some degree of positive control by the ATC system.

Our feeling as far as expansion of TCA's is concerned is that at some overall volume of traffic, the precise amount of which we at the Board don't know—you are going to have to depart from the TCA system and go to some other system, and that is where the corridor concept seems to us to have pretty good appeal.

Senator CANNON. Do you believe that airport surveillance radar should be provided at all terminal areas having air carrier operations?

Mr. REED. Mr. Chairman, this would be highly desirable if it would be feasible for the FAA to implement such a system.

Senator CANNON. And also that they should expand the radar coverage—to more terminal areas than now have it?

Mr. REED. Once again, I think this would be of benefit if it can be worked out from the standpoint of resources.

Senator CANNON. Now, you suggest that radar reflectivity be improved on aircraft operating in the high density terminal areas.

Didn't the Board make a detailed recommendation to the FAA on this matter which was ultimately rejected by the FAA?

Mr. REED. Mr. Chairman, the Board did make a recommendation concerning radar reflectors, and the response from the FAA questioned whether the state of the art had advanced to the point where they were feasible.

We put some manufacturers in touch with the FAA to explain the type of hardware which was available.

Mr. Miller, you might want to amplify on this.

Mr. MILLER. Yes, sir.

We went back and forth a couple of times with the FAA and most recently in November, in which we have been advised that there was R. & D. underway to continue to develop a suitable device.

But I believe in this particular case, we have a somewhat difference of opinion with some of the FAA people on the practicality of the existing systems.

Senator CANNON. What is the fundamental disagreement?

Mr. MILLER. As to whether or not they are practical and compatible with the air traffic control radars as we know them today. We have heard from manufacturers, whose story sounds good to us.

I am sure the FAA has heard from these same manufacturers and they have a different view.

But, suffice to say, according to our last information from the Administrator, they are continuing the program of R & D. in these areas, and we certainly support it.

Senator PEARSON. Mr. Reed, you indicated that, based on studies and reports, you made at one time 14 recommendations to the FAA. Later you made 11 additional recommendations.

How many of those have been implemented, and how many of them represent a difference of opinion?

Mr. REED. Senator Pearson, we did, as you indicate, send the FAA a total of 25 recommendations. I checked this yesterday with our Bureau of Aviation Safety, and found that approximately 75 percent of these recommendations have been implemented in whole or in part.

Senator PEARSON. What is in issue today?

What principal recommendations are in issue between the Safety Board and the FAA?

Mr. REED. I would say the two major ones; training for pilots and the use of the corridor system.

Senator PEARSON. There is some difference of opinion as to a scanning, training technique between the Safety Board and the FAA?

Mr. REED. There has been correspondence between the Board and the FAA on this, and I will ask Mr. Miller to give you the specific items. I don't recall them at the moment.

I don't know that they disagree; I believe it is a matter of techniques.

Mr. MILLER. I think that is right. It is not a matter of disagreement, but rather an assessment of how rapidly the improved training can be done.

There has been some excellent work done by the Douglas Co. in California, working with some Navy and Marine Corps pilots. I believe they may have now obtained a contract from FAA. I am not sure of that.

Suffice to say, it is a matter of how rapidly do you go to some synthetic device which can be better used for scanning training of pilots. I am sure there is no disagreement on the desirability of it. I am sure there is no disagreement anywhere on its ultimate use.

I think the only question arises is how rapidly can this be put into effect.

Senator CANNON. Are you talking about training of the general aviation pilot, the student pilot, or are you talking about the training of the airline pilot?

Mr. MILLER. Both, sir; very definitely both.

Senator CANNON. Is there some difference of opinion between yourself and FAA as to whether the airline pilots are being trained adequately in this area?

Mr. MILLER. I am not aware of it, sir. I think any of us—and I include yourself—in the piloting field who have ever gone through days of recognition training and night flight training, will remember the gains that could be made by all pilots on appropriate use of visual skills.

This is what we are talking about in the advance training for scanning, if you will, which in my judgment applies to all pilots.

Senator CANNON. Do you think airline pilot training is adequate in this area?

Mr. MILLER. To the extent the devices are available, it is probably adequate.

But, I think there are better devices that are required to do the job right.

Senator CANNON. You suggest that "mandatory use of transponders and radar reflectors must be considered."

Would you recommend that all aircraft operating in controlled airspace be required to be equipped with radar beacon transponders, and if not, why not?

Mr. REED. Here again, if there are too many operating in this airspace, you could actually blank the scope out.

Senator CANNON. What do you actually mean by your recommendation? It seems to me like you are being quite evasive about this whole problem.

Mr. REED. I would say that, it should be used where it is feasible. In other words, use it when it doesn't saturate the area.

Senator CANNON. Is there saturation of radar systems today?

Mr. REED. In certain instances, and at certain times, there is.

Senator CANNON. Where would you say those areas are?

Mr. REED. Well, it could be a hub like New York, or probably Los Angeles on a heavy day.

Senator CANNON. Would you require that all aircraft operating in controlled airspace be equipped with some type of radar reflecting device?

Mr. REED. Yes; we recommend either a radar reflector or a transponder.

Senator CANNON. Is the Board generally satisfied with the consideration given and the action taken by the FAA regarding the Board's recommendations relating to the midair collision problem?

Mr. REED. I would say, on balance; yes. The fact that approximately 75 percent of our recommendations have been accepted in whole or in part and some others are in various stages of implementation attests to this fact.

We realize of course, that some of them are complex and we could not expect immediate action.

The Board feels that a positive job is being done by the FAA in respect to our recommendations.

Senator CANNON. In your reference to the various CAS equipment devices, you say that these systems, if universally required, would not solve the midair collision problems.

Have you fully considered whether they might or might not solve the collision problem?

Mr. REED. Yes, Mr. Chairman, we have.

We feel these devices have promise and, as I have indicated, we urge that testing continue.

We believe that these devices would serve as a backup to the basic air traffic control system and that, by themselves, they would not correct the problem at it exists.

Senator CANNON. During the hearing on the midair collision between an Air West DC–9 and a Marine Corps F–4 near Los Angeles, testimony disclosed that the F–4 was operating VFR at speeds in excess of 400 knots on a routine training flight.

Will the Board have any recommendations relating to military operations and the use of the airspace as a result of that investigation?

Mr. REED. Yes, Mr. Chairman, Mr. Miller was at the accident scene and he was at the hearing. I will ask him to describe that for you.

Mr. MILLER. Yes, sir.

We made several recommendations in this regard that had to do with the possible use of mandatory IFR by military aircraft when they are operating above 10,000 feet.

It involved the possible use of airborne radar. It involved the control of speeds below 10,000 feet by military aircraft.

All of these are detailed in the "Summary of Status of Recommendations Related to Midair Collision Hazard."

The only one that has not been acted upon either by the FAA or by the DOD is the one that deals with the filing of IFR flight plans when operating above 10,000 feet. The Administrator has advised us that this was considered to be infeasible by the FAA Regulatory Council. But for the most part, the military and the FAA stepped up quite rapidly to implement the recommendations of the Board following this collision.

Senator CANNON. Testimony at that hearing disclosed that the F-4 was operating with a nonfunctioning transponder and was not observed on the ATC system radar prior to the collision.

Will the Board make a recommendation relating to the requirement that military flights must operate with functioning transponders?

Mr. REED. We already have, Mr. Chairman.

Senator CANNON. What has happened as a result?

Mr. MILLER. The DOD has already taken action through the instructions that we have seen to encourage this to a very high degree. I know——

Senator CANNON. What do you mean to encourage it?

Have they issued a regulation that they will or will not?

Mr. MILLER. Yes, sir.

The only proviso, as I recall from reading this, is they do have certain operational situations where they could not let it impede the mission. But their basic rule is, they fly with transponders or they don't fly.

This is true, I know, on the west coast area. This is based on discussions with some of the pilots.

Senator PEARSON. Since you made reference to the fact that the great percentage of midair collisions in general aviation are at uncontrolled airports, have you made any recommendations or can any be made to increase the visibility through coloration or light systems of some sort?

I am forever being told where some traffic is and can't find it.

Mr. REED. We did, Mr. Chairman. One of our recommendations was for increased conspicuity.

The FAA conducted some tests that I believe proved inconclusive.

Mr. MILLER. Actually they preceded the period of time we are talking about here, say, 1968, 1969 to now. The test results showed that a given visibility marking would be of very limited value, if not at all perhaps, in a large percentage of the time the aircraft is operating.

Considering, the background of the terrain, the lighting, the clouds, you name it. What is good under one condition is not too good under the other.

I think it has also been shown through tests that when we talk about condenser discharge lighting, this is by far a better approach to gaining increased visual detection than any painting that may be there.

There are exceptions. For example, if you are operating up in Alaska, or a snow-covered terrain, there is no question about it, red tips and red tails are a big help.

As I recall the research reports, what you find under one condition does not necessarily do the job for you entirely. So, other methods have been looked at, particularly strobe lighting.

Senator CANNON. Senator Moss?

Senator MOSS. Thank you, Mr. Chairman.

Mr. Reed, you say the Safety Board concurs with the FAA that action on S. 2264 should be deferred, and then on the bottom of page 4 and the top of page 5, you talk about the collision avoidance equipment being tested by various companies, and you recommend that the testing of these systems be continued and expedited.

Now, that is my question. What do you mean by expedited?

Mr. REED. Well, we think there should be no delay, and that the timetable for the testing the FAA is conducting will be stepped up—we would urge that it be stepped up.

Senator MOSS. S. 2264 requires FAA to have a standard, a minimum standard by January 1, 1973, and that the systems be on board by 1975.

Now, do you want it deferred beyond that?

Mr. REED. Actually, as far as the timettable is concerned, the FAA is conducting these tests, and they are the only ones who would know how fast they can proceed.

We are anxious that these tests be conducted and concluded as swiftly as possible.

Senator MOSS. There has been a considerable amount of testing already done, but some manufacturers are asking for additional time while they test their systems.

How long are we going to wait for them?

Mr. REED. This is something I believe, Senator, the FAA would have to decide, because they have the responsibility in this area.

Our particular authority does not provide for research. So, we have to depend upon the FAA. If they say they need more time, they are in a better position to judge that than we are.

Senator MOSS. You also, in your recommendations, recommend the continued development of a pilot warning indicator that will be cost feasible to the general aviation pilot.

What amount do you have in mind there as cost feasible?

Mr. REED. I would say about $500 or less.

Senator MOSS. $500 or less?

Mr. REED. From what I have read and from the pilots I have talked with, yes sir.

Senator MOSS. Your report shows that the predominance of midair collisions occur between general aviation aircraft in the daytime, VFR weather, low altitudes, at or near uncontrolled airports; is that correct?

Mr. REED. That is correct.

Senator MOSS. But it seems to me that your recommendations go largely as to what should be done around controlled airports.

Mr. REED. Senator, we have attempted to develop recommendations that would cover the entire problem.

Actually, however, most of the near-misses occur near high-density airports. So, the problem is not isolated to one particular area. Our report definitiely pointed out that most of the collisions occurred near uncontrolled airports.

However, the one at Asheville, N.C., is an example of a midair collision at a low-density controlled airport.

I might point out that our last recommendation is not limited to air carriers. We meant it to apply to all users.

Senator Moss. If FAA said they could have a standard out by the first on January 1973, would that be satisfactory to you?

Mr. Reed. Yes, sir; we would be very pleased.

Senator Moss. Thank you.

Senator Cannon. Senator Spong?

Senator Spong. Thank you, Mr. Chairman.

Mr. Reed, I was not here when you began your testimony, but is part of your opposition to Senator Moss' bill based upon the fact that you believe 75 percent or more of the 25 recommendations are being acted upon?

Mr. Reed. Not necessarily, Senator Spong. We feel, and our General Counsel's office has indicated that the FAA does have sufficient statutory authority now to implement the use of the new devices, and it would not be necessary to have the bill enacted.

Senator Spong. This has been touched upon, but would you, for the record—not this morning, but for the record—would you review the 25 recommendations and delineate for the committee those on which you do not feel sufficient attention has yet been given?

Mr. Reed. Yes, Senator, we certainly will.

We have provided one, up to November 1, 1971.

We will be glad to update it and give you a more current report.

Senator Spong. Thank you.

On Senator Moss' bill, on page 2, paragraph No. 1, it calls that "a collision avoidance system shall be installed on any aircraft having a maximum certificated takeoff weight of 12,500 pounds or more."

Wouldn't all aircraft, regardless of weight, have to have some special equipment to make a collision avoidance system workable?

Mr. Reed. They are all part of the basic system, Senator, that we have to be concerned about.

The 12,500 pounds, as you know, is the kind of dividing line between the aircraft. As I understand it, the collision avoidance system, of course, would be more complicated, more sophisticated for the larger aircraft, but the smaller aircraft would have to have some devices to complement the entire arrangement.

Senator Spong. So, your answer to my question would be, yes?

Mr. Reed. Yes, sir.

Senator Spong. Thank you.

Thank you, Mr. Chairman.

Senator Cannon. Thank you very much.

The next witness is Mr. Kenneth M. Smith, Deputy Administrator, FAA.

STATEMENT OF HON. KENNETH M. SMITH, DEPUTY ADMINISTRATOR, FEDERAL AVIATION ADMINISTRATION, DEPARTMENT OF TRANSPORTATION; ACCOMPANIED BY GEN. GUS LUNDQUIST, ASSOCIATE ADMINISTRATOR FOR ENGINEERING AND DEVELOPMENT; DAVID ISRAEL, DIRECTOR OF THE OFFICE OF SYSTEMS ENGINEERING AND MANAGEMENT; WILLIAM M. FLENER, DIRECTOR OF AIR TRAFFIC SERVICE; AND ALLAN MARKHAM, OFFICE OF THE GENERAL COUNSEL

Mr. SMITH. Mr. Chairman and members of the committee: We appreciate the opportunity to appear here today to discuss airborne collision avoidance systems and S. 2264. With me today are: Gen. Gus Lundquist, Associate Administrator for Engineering and Development; David Israel, Director of the Office of Systems Engineering and Management; Bill Flener, who is the Director of Air Traffic Service, and Mr. Allan Markham of the Office of General Counsel.

The FAA is constantly and acutely aware of the ever-present threat of midair collisions. But we are also aware of the fact that the statistics clearly show those fatalities resulting from midair collisions are a relatively small percentage of the total aviation fatalities.

We have a chart here on the right-hand side. It is also an attachment to the statement. The midair collisions accounted for 3.7 percent of the total fatalities in 1970, for example. This tells us something about where the investment of resources and efforts will produce the greatest benefit and probably result in the greatest savings of lives. This is not to say, of course, that we should not take positive steps to improve safety in all areas, no matter how small a percentage of fatalities may be involved. But clearly priorities must be established and aggressively pursued. This we have done and this we are doing.

The FAA is firmly committed to the premise that the ground-based Air Traffic Control system is, and will be for the foreseeable future, the primary collision avoidance system for U.S. domestic aviation. This policy is founded on the necessity of closely coordinating improved safety with other requirements in air traffic management, namely, efficient use of the airspace and the expeditious movement of air traffic. None of these three major functions of the ATC system can be served to the exclusion of the others.

We do believe, however, that independent airborne collision avoidance systems (CAS) have potential value in expanding the collision avoidance capability and as a backup in the event of failures in the ground system.

Experience clearly indicates that the greatest threat of midair collisions occurs in terminal areas outside our ATC positive control airspace. As this committee is aware, one of the FAA's major research and development programs in recent years has been the upgrading and automation of the terminal and en route ATC facilities. Automated terminal control—ARTS III—has already been installed in 31 terminals, and will be installed in another 33 within the next year.

This we have shown on a schedule, exhibit B, which is now on the wall. I would like to ad lib just for a moment, if I may, Mr. Chairman. There has been some criticism leveled against the FAA with regard to our ability to manage programs. This is the most complex air traffic control system of its kind in the world today, and yet it is on schedule.

ARTS III will give us the potential capability to manage terminal air traffic with increased safety and efficiency.

There are other potential improvements in the ATC system undergoing development and evaluation. One of these is a new computer application currently being evaluated at Knoxville, Tenn. This system would initally provide warning to the controller and, in future versions, direct automatic advisories to participating aircraft of potential collision situations. Innovations such as this, in conjunction with ARTS III, offer the potential of even greater collision avoidance capability in the ATC system.

In addition, through rulemaking actions we are establishing Terminal Control Areas (TCA) at the nine busiest terminals in the Nation to extend the safety of ATC positive control. This concept requires that all aircraft operating within the terminal area—whether general aviation, air carrier, or military—be under positive control of ATC. The results thusfar of this program at the five terminals where TCA's have been established has been most gratifying. Here in Washington, for example, there were 15 hazardous incidents in 1969 compared to only one in the first 10 months after the local TCA was established. At all other terminals equipped with ARTS III we will provide expanded radar service which will provide positive separation for all participating aircraft. These TCA and ARTS III terminals account for approximately 85 percent of the annual passenger enplanements in the United States.

In concert with the establishment of the TCA's, we are lowering the floor of our en route positive control airspace to coincide with the ceiling of the TCA to permit an aircraft to operate between the en route airspace and the major terminals under continuos positive control.

As I noted earlier, our efforts to improve the collision avoidance capabilities of the ATC system do not indicate a lack of interest or effort to find workable CAS and pilot warning instrument (PWI) systems. The FAA has participated in the evaluation of all CAS and PWI systems developed to date which we are aware of. We have carefully reviewed the present prospects for implementation of these systems and I would like to briefly highlight our conclusions:

1. The time/frequency CAS is the only design that is essentially proven and ready for production.

2. The full-capability time/frequency CAS is quite expensive, about $50,000 per airborne unit, and therefore suitable only for air carrier and very limited general aviation use, which will protect only 3.7 percent of the civil aircraft fleet, and only from each other.

3. A limited-capability time/frequency CAS is being evaluated which may be available for approximately $2,500, still substantially too expensive to be practical for widespread general aviation use.

4. The maintainability of the time/frequency CAS has not yet been determined.

5. The full range of potential problems stemming from interaction of CAS and the ATC system in terminal areas is not yet fully known.

6. Because it is a cooperative system, virtually all aircraft will have to be equipped with the time/frequency CAS to provide significant protection.

7. The FAA supports the permanent allocation of the 1592.5 to 1622.5 MHz frequency band for primary use by an airborne CAS.

8. Although several PWI concepts have been tested, there is no system available at this time that merits mandatory implementation.

To summarize, although a functional CAS system has been developed, unresolved problems remain regarding high initial cost, maintainability, and potential interference with the ATC system. The search for an implementable CAS or PWI continues. In short, there is insufficient information at this time to select a specific CAS or PWI design for national implementation.

So that we can make such selection and provide the necessary ground facilities, procedures, and rulemaking at the earliest possible date, the FAA has augmented its current program to investigate fully all promising CAS and PWI concepts. We are continuing high priority efforts which respect to the time/frequency CAS to insure no time will be lost should that system ultimately be selected. The plan for this augmented program has been prepared in conjunction with the Department of Defense and NASA through the recently created Interdepartmental Group on Collision Avoidance and Pilot Warning and is being coordinated with user groups. The program contains the following main features:

1. Continue the system simulations to investigate and insure a compatibility of any airborne system with the ground-based air traffic control system.

2. Continue investigation, development, and testing of CAS systems which appear promising.

3. Consider the possibilities of implementing automatic VFR radar advisory services and other early exploitations of the NAS en route and ARTS ground systems, including en route and terminal area capabilities deriving from the Knoxville evaluation.

4. Speed up and augment all aspects of current research and development efforts in the PWI field. The objective of the augmented program will be the collection of necessary information and preparation of an initial status report concerning implementation possibilities by January 1, 1973.

There is a possibility that this last statement may be misunderstood, Mr. Chairman. We propose to have a status report ready by January 1 next year, not to have the solution in hand. That will depend upon the progress of the manufacturers.

The bill before this committee, S. 2264, would direct the Secretary of Transportation to prescribe regulations requiring aircraft with maximum certificated takeoff weight of 12,500 pounds or more to be equipped with a collision avoidance system and aircraft with a maximum certificated takeoff weight of less than 12,500 pounds to be equipped with a pilot warning indicator, by no later than January 1, 1973. The bill would also direct the Administrator of the Federal Aviation Administration to require public aircraft to be equipped with a CAS or PWI no later than January 1, 1975.

The Secretary and the Administrator have adequate statutory authority now to require any and all aircraft to be equipped with CAS or PWI and will not hesitate to exercise this authority when it is deemed appropriate. As I have noted, a number of technical, practical, and economic problems remain to be resolved before this authority can be effectively exercised. I, therefore, respectfully urge this committee to defer action on S. 2264 at this time. I hope that we will have the answers to enough of these questions by next year to determine whether changes to CAS or the ATC system—or both—will allow safe and effective utilization of an independent airborne CAS in conjunction with the ground-based ATC system.

Mr. Chairman, this concludes my statement. We shall be glad to answer any questions.

(The exhibits referred to follow:)

EXHIBIT A

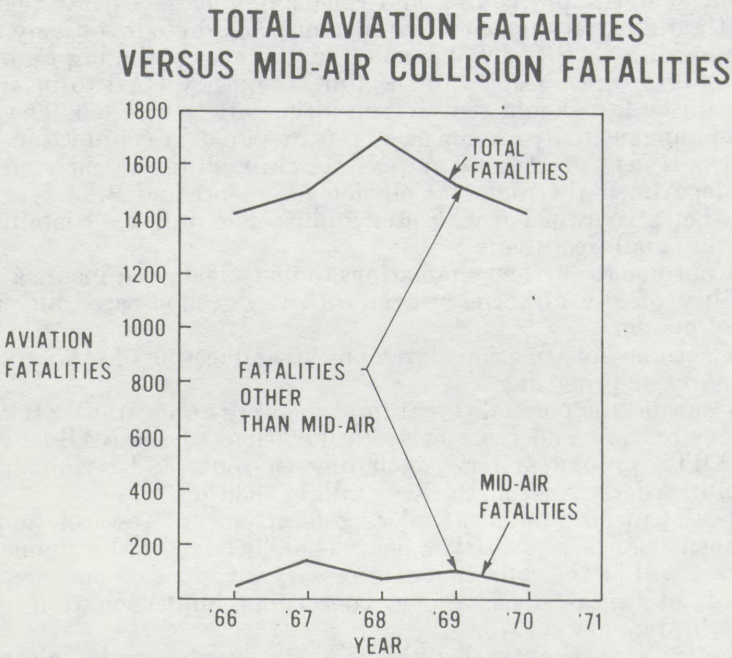


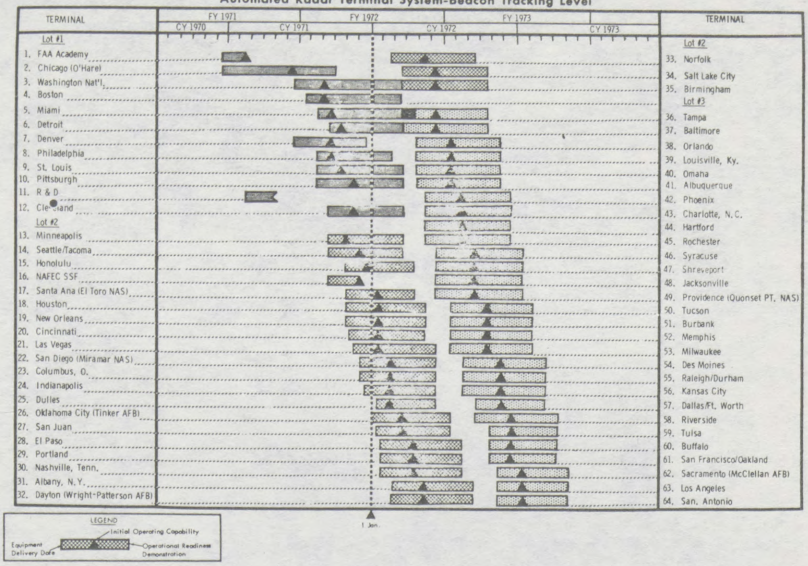
EXHIBIT B

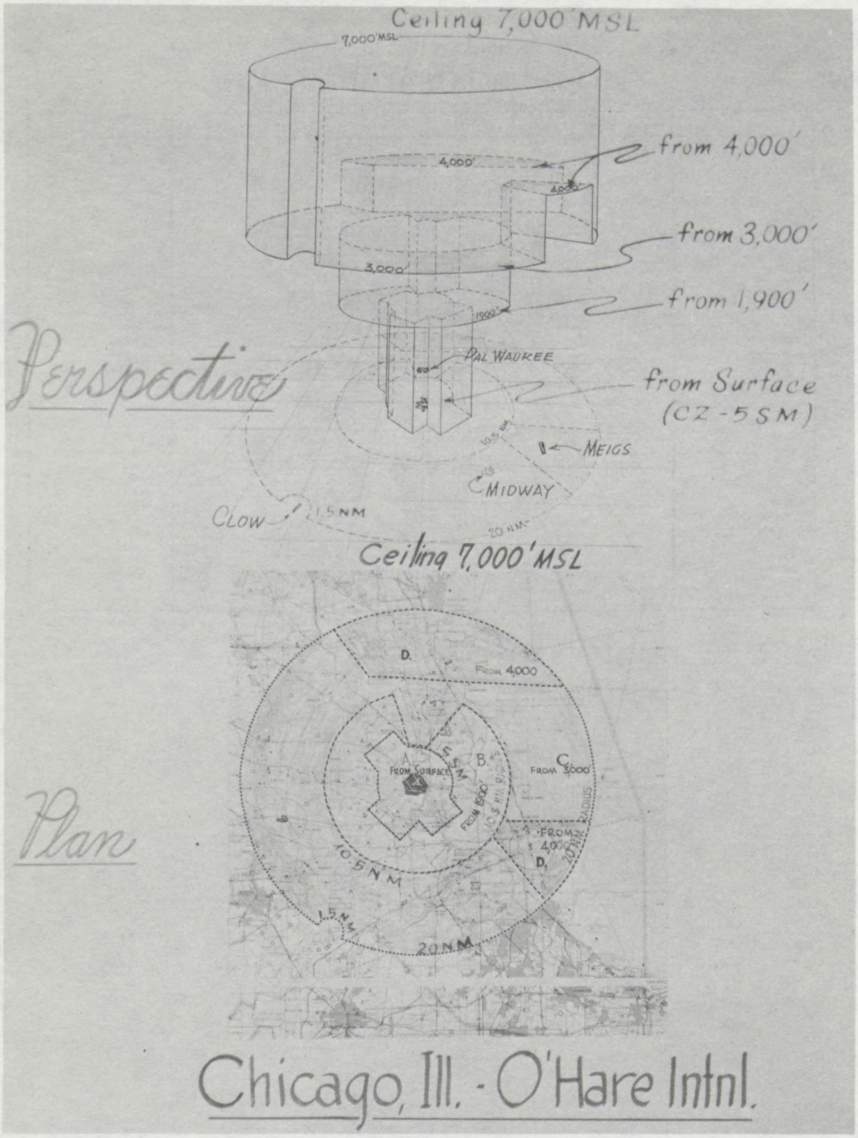
Department of Transportation

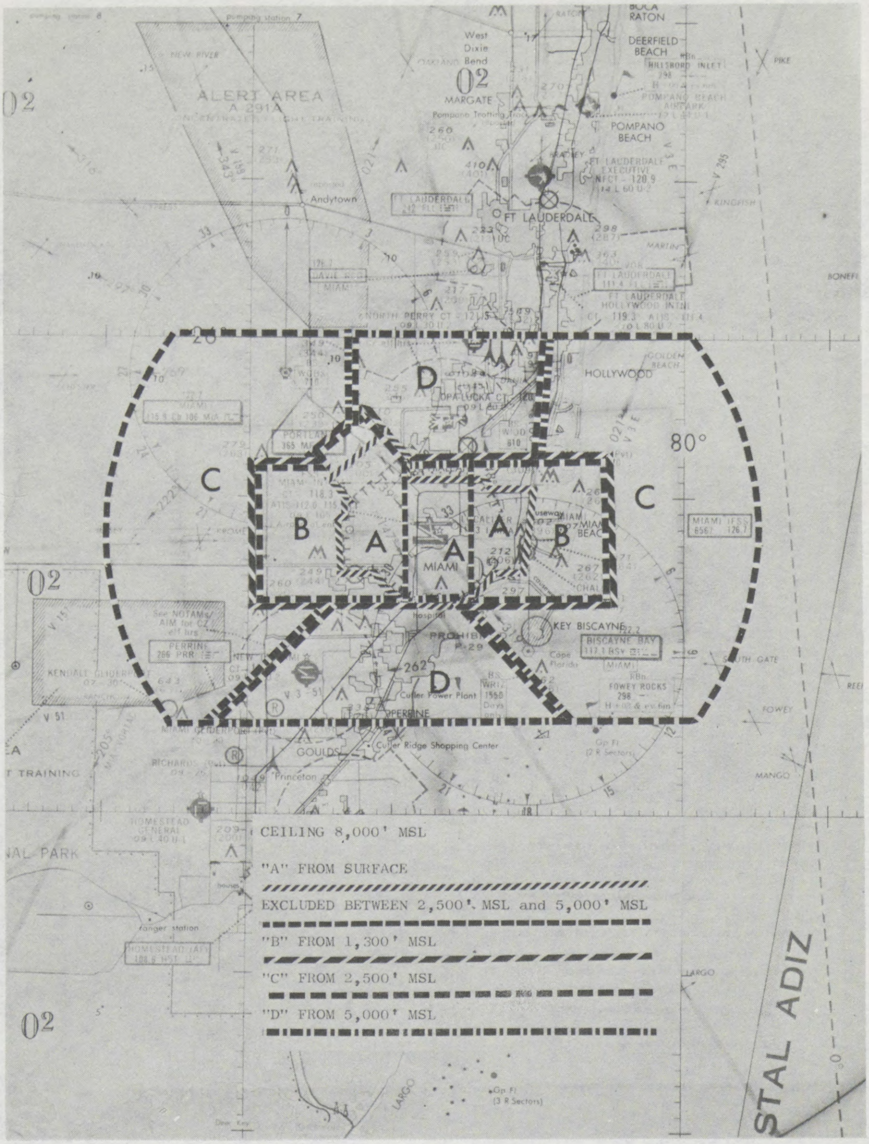
Federal Aviation Administration

NAS ARTS III SYSTEM IMPLEMENTATION SCHEDULE

Automated Radar Terminal System-Beacon Tracking Level




Ceiling 7,000' MSL
7,000' MSL
from 4,000'
4,000'
from 3,000'
3,000'
from 1,900'
1900'
Perspective
PAL WAUKEE
from Surface
(CZ - 5 SM)
10.5 NM
MEIGS
MIDWAY
CLOW
1.5 NM
20 NM
Ceiling 7,000' MSL
D.
FROM 4,000
A.
FROM SURFACE
5 SM
B.
FROM 1900
10.5 NM RADIUS
C.
FROM 3000
FROM 4000
D.
20 NM RADIUS
Plan
10.5 NM
1.5 NM
20 NM
Chicago, Ill. - O'Hare Intnl.


ALERT AREA
A 291A
MARGATE
POMPANO BEACH
FT LAUDERDALE
HOLLYWOOD
OPA LOCKA
MIAMI
KEY BISCAYNE
GOULDS
Princeton
Cutler Ridge Shopping Center
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C
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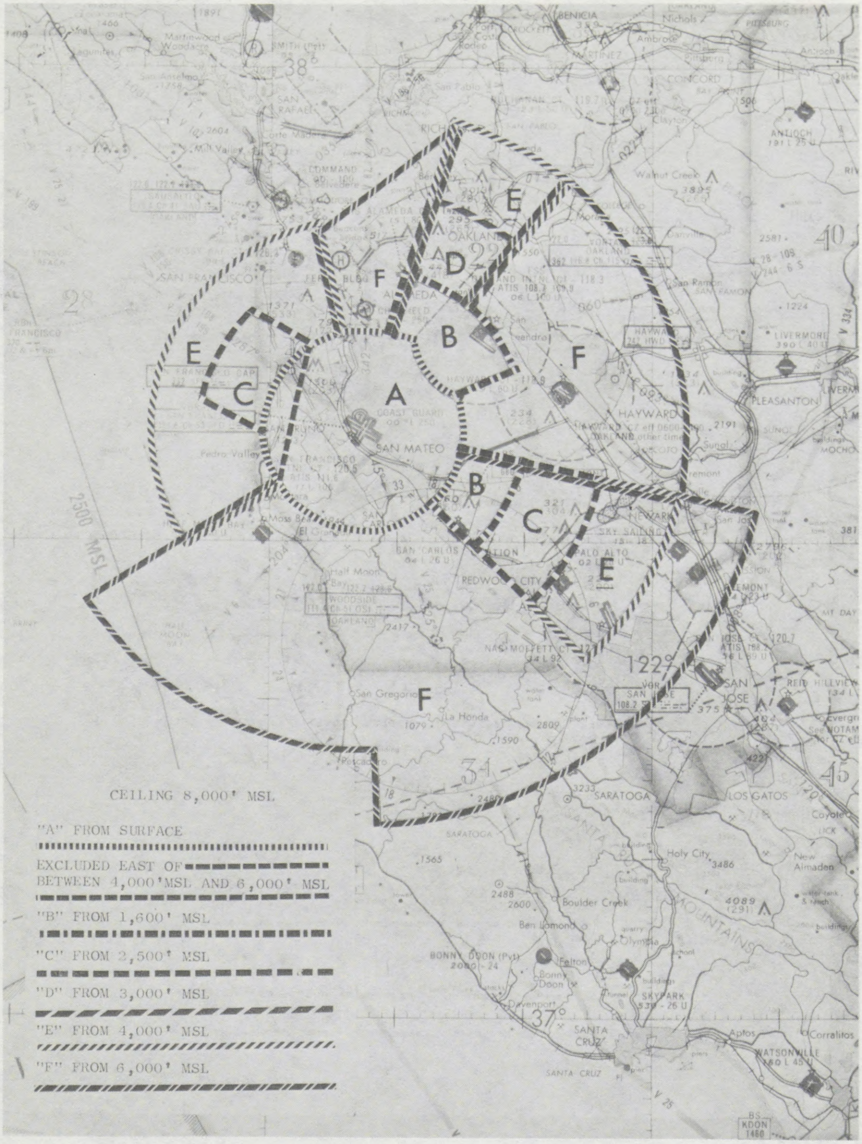
CEILING 8,000' MSL
"A" FROM SURFACE
EXCLUDED BETWEEN 2,500' MSL and 5,000' MSL
"B" FROM 1,300' MSL
"C" FROM 2,500' MSL
"D" FROM 5,000' MSL
STAL ADIZ


CEILING 8,000' MSL
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BETWEEN 4,000'MSL AND 6,000' MSL
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"D" FROM 3,000' MSL
"E" FROM 4,000' MSL
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A
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SAN MATEO
OAKLAND
HAYWARD
REDWOOD CITY
SAN CARLOS
PALO ALTO
SAN FRANCISCO
SAN JOSE
SARATOGA
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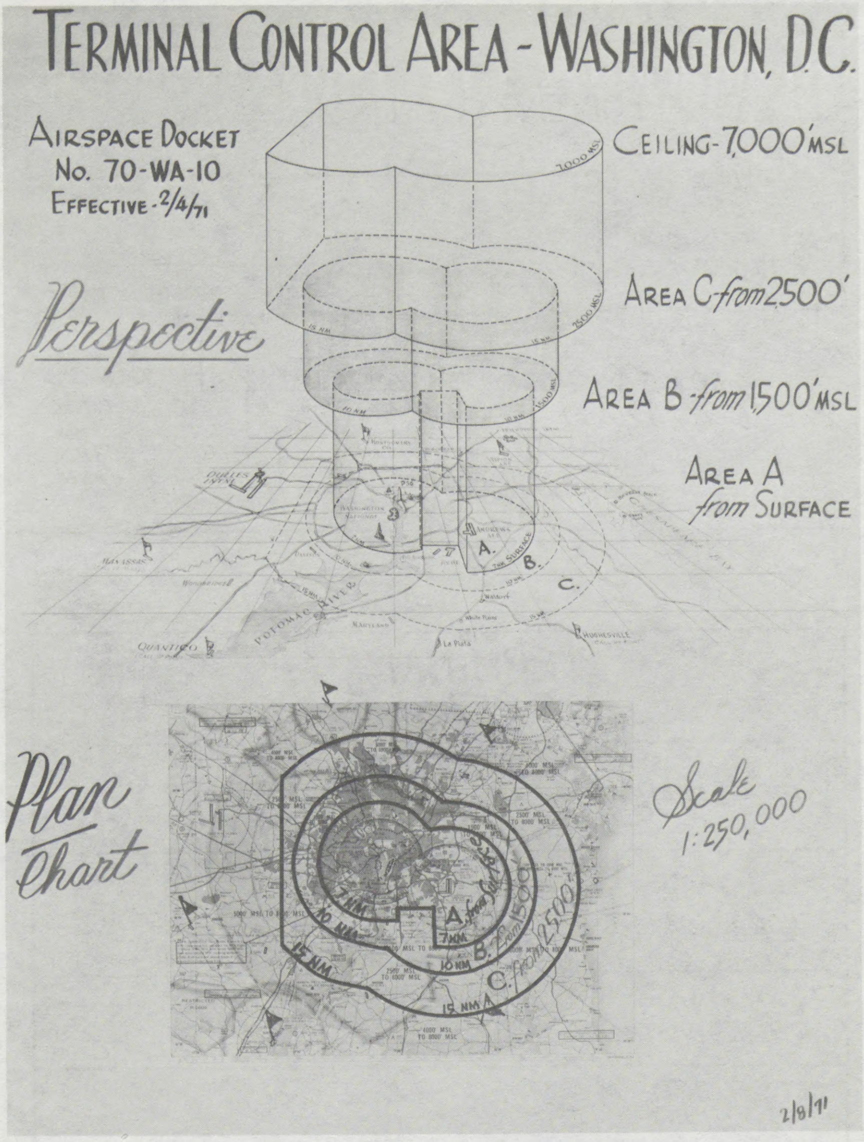
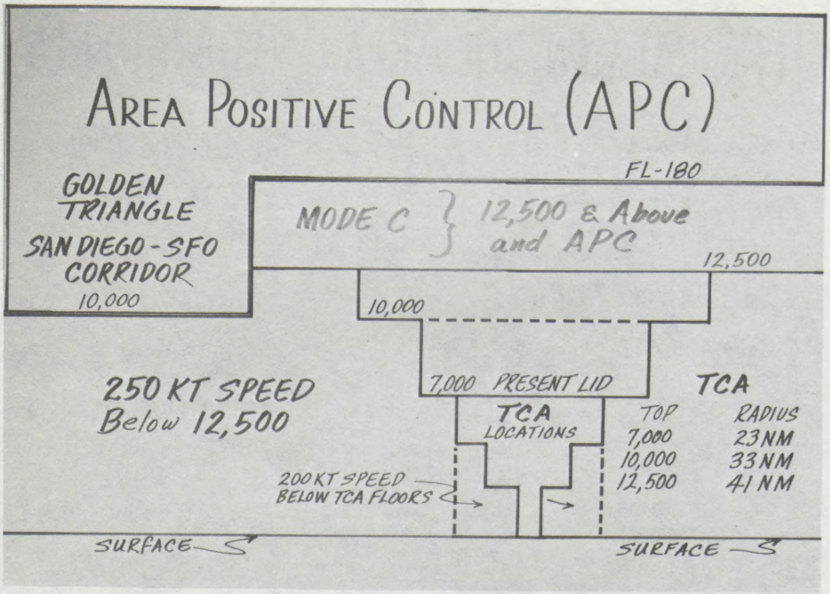
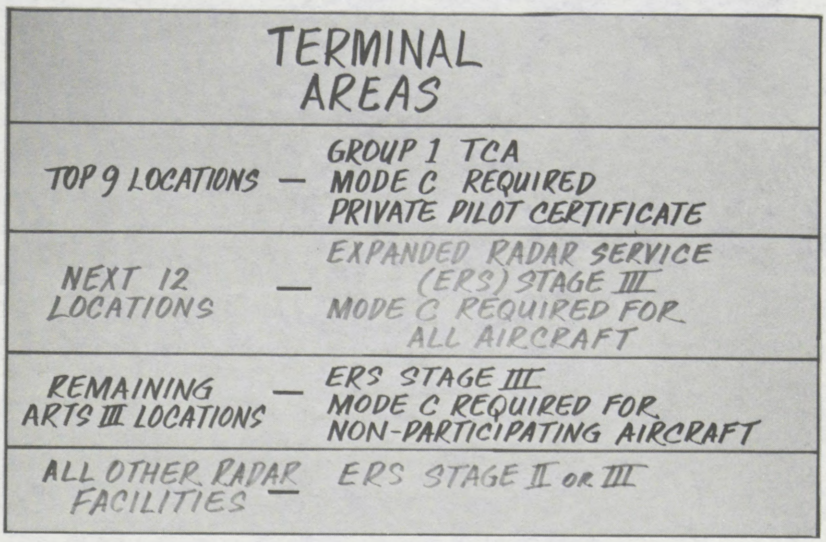
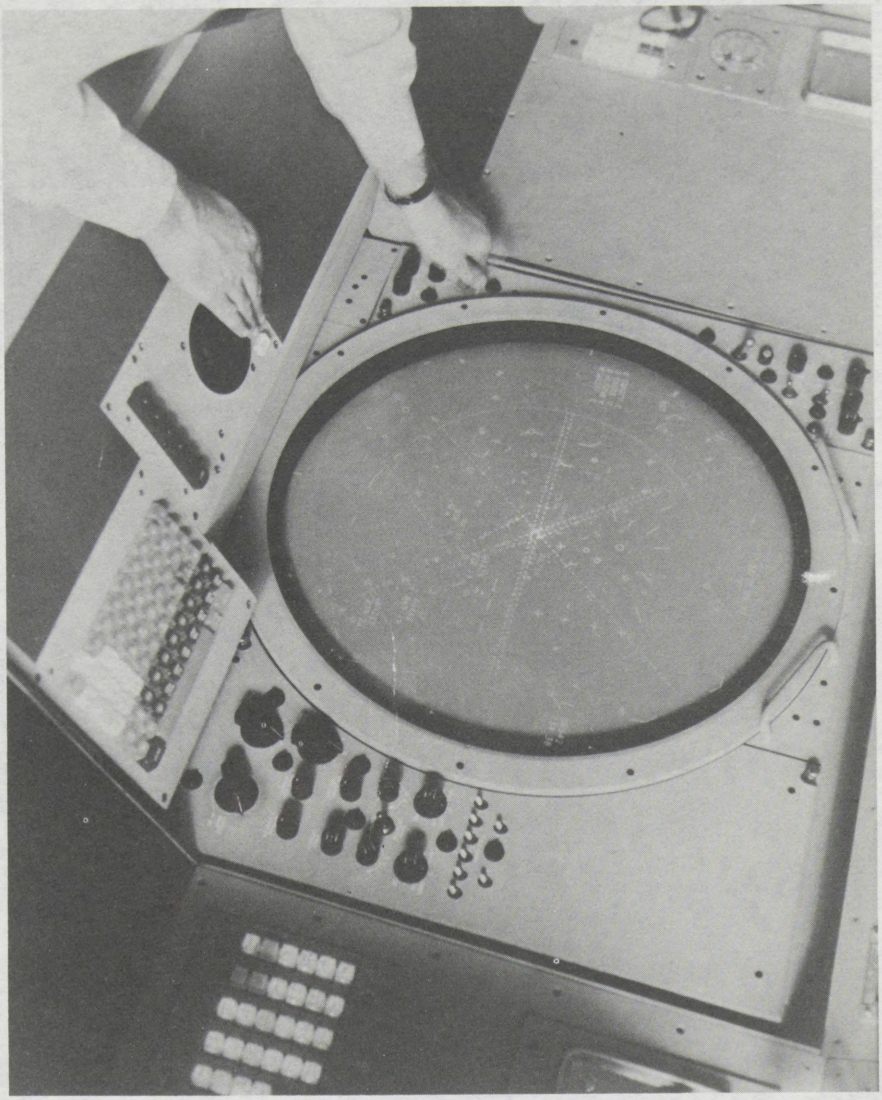

TERMINAL CONTROL AREA - WASHINGTON, D.C.
AIRSPACE DOCKET
No. 70-WA-10
EFFECTIVE-2/4/71
CEILING-7,000'MSL
AREA C-from 2500'
AREA B-from 1,500'MSL
AREA A
from SURFACE
Perspective
A.
B.
C.
POTOMAC RIVER
QUANTICO
HUGHESVILLE
Plan
Chart
Scale
1:250,000
7 NM
10 NM
15 NM
A. from Surface
B. from 1500
C. from 2500
2/8/71

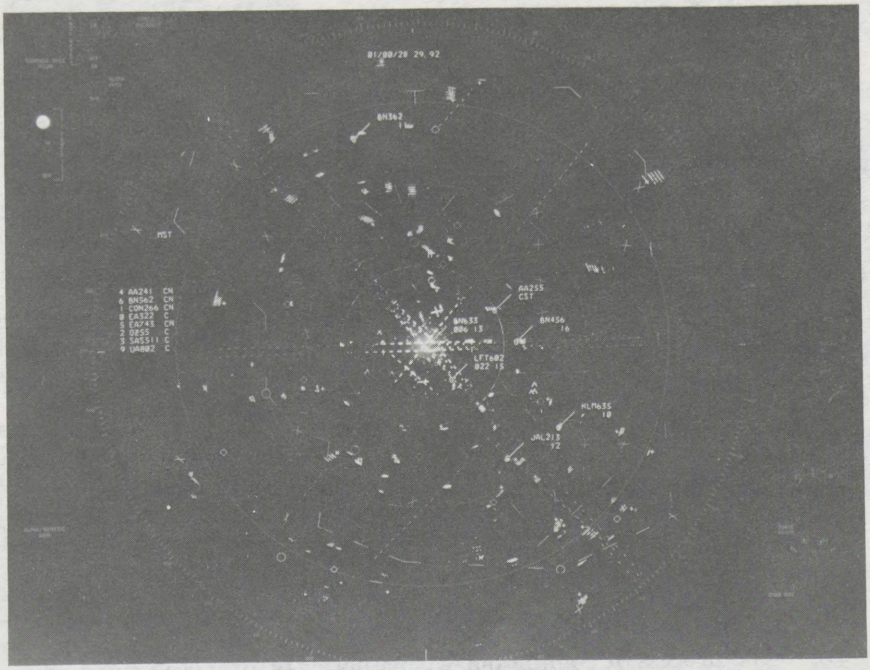


AREA POSITIVE CONTROL (APC)
FL-180
GOLDEN TRIANGLE
SAN DIEGO-SFO CORRIDOR
10,000
MODE C } 12,500 & Above and APC
12,500
10,000
250 KT SPEED Below 12,500
7,000 PRESENT LID
TCA LOCATIONS
TCA
TOP 7,000 10,000 12,500
RADIUS 23NM 33NM 41NM
200 KT SPEED BELOW TCA FLOORS
SURFACE
SURFACE



TERMINAL AREAS
TOP 9 LOCATIONS — GROUP 1 TCA MODE C REQUIRED PRIVATE PILOT CERTIFICATE
NEXT 12 LOCATIONS — EXPANDED RADAR SERVICE (ERS) STAGE III MODE C REQUIRED FOR ALL AIRCRAFT
REMAINING ARTS III LOCATIONS — ERS STAGE III MODE C REQUIRED FOR NON-PARTICIPATING AIRCRAFT
ALL OTHER RADAR FACILITIES — ERS STAGE II OR III





Senator CANNON. Thank you very much, Mr. Smith. The Senate is having a vote on the floor now, and I am advised that there will be a series of them, probably four or five, to follow in sequence. Therefore, I am going to recess the hearings at this time until 2 o'clock this afternoon, and hopefully we will be able to resume at that time.

(Whereupon, at 11:50 a.m., the subcommittee was recessed, to reconvene at 2 p.m., this same day.)

AFTERNOON SESSION

Senator CANNON. Senator Moss.

Senator MOSS. Mr. Chairman, it has been brought to my attention that some copies of S. 2264 have been passed out which have an erroneous line in them on line 3, page 2. That is a misprint, and there is a second print—what they call a star print—which has the correct line in it. The difference concerns the weight divisions between the collision avoidance system and the pilot warning indicator. That breaking line, as the witnesses have testified, is 12,500 pounds.

The one that says 2,500 pounds is in error. Throw that one away if you happen to have one of those.

Thank you, Mr. Chairman.

Senator CANNON. Mr. Smith, you testified that the air traffic control system is the primary collision avoidance system for the U.S. domestic aviation system. And yet the great majority of aircraft operations in this system operate without positive control from the air traffic control system. Given this situation at the present, is the ATC system an adequate safeguard against midair collisions?

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Mr. SMITH. It is an adequate system. I think it can be improved upon.

Senator CANNON. How can the present air traffic control system provide positive safeguards against collisions when the great majority of operations are conducted under VFR and outside the control of the air traffic control system?

Mr. SMITH. In those areas where we have heavy air commerce, general aviation activity as well as scheduled air carrier service, we have extensive air traffic control services, as you know. There are many parts of the country that are not covered at all—by radar, by towers, by voice communication.

These latter areas are not under positive control and the air traffic control system does not serve these areas; we must rely on rules and regulations which require aircraft to fly at certain altitudes on certain headings to maintain separation in these areas.

Senator CANNON. You have testified that ARTS III, "Will give us the potential capability to manage terminal air traffic with increased safety and efficiency." Isn't it a fact that the majority of terminal airspace users do not have aircraft equipped with the mode C transponders so that they may be identified as to altitude and aircraft and thereby be continually monitored by the ARTS system?

Mr. SMITH. Approximately 85 percent of today's air carriers are equipped with the mode C transponder. A great number of the executive aviation aircraft are equipped with the mode C transponder. We are in the process of coming out with a notice of proposed rulemaking within the next 10 or 12 days which will establish our requirements for the mode C transponders in the positive control areas.

Senator CANNON. What will that requirement amount to?

Mr. SMITH. It will require aircraft flying under positive control—that is, above 18,000 feet or in some areas above 10,000 feet—to be equipped with the mode C transponder.

Senator CANNON. Your statement indicates that the FAA is "establishing terminal control areas at the nine busiest terminals in the Nation to extend the safety of ATC positive control." However, in 1970 the agency announced proposed rules which would create TCA's at the 22 large hubs in the U.S. and said further that TCA's would ultimately be established at more than 90 other terminals having terminal radar service.

Has the FAA abandoned the concept of requiring terminal control areas at all of the Nation's busiest hubs?

Mr. SMITH. No, Mr. Chairman; we have not abandoned the idea. We have gone slower than perhaps some people would like to have us go. We had a major demonstration in Boston last year to evaluate the corridor concept with the TCA concept. I think it was proven at that point—and further through experience in the five TCA's now that exist—that TCA's are practical, they are workable, they are capable of being shaped and formed to allow smaller airports to operate in compatible fashion with them.

We are in the process now of establishing four more which will bring us to a total of nine. This is in phase 1. In phase 2 we will establish additional TCA's, another 12, and we will continue to increase the number as increased traffic requires.

Senator CANNON. Why is this lag? It was 2 years ago you proposed the establishment of 22. You only have five now. Now you say you are going to have four more and go up to nine.

Mr. SMITH. Well, we had considerable opposition to the TCA's, massive opposition. And in our consultative process we wanted first to see if the system would work before we imposed it upon the users of the airspace.

It has worked, it has become successful and many of the people that originally had great doubts about it now are accepting it.

Here in Washington we had the original TCA which was not well designed. We had to go back and redesign it. We learned a lesson from that. We are proceeding as rapidly as we think we should, adding the four and then 12 more later which will bring us up to the 21.

Senator CANNON. Do you think that establishment of TCA's at major terminal areas will materially reduce the risk of midair collisions? Would this be better than an airborne CAS system?

Mr. SMITH. I feel that establishing TCA's at major terminals will very definitely reduce the risk of midair collision. It already has. We have examples of that right now. In 1969, for example, we had nine hazardous incidents as I mentioned in my opening statement. In the first 10 months of 1970 we had only one case. Here is proof positive.

As to whether or not it takes the place of a CAS yet to be developed, yet to be required, I cannot say, because I do not know yet what that CAS will be like.

Senator CANNON. In the summer of 1971 a Continental Air Lines B–707 and a light plane collided near the Los Angeles International Airport. Fortunately the jetliner was able to complete its approach and landing without any fatalities. About a month later the FAA's terminal control area airspace plan went into affect in the Los Angeles area. Had that TCA been in effect at the time of the accident, would that accident have been avoided?

Mr. SMITH. I will have to ask Mr. Bill Flener, director of Air Traffic, if he recalls the circumstances of that.

Mr. FLENER. Mr. Chairman, as I recall that particular circumstance, the altitude at which the Continental 707 struck the light aircraft was below the base of the terminal Control Area as it was subsequently established.

Senator CANNON. Which was?

Mr. FLENER. I have a chart here. I could check it. I have forgotten the exact altitude. But it was about 500 to 1,000 feet below the TCA base. Subsequent to that when we went into the TCA and established the standards, the requirement was placed on all jet aircraft that they remain at higher altitudes and come into the TCA, in this case over San Bernardino, at a higher altitude than that particular aircraft was. This was associated with our "keep 'em high" program, which is primarily intended for just that purpose, to keep them as high as possible as long as possible. Coupling the two factors, the two aircraft would not have been in the same place at that time.

Mr. SMITH. The answer is yes; had the TCA been in effect, the two aircraft would have been separated or, if not separated, the small aircraft would have been under positive control. We think that would have avoided the accident.

Senator CANNON. Your statement says, "At all other terminals equipped with ARTS III we will provide expanded radar service which will provide positive separation for all participating aircraft."

What does the term "all participating aircraft" mean?

Mr. SMITH. Aircraft that come into that particular system, whether they are under positive control or wish to volunteer to receive the expanded radar service, assistance from the tower, et cetera.

Senator CANNON. Can this service be provided in an environment with VFR aircraft operating without transponders?

Mr. SMITH. Well, we get into the question of primary target return. Non-beacon aircraft can be detected by radar. We plan to modify our ATC radar to receive this "primary return". We would prefer to have transponder-equipped aircraft. I am happy to report that many general aviation aircraft are being equipped with transponders.

Senator CANNON. To what extent would a universal requirement for radar beacon transponders for aircraft operating in controlled areas reduce the danger of midair collision?

Mr. SMITH. We think it will have a tremendous effect to have aircraft under positive control and equipped with transponders. In certain areas we are also considering, the requirement for mode C capability which will further enhance the safety of the system. We believe if aircraft were properly identified, and we have proper radar coverage, that we can guarantee an almost perfect system.

Senator CANNON. Why hasn't the agency so far not established a requirement for that type of equipment on all aircraft operated in controlled airspace?

Mr. SMITH. Mr. Chairman, there are a number of reasons for not yet requiring this. They relate first of all to the capability of the air traffic control system. For many years the agency has been very shy on funds, shy on radar equipments that can read mode C, for example, or even basic transponder signals.

In addition to that, the industry has in the last couple of years, because of the greater demand for aircraft transponders, come along with better transponders at a lower unit price, which makes them more available to the general aviation user.

It has been a combination of these factors.

Senator CANNON. Testimony during a public hearing regarding the collision of a DC–9 and a light plane near Indianapolis in 1969 indicated that the light plane was never seen on the surveillance radar being manned by an FAA controller. How will the air traffic control system absent transponder requirements or positive control of all aircraft prevent a midair collision such as that one that occurred?

Mr. SMITH. There is, and I think there will continue to be for many years to come, large areas throughout this country where traffic is so light that it is not economically feasible to provide complete radar coverage. In this particular collision, had the smaller aircraft been equipped with the transponder, there is a very good possibility that accident would not have occured.

Senator CANNON. Isn't it a fact that in at least two recent midair collisions involving light aircraft and airliners or military aircraft and airliners, these aircraft did not show up on the controller's display and the controller therefore did not have the opportunity to alert the transport aircraft of uncontrolled traffic which posed the threat of collision?

Mr. SMITH. Yes; if you want to take the example in the Los Angeles basin of the military aircraft, as Mr. Reed testified, it is our understanding the transponder was not functioning at the time. But in addition to that, there was a terrain problem in that the aircraft was coming across the mountain range in the basin. We were not getting a primary return from the target. Since that time we have had considerable discussions with the military, with the Navy, and they have been most cooperative in requiring a functioning transponder for dispatch of aircraft.

Senator CANNON. In 1968 the National Transportation Safety Board recommended to the FAA that "climb and descent corridors" be established at high-density airports to separate high- and low-performance aircraft. Since that time the Aircraft Owners and Pilots Association and the Air Line Pilots Association have made similar recommendations. What has the FAA done in response to these suggestions?

Mr. SMITH. As a direct result of these recommendations one of the actions we have taken was to conduct for all to see a Boston corridor TCA type of experiment, where we piped live traffic into an experimental room equipped with a large screen display. Then we artifically moved targets into and out of these corridors, and we had four different configurations, one of which was a TCA type.

It is our feeling that most of industry has accepted the TCA as being in effect an infinite number of corridors approaching and departing from a particular terminal.

Mr. Chairman, if the committee has time, we are prepared to go in a little more detail with a view graph of the typical TCA if you would like to see it.

Senator CANNON. I think it would be helpful.

While they are getting set up there, what steps has the agency taken to implement a proposed rule of 1971 which would require a standard traffic pattern at all the U.S. airports?

Mr. SMITH. We are in the rulemaking process right now, Mr. Chairman, on this subject, where we have standard approach procedures, standard altitudes above ground, and so forth. We think this is a very valuable asset to air traffic control, and we are proceeding to implement that now.

Senator CANNON. The Air Line Pilots Association has testified that it has requested the agency to require all aircraft operating in controlled airspace to be equipped with xenon strobe lights as an added protection against midair collision hazards. Why has the agency not adopted the requirement for strobe lighting?

Mr. SMITH. I can understand the airline pilots' interest in the subject. We think it would be an adjunct to air safety, particularly at nighttime, but there are many hundreds of thousands of pilots that disagree with the Air Line Pilots Association on this point.

We are trying to identify better means of aircraft identification at night as well as in the daytime. We are working on that now. We do not feel we are at a point where we can suggest that xenon lighting is the answer.

Senator CANNON. You may proceed.

Mr. SMITH. I would like Mr. Flener to identify the TCA we have here on the screen.

Mr. FLENER. Mr. Chairman, this is the local terminal control airplane for Washington/Andrews.

As Mr. Smith stated, our first design was much too complicated and within 24 hours after implementation we shut it down, went back to the drawing board, and simplified the design. This configuration has been in effect now for about a year and a half.

In the previous year prior to going into this particular design, we had some 15 near midair collision reports in the Washington/Andrews area. Subsequent to placing this into operation, we have had one near midair collision in this area.

You can see the various shades of color around the concentric rings, the center ring being from the surface up to 7,000, and each of the other rings out step up 1,500 and 2,500, 3,000, up to 7,000 at the top within a 20-mile radius of the center of Washington National Airport and Andrews.

The reason for encompassing the entire area rather than a single quarter is to allow the traffic controllers to maneuver the aircraft about, feed them into the runway, and set them up in sequence by vectoring.

The difficulty we had in the Boston test was that the aircraft were required to remain in trail, when they were arriving or departing. With the performance incompatibility of various aircraft coming into this system, even if they were all jets, it delayed and slowed the system down very dramatically, whereas in this particular type of circumstance, they can clear an aircraft off, turn them, keep them in positive control, clear another departure out and provide the proper separation.

This next view is of the Chicago TCA. It is the same thing, concentric rings, stacking up to 7,000, with the top ring being a 20-mile radius of the center of the airport.

This next one is a proposed TCA plan for Miami. The first five that were implemented were Chicago, Washington, New York, Los Angeles, and Atlanta. The remaining four, of which this is one, are Miami, Boston, Fort Worth/Dallas, and San Francisco.

As you can see, in some aspects the Miami TCA does resemble a corridor since it is an east-west flow.

The area you see marked "C" comes up to 2,500 and the top is at 7,000 feet. We try to cut and fit the particular TCA pattern to suit the particular airport.

This next one is quite a bit different in style. This is the San Francisco TCA. Again it is to try to cut and fit in that particular area over the Oakland Airport, N.A.S. Alameda, and San Francisco International itself with the outer edges, as you see, down at the left side covering the oceanic route to Honolulu, providing separation to all aircraft in that area.

The minimum requirements for flight in these TCA's are a private pilot certificate, two-way radio, VOR or TACAN receiver, and a transponder.

The corridor that Ken has pointed out there is a step up from the surface proceeding out, each one of the particular areas going up 500 to 1,000 feet until it reaches the base of the outer ring, which in this case would be 3,000 feet.

In effect, within the TCA we provide a corridor of the main flows to and from the major instrument runway, but the very fact that we have the outer concentric areas gives us the flexibility to move traffic out as we clear them up into the corridors and out into those areas. That is the big advantage of an infinite number of 360 different corridor radiating out from the airport.

Senator CANNON. Your statement indicates that the FAA "has participated in the evaluation of all CAS and PWI systems developed to date which we are aware of."

What initiative or leadership has been exercised by the FAA toward the development of airborne collision avoidance systems?

Mr. SMITH. Mr. Chairman, we have considerable knowledge on the collision avoidance and PWI systems that have been brought to our attention. I think we have a complete inventory on them.

We have programed substantial sums to continue our research and development.

Mr. Lundquist and Mr. Israel have personnally visited various locations where they have flown the McDonnell-Douglas, RCA, and Minneapolis-Honeywell, and so forth.

For fiscal 1972 we have programed approximately $7½ million for further research and development and flight investigations, including military aircraft. This in conjunction with the Department of Defense and with NASA.

Mr. Israel is chairman of the committee that has been established, an interdepartmental committee with DOD and with NASA. This is evidence in terms of dollars and in terms of visits of our continued interest in development of a CAS system.

Senator CANNON. Have you just been principally evaluating systems that have been developed by other people, or do you have some development contracts out or what is the situation?

Mr. SMITH. We have been evaluating various devices that private industry has come up with. We have been examining developments that are spin-offs from military requirements where hardware has been developed.

The Knoxville experiment, for example, is a spin-off from a military contract which has the computing capability with a parallel array to give us collision avoidance application for targets in the ARTS II system.

We really haven't developed any collision avoidance system on our own, nor do I think that it is the FAA's mission to do so.

In our opinion, industry will solve this problem, and we will evaluate what they have presented.

Senator CANNON. Now, the systems that were described to us in our hearing in December, have you flight tested those?

Mr. SMITH. Yes; I would like to ask General Lundquist to report on the flight test evaluation that he and his people have come up with.

Mr. LUNDQUIST. Mr. Chairman, I have participated with other officials from FAA in the test of the RCA SECANT system at the Naval Air Development Center at Philadelphia.

We also witnessed and had briefings and flew the Minneapolis-Honeywell system at Fort Belvoir which was developed by the Army.

We had people taking part in the United Air Lines experiment on the west coast where they were evaluating both the full ATA collision avoidance system, plus the Micro-CAS, which was installed in their flying club aircraft.

Further, this Saturday I will be flight testing a Bendix bearing measurement device which will be applicable to the proximity warning instrument equipment. We are keeping tabs of other developments in this area.

We are sponsoring a PWI effort at the transportation systems center, which is basically the xenon strobe light, including a silicon detector.

But we have an open mind. We would like to evaluate all the possible equipments that are available and we hope to come up with a best choice sometime in the next year or two.

Senator CANNON. Does the relatively less complex nonsynchronous approach used by the SECANT system offer a realistic alternative to the more expensive and more complex time frequency system which you say is "essentially" proven?

Mr. SMITH. We would prefer not answering that right now, because we don't have enough technical background in these areas. We understand that one is expandable to greater capability; another system, cost is a factor.

We think that this further development can bring the cost down. Certainly we have seen this reduction in the last 6 months since we testified before the House.

It is difficult to answer that question at this time with as little knowledge as we have.

Senator CANNON. What are the latest cost figures that you have been given?

Mr. SMITH. Mr. Chairman, I don't believe that we have anything in the way of firm numbers. We think that $50,000 is still the price for the more complex, more complete air carrier system, $2,500 for the Micro-CAS.

We have heard some numbers that have only been verbal, at least to my knowledge, in terms of $1,500 as a ceiling price from McDonnell Douglas, for example, for the small CAS. That excludes retail profit. When it gets to the retail of that item with the usual 40- or 50-percent markup, I think that will increase the price.

So I am confused about the current pricing.

Senator CANNON. And has the agency adequately determined whether CAS would interfere with the primary ATC system and impose hazards of its own because of its independence of the system?

Mr. SMITH. No, sir; we have not yet determined that. We have conducted one particular series of simulator runs at NAFEC where we were considering at that time the problem of two air carrier aircraft with collision avoidance equipment. That is the first step. We found some difficulties in this particular system utilization, but they are not insurmountable.

The real difficulty will come with a mix of small aircraft with Micro-CAS, some without, as well as air carriers which will be equipped. We will have to continue until this simulation we have comes up with a firm answer.

Senator CANNON. Last year, you told the NTSB that you would have your analysis completed by the end of calendar 1971.

Mr. SMITH. I went back into the record on that point, Mr. Chairman, and we indicated that we would complete the simulation of the two air carriers by 1971, which we did. That was not the full simulation including that which I have just mentioned, including general aviation aircraft equipped and nonequipped. That was the testimony before the House committee at that time.

Senator CANNON. Do you think that it is going to be possible for you to attempt to arrive at some type of a national standard for an airborne CAS system relatively soon?

Mr. SMITH. If this is the way to go. I hope we can do it soon, but it will depend upon answers which we haven't received, basic information, nor have we had a chance to evaluate some of the facts that have been submitted to us.

I don't know, for example, and I cannot be reassured by our technical people, that we have in fact a failsafe series of systems being proposed, that we have a reliable system, or if it has to be a dispatch item. I don't know enough about the ground stations, either the number of ground stations or the degree of reliability we must expect to build into them.

There are these questions that have to be answered before we can give you a definite date.

All I have said in my opening statement is we will by the first of next year tell you everything we have developed to that point in time, and as a result of the hearings, Mr. Chairman, we have certainly stepped up our development interest in this program.

Senator CANNON. When could Congress reasonably expect the FAA to designate one or another CAS concept as the official U.S. standard so that manufacturers and industry could begin to design, construct, and sell the aircraft hardware?

Mr. SMITH. I can't answer that question, Mr. Chairman. I just can't until we know more about what equipments are available and what they will do versus what we are hearing now in terms of proposed capabilities.

Senator CANNON. Would it be helpful if Congress established a deadline, either legislatively or otherwise, by which a decision would have to be reached?

Mr. SMITH. No, sir, it would not. We have within our authority now, as granted by Congress, authority to impose the requirement of the collision avoidance or proximity warning system.

Senator CANNON. In April, ICAO is meeting to discuss, among other things, airborne collision avoidance concepts and systems.

What will be the U.S. position on this subject at that time?

Mr. SMITH. Identical to this one. We have already discussed this with our international representatives.

Senator CANNON. The FAA has been quoted as saying that if the time frequency CAS was adopted as the U.S. standard, that 65 ground synchronization stations would be required. However, RCA tells us informally that one station will have to be located at each 200-mile interval throughout the country, thus requiring hundreds of ground stations.

What will be the actual requirement?

Mr. SMITH. Here again we need another answer. It depends upon the altitude at which we want collision avoidance to function.

If it is above 20,000 feet, obviously we can lessen the number of stations because it is a line if sight communication method.

We don't have the answers to these questions. I have heard the number of 37 ground stations, which would not cover enough of this country. This again is one of the questions that we must answer as well as the cost of the ground station.

Senator CANNON. We are in the middle of a vote, so we will recess momentarily.

Senator Moss will be back very shortly, and we will resume then while I am gone.

(Recess.)

Senator Moss (presiding). The hearing will come to order.

The Chairman has suggested that I go on with a few questions that I have, and he will be back as soon as he has cast his vote on the floor.

Mr. Smith, when we talk about evaluating the competing collision avoidance systems and the pilot warning systems, is not the basic question what criteria or model we are going to have? Does the FAA have a model with regard to the specification and criteria for the collision avoidance system?

Mr. SMITH. Yes, Mr. Chairman. We have separation standards that are required, we have various in-trail separation and altitude separation for en route end terminal areas. These are well known and well established.

Senator Moss. Yes, but what about the model for the system.

Mr. SMITH. I might indicate that many of the collision avoidance and PWI systems that have been brought to us have been developed by various users of the National Airspace System, the electronic industries, and the Department of Defense. Through these efforts we have established requirements, let's say in committee action, but the complete acceptance of these by the FAA is yet to be determined.

Senator Moss. When the FAA speaks of a flyoff of competing systems, what more should be demonstrated than was done by the ATA Baltimore tests or the United Air Lines San Francisco demonstration on February 15? In other words, what is the FAA's criteria used to justify it?

Mr. SMITH. A great number of things will have to be determined before we could impose any kind of a specific system at this time on the users of the airspace. For example, we do not yet know how many ground stations would be required for the time frequency system. We do not know yet how the system will interact with other aircraft equipped with a different type of CAS, a small or micro CAS, or with other aircraft that are not equipped. I am not certain in my own mind what happens when a black box in an aircraft gives a command to a pilot that is contrary to the instructions given to him by air traffic control.

Many of my people assure me that the control maneuvers, the directions indicated would be compatible with the system. This yet has to be demonstrated to my satisfaction and must be before we proceed.

Senator Moss. What specific steps is FAA taking to provide a satisfactory anticollision device for general aviation?

Mr. SMITH. Well, here again, Senator, the basic system of air traffic control, the rules and regulations that have been established relating to flight altitudes, those that are being put into effect for smaller and uncontrolled terminals, and TCA's are all methods that we are employing to minimize the risk of collision.

Senator Moss. In your view, what is the appropriate timeframe for requiring CAS installation? We understand from previous witnesses it is well within the state of the art.

Mr. SMITH. I don't have any particular timeframe at this point to establish CAS as the augmented system for air traffic control collision avoidance. I am not sure this is the right way to go. I think there are other developments which we have been working on as well. Those, for example, at Knoxville, Tenn. as part of the ground based air traffic control system may be the answer. It may be that CAS will be the answer. But we are not far enough down the road to determine the reliability, the cost, the distribution, the compatibility working within the air traffic control system, to say there should be a nationally implemented CAS.

Senator Moss. I am sure you must have read the transcript of the previous days of hearing that we held here. O'Donnell, president of the Air Line Pilots Association, testified before and he submitted an additional statement since he wouldn't have an opportunity to appear at this time in person. I want to read just about six or seven lines from the supplemental statement.

He says:

> It is ironic in this area of space flight that there should be a controversy about collision avoidance systems. We have the technical know-how to produce systems that will keep aircraft from running into each other. We have the governmental organization that can organize the research and development of the hardware. We have a number of manufacturers ready to make the equipment. What we do not have is action on the part of the Federal Aviation Administration, action in the form of live, competitive testing of the known concepts and action in the form of a decision on some basic parameters to challenge the scientists to come up with the best, least expensive system.

In view of your answer that you just don't know about a timeframe because you don't know yet whether CAS is the way to go, that is a pretty sharp deviation from what Mr. O'Donnell says, isn't it?

Mr. SMITH. Yes, it is, Mr. Chairman. I am not particularly surprised at Mr. O'Donnell's opinions, and these are just his opinions. It is great to have the luxury of criticizing without the responsibility for designing an air traffic control system for air transport of all kinds: military, commercial, and general aviation.

Senator Moss. You say that Mr. O'Donnell, who is president of the Air Line Pilots Association, is speaking just for himself?

Mr. SMITH. I think he is speaking in a critical vein without having the responsibility to consider all the factors for a CAS system.

Senator Moss. It was my impression that the airline pilots are men in charge of these aircraft and in charge of thousands and thousands of flights, and with whom I ride all the time. They have great responsibility and I put quite a bit of confidence in them.

Mr. SMITH. I put a great deal of confidence in them, and they are truly professional people, Mr. Chairman. But there are other users of the airspace besides the members of ALPA, such as general aviation and the military.

Senator Moss. Agreed. They all have the responsibility of an aircraft when they are in the air, but it seems to me that the airline pilots have the largest responsibility because they have the most number of lives in their care when they are in flight.

So, I am considerably impressed at the efforts they have made, and it isn't only Mr. O'Donnell who has come to me. Many, many other airline pilots have come and they simply feel that we are dragging our feet. We are not going ahead to solve a problem that is of gravest importance at this time.

Mr. SMITH. Well, the only answer to the question, in my opinion, Mr. Chairman, is for about the past 7 or 8 years, the FAA has been woefully short of funds to establish a better air traffic control system than it presently has.

I suppose it never will be good enough, and we shouldn't be complacent and hope that today's system is going to be good enough. But funding limitations have prevented us from having ILS's at the end of every runway at every airport serving commercial aviation in this country. Mr. O'Donnell would like to have that, so would we. Funding limitations have prevented us from having terminal radars at all airports serving air carriers and many for general aviation.

We too would have liked to have had those radars, but we can't afford them.

I have just had the privilege of being with members of foreign governments, our counterparts, directors general of aviation, and it is clear to all of us in the FAA that while we have definite deficiencies in our air traffic control system, we have the finest system in the world, bar none, and others are coming to us and copying what we are now doing. I include the Japanese, the French, the Spanish, and other foreign governments.

Senator MOSS. In August of 1971 when you testified—I think it was before the House—you promised that RFP's would be issued to the industry for ground station implementation and for a study of where resynchronization stations were to be located. These were to be issued by FAA within 2 months.

What is the status of this procurement?

Mr. SMITH. I am very sorry to report, I am ashamed to report that we have not yet issued those. We have had some problems internally in establishing the correct specifications. We have had some difficulties in our own purchasing requirements.

Now that we have funds to buy ILS's and radar and other equipment—and it has not gone along as promised and for that I am to be held completely responsible—it is moving forward now, and I think perhaps Mr. Israel can respond further on that answer.

March 15 is the date the RFP will be out.

Senator MOSS. In that same testimony, you talked about the controlled collision avoidance interaction question and said it would be reached by the end of 1971.

In Phoenix, Mr. Shaffer said that the answer to these questions would be obtained only by the first of 1973. In the meantime, FAA published the results of the Chicago O'Hare traffic simulation with and without collision avoidance.

How is it possible that in a 6-month period with more data available, the results and answers can be postponed for a year?

Mr. SMITH. The simulation tests we conducted at NAFEC, as I described earlier, were between two air carriers that were equipped with CAS. Those tests indicated certain difficulties, but not insurmountable. We now have to go further in the simulation tests to look at aircraft that are equipped with the full CAS system, Micro CAS and other aircraft that are not equipped before we have an answer as to how these systems will blend together with air traffic control.

Senator MOSS. Recognizing that the majority of midair collisions have occurred in low density airspace, when do you propose to provide full ground based air traffic control service over the entire United States extending from the minimum flight level to the base of positive controlled airspace?

Mr. SMITH. That is quite a question, Mr. Chairman. I can't possibly tell you that at this point in time. A great deal will depend upon the growth of our industry, the revenues from the airport-airways bill, the cost of installing ground equipment, and new methods that industry may yet devise to give us, for example, satellite air traffic control, which would give us control down to the surface of the earth.

Senator MOSS. I understand that one of the basic pieces of equipment necessary on the aircraft to operate in the automated environment is the automatic altitude reporting transponder. We understand that in 1965, there was an advance notice of proposed rulemaking which was followed in 1969 by a proposed rule that would require mandatory carriage of transponders with altitude recorders.

However, this safety item has not been issued as a rule. Why is this?

Mr. SMITH. First of all, there were problems with regard to the cost of the mode C transponder. Second, there were problems regarding the technical output of these units and their accuracy.

Third, we were not prepared in the air traffic control system to receive the mode C information that the transponder was capable of transmitting.

I am happy to report that within 2 weeks' time we will have a notice of proposed rulemaking which couples together with the areas of positive control and TCA development that will require mode C transponders transmitting these particular areas.

Senator MOSS. I notice in your statement where you indicated the facilities of midair collisions were relatively small and they accounted for only 3.7 percent of the total facilities in 1970.

Can you tell us what percentage they accounted for in 1971?

Mr. SMITH. Yes, if we may, we will put this chart on the easel, Mr. Chairman.

In 1971 there were 44 air carrier facilities and the percentage number for 1971—we are going through a little mathematical exercise at the moment.

Senator MOSS. I can see the number now in that column is 44 in absolute numbers.

Mr. SMITH. Forty-four facilities.

Senator MOSS. And now the collision number is what you are trying to figure out?

Mr. SMITH. That is correct.

If I may, Mr. Chairman, can I volunteer a piece of information regarding TCA's?

Senator MOSS. Sure.

Mr. SMITH. In 5 months of 1968, for example, in Atlanta, we had seven near midair collisions without the TCA. In 1971 with the TCA there have been none. In New York City we had 53 near midair collisions in 1968. In 1971 there was none.

And for the same period in Los Angeles, 74 to 1 before and after the TCA was in, Washington, D.C., 24 to 1. Chicago, 21 to 5.

I think this is a pretty good indicator of what the TCA will do for us in the way of controlling aircraft within those high-density areas.

Senator Moss. Those are impressive figures. On the number of passenger fatalities, wasn't it higher than that just in the one Air West collision out there in Los Angeles?

Mr. Smith. No, sir, that is the number of the Air West passenger fatalities. There have been general aviation fatalities that are not listed on the chart.

That number for air carrier passenger fatalities incidentally is 6.5 percent.

Senator Moss. You say, "The FAA participated in the evaluation of the CAS and PWI systems developed to date. The time/frequency CAS is the only design that is essentially prudent and ready for production."

Now, the fact that you have not approved it, does that mean you have disapproved then the time/frequency CAS?

Mr. Smith. No, sir, it does not mean we have disapproved it. In fact, we have gone further than that and we have requested from the FCC a frequency reservation which I mentioned in my opening statement. This may be available for the time/frequency system or other CAS's if ground stations are required.

Senator Moss. What parameter have you set for costs? What do you calculate to be the cost of the system that must be met in order to make it suitable for general aviation for the pilot warning and for commercial aviation for the collision avoidance?

Mr. Smith. To stay away from the numbers game, if we are talking about the cost of a black box to a general aviation aircraft owner, I would hope that we could get this number down to about something like $750. Years ago it was unheard of to think of a transponder selling for less than anything under $2,000 or $1,500. Today good units are available for almost half that price.

I think the day will come, if CAS is the right system, that we will be able to afford that. But until general aviation can be equipped with these kinds of equipment, we are not going to solve or assist in midair collision prevention.

Senator Moss. I guess you were in the room when I was talking with Chairman Reed of the Safety Board and I asked him what timeframe it was when he suggested they be expedited. Perhaps I could ask you that same general question. Can you give us any kind of a timeframe when we are going to arrive at this requireemnt?

Mr. Smith. As I mentioned, Senator, during my opening statement, I hope that with the stepped-up efforts now of evaluating what industry has come up with, that by the first of next year, in aobut 10 months, we can give you a more meaningful report as to where we are headed. We do not yet have enough information to make a choice of one system over the other.

I am well aware of the pressures that have been put upon this committee as well as upon the FAA and other elements of Government to make a choice now. But we are not in a position to do that. Therefore, I cannot promise when we will have a CAS or if we will have one.

But I hope within about 10 months, with our stepped-up evaluation efforts, that we will be in a better position to say what we think is the right way to go and to give you our advice as well.

Senator Moss. Of course, that leaves us about where we were when we started considering the bill. Maybe we should have just said hurry up.

It is of such pressing need that it seems to me we ought to have a date. That is the reason for the bill. But I appreciate your answers and responses.

Thank you.

Senator Cannon (presiding). Thank you, Mr. Smith, and your colleagues.

The next witness is Secretary Whittaker.

STATEMENT OF HON. PHILIP N. WHITTAKER, ASSISTANT SECRETARY, DEPARTMENT OF THE AIR FORCE; ACCOMPANIED BY DAVID R. S. McCOLL, DEPUTY FOR RESEARCH, OFFICE OF THE AIR FORCE ASSISTANT SECRETARY FOR R. & D.

Mr. Whittaker. Mr. Chairman, members of the committee, I appreciate this opportunity to appear before you today on behalf of the Department of Defense, to discuss the important matter of aircraft collision avoidance and S. 2264. Your concern for reducing midair collision hazards is shared by the Department of Defense; in fact, we have a considerable history of concerned interest and of significant effort. directed toward enhancement of air safety. Many important air safety devices in use around the world today, both in aircraft and on the ground, have either been directly developed by, or have resulted from pioneering work done through the Department of Defense. Instrument landing systems, airport surveillance radar, and the air traffic control radar beacon system (which evolved from the military IFF system) are excellent examples.

The years of work directed towards safety in the air have indeed shown good results overall. We have worked diligently for a long time with the FAA using the framework of the national airspace system and also within the services themselves to reduce accidents of all kinds—not only those due to midair collisions. The Air Force accident rate has decreased from 20.2 accidents per 100,000 flying hours in 1954 to a rate of 2.5 accidents per 100,000 flying hours in 1971. Similar improvements have been made by the other services.

The past effort has thus been productive. In the future, as traffic densities gradually increase, we should, of course, continue good and pratical ways of maintaining the progress of the past. As statistics have shown ground control is one element which can materially improve our safety record. As a result, the military departments now have all implemented procedural steps to require that, when possible, their flights in the national airspace are conducted under instrument flight rules on prefiled flight plans and preferably under positive control by ground air traffic control authorities. Now we are looking for additional ways to reduce hazards still further.

With me today is Mr. David R. S. McColl, the Deputy for Research in the Office of the Air Force Assistant Secretary for R. & D. Mr. McColl is the DOD member of the Interdepartmental Group on

Collision Avoidance and Pilot Warning. This group, on which NASA is also represented, operates under the leadership of the FAA. The purpose is to give focus and to add emphasis to our joint efforts.

Your invitation to testify today noted that the committee would be interested in current DOD activities relating to the midair collision problem and what action is being taken or considered in this area. I have already mentioned the procedural steps which have been taken by the DOD and our cooperation with the FAA. We have now formulated other action plans for 1972. We intend to:

a. Investigate all promising airborne techniques, including time/frequency and interrogator/transponder systems to insure that the claims made for their performance are correct and to see if it is truly practical to recommend any for general service.

b. Cooperate with the FAA in investigation of all promising ground-based techniques, particularly those which are extensions of the existing air traffic control radar beacon system.

c. Take any other reasonable actions (such as procedural) to reduce danger of midair collision between all aircraft, and most particularly between commercial aircraft and military aircraft.

Turning to the techniques which have been advocated, I would like to draw the committee's attention to the fact that many of them are complex. As implied earlier, these fall into two main categories. All systems now under serious consideration involve cooperation either with installations in other aircraft, or with ground installations or with both. The techniques which are air-to-air in nature include airborne interrogator and transponder techniques and time/frequency.

Other than purely optical systems, all proposals to date have been relatively complex and hence are expected to be expensive, perhaps prohibitively so. As our experience in developing weapon systems has brought out, other bad problems, such as lack of reliability in service and high cost of maintenance come with complexity.

Ground-based systems have their own advantages and disadvantages. An important advantage is that the airborne elements of a ground-based system, which has to be replicated in all aircraft to be protected, are generally much simpler, cheaper and may be expected to be more reliable. Furthermore, if we can succeed in capitalizing on our existing investment in tens of thousands of airborne transponders through modification or relatively simple addition so as to provide additional collision avoidance capability, the benefits are obvious.

As you undoubtedly recognize, the DOD has a tremendous investment in the Nation's air traffic control system. We have spent more than $700 million on the beacon system alone, and we would like to get maximum benefit from it.

I would like to impress to the committee some general caveats. No sure-fire CAS system is around the corner. Even if an immediate mandate were given, with the money to implement it, a minimum of 5 years would ensue to get installations in substantial numbers. Protection would still fall short of 100 percent, and while perhaps reducing collisions, should not be expected to eliminate them. Before this, however, we have to step up to the problems of complexity, reliability, maintainability, and considerable cost reduction. The latter, I believe, should be motivated by free competition. Implementation of the time/frequency system in today's form for military aircraft alone is estimated by the manufacturer to run to over $660 million. Our own estimates run higher still.

In conclusion, while the DOD supports the objective of S. 2264, we do not support the bill. It would not be feasible to complete development, select a system, and complete the implementation in time to comply with the provisions of the bill.

We further believe that to force establishment of a national CAS standard within the deadlines specified in S. 2264 would be a serious error. We believe it is premature to endorse any system at this time although we agree fully with the need to proceed vigorously to see if we can define a national standard which would give added protection from midair collisions. The critical problem of avoiding such collisions motivates us all and will cotinue to do so. We are convinced that together we may reach our goal with an orderly national program, given the time, opportunity and resources to explore all good alternatives.

Thank you, gentlemen. This completes my prepared statement.

Senator CANNON. Thank you very much. Mr. Secretary. In your statement, you say:

> . . . the military departments now have all implemented procedural steps to require that, when possible, their flights in the national airspace are conducted under instrument flight rules on prefiled flight plans and preferably under positive control by ground air traffic control authorities.

Is this a change of policy that has resulted since the midair involving an airliner near Duarte, Calif., last summer?

Mr. WHITTAKER. This is a change in policy, Mr. Chairman. The exact date of this being handed down, I don't know. I will have to supply it for the record. It has been within the last several years.

Senator CANNON. The last several years? It has been more recent than that, hasn't it?

Mr. WHITTAKER. I will have to get the date for you.

(The following information was subsequently received for the record:)

MANDATORY INSTRUMENT FLIGHT RULE FLIGHTS

The policy was established prior to the mid-air collision near Durarte, Calif., last summer. Steps taken by the military departments to conduct the maximum practicable amount of flight activity under IFR procedures were begun as early as 1962. Subsequently directives, issued during 1967–1970 and as late as December 1971, reemphasized the importance of IFR fight in the National Airspace System and directed increased participation in the Air Traffic Control System. The emphasis has grown on integrating military operations under IFR control. For example, certain categories of Air Force flight activities that routinely operate in the National Airspace System were, on 21 December 1971, directed to fly under IFR procedures. The Navy stipulated on 16 June 1971 that all flights in fixed wing aircraft shall be conducted in accordance with instrument flight rules to the maximum extent practicable. The Army issued comparable instructions on 18 June 1971. In addition, directives have been issued which are designed to reduce, and eventually eliminate, VFR flight in high density airport terminal areas. Many special categories of military flight activity, such as exercises and tests, are initegrated into the system as capacity increases and technology advances. As a further indication of the military commitment to the Air Traffic Control System, for the past four years the Air Force has reimbursed the FAA (a total of nearly $20 million) for additional FAA personnel and equipment to accommodate undergraduate pilot training at our training bases into the IFR system.

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Senator CANNON. Under what circumstances—when operating in nonrestricted airspace—would it not be possible to operate all military flights under IFR and under positive control by ATC?

Mr. WHITTAKER. Mr. Chairman, I think essentially all of our flights except those that represent emergancy-contingency kinds of operations or military exercise of various kinds could in fact be conducted under IFR.

Senator CANNON. Is it possible to conduct all nonemergency Department of Defense aircraft operations in restricted airspace when operating at high speeds under visual flight rules?

Mr. WHITTAKER. I believe, Mr. Chairman, this would inhibit the operational effectivity of our military flying to some degree, the exact extent of which I am not quite prepared to respond to.

Senator CANNON. You have me a little confused now. I wonder if you would elaborate on that for the record.

Mr. WHITTAKER. I would be glad to, sir.

record :)

(The following information was subsequently received for the

MANDATORY IFR AND RESTRICTED AREA OPERATIONS

Present Restricted Airspace does not have the capacity to contain all DOD operations that have been authorized by the FAA to exceed FAR speed limitations while VFR. Commercial and general aviation users have opposed expansion of Restricted Airspace. Military directives require flight under instrument flight rules commensurate with mission requirements. The hub to hub design of the present air traffic control system is unable to accommodate solely in restricted air space all of the essential military operations (e.g., long distance low level training, air combat training, etc.). In recognition of this fact, areas are carefully selected for high speed VFR flight to avoid metropolitan and other sensitive areas. As the FAA capacity for control increases more of these activities can be conducted under IFR procedures.

Senator CANNON. Is it DOD policy to allow military aircraft to operate in controlled airspace without operative radar beacon transponders?

Mr. WHITTAKER. No, sir; it is not, except under emergency conditions. Such operations might be required when there is an emergency.

Senator CANNON. Is the policy now that they would not be operated without an operative transponder unless there is an emergency condition?

Mr. WHITTAKER. This will be the policy as the AIMS program is completed, which will occur by the 1st of January, 1973.

Senator CANNON. Why does it require that long a wait? I am talking now about nonemergency conditions. Why can't you prescirbe ing now about nonemergency conditions. Why can't you just prescirbe that if you don't have an operative transponder that your aircraft has to stand down?

Mr. WHITTAKER. Well, we have been equipping all of the military aircraft, both Air Force, Army, and Navy, with the new automatic beacons, the installation of which is to be completed by the 1st of January, 1973. To the extent that we can keep them out of controlled airspace in the interim, we would try to do so, but I won't think we can assure that this would be the case.

Senator CANNON. You are talking about equipping them with updated equipment rather than the existing transponders. In the accident that occurred in California, the military aircraft apparently had a nonoperating transponder. Now, that was known at the time the aircraft took off.

Mr. McColl. I understand it was not operating, Senator. Whether there are anything at fault with the transponder, we would like to supply that information.

Senator Cannon. It was my understanding it was inoperative and that was known at the time the aircraft took off. I may be in error, but I wish you would supply that for the record.

(The following information was subsequently received for the record:)

That is correct, the transponder was inoperative at takeoff.

Senator Cannon. My question is if it is a nonemergency flight and particularly in high density areas and in controlled areas, why can't you just ground that aircraft and say you don't fly it under those conditions?

Mr. Whittaker. Let me provide for the record the information about that specific flight and also the regulation with respect to the grounding of aircraft that have a nonoperable transponder.

(The following information was subsequently received for the record:)

Requirement for Operable Transponders

All military flights in Positive Controlled Airspace (PCA) are now required to have operating transponders. Pre-flight/in-flight malfunctions of this equipment could be construed as adequate cause to cancel/abort missions other than those of urgent military necessity. Aircraft with inoperable transponders can, with FAA approval, be authorized one-time flight to repair facilities in the event they land where no repair capability exists. Not all military aircraft are presently transponder equipped, hence they are not allowed to operate in Positive Controlled Airspace.

Senator Cannon. Is it now DOD policy to require all military aircraft operations below 10,000 feet to comply with the FAA's 250-knot speed limit?

Mr. Whittaker. I believe so. I will have to verify that, sir.

Senator Cannon. You supply that for the record if it is not the case.

(The following information was subsequently received for the record:)

Military Policy on FAA Aircraft Speed Limit

The military services comply with the FAR on aircraft speed except where they have been authorized to deviate by FAA waiver. As a general rule, these waivers pertain to high speed fighter/trainer aircraft and have been granted primarily in recognition of safety considerations. Most modern fighter aircraft flight handbooks require airspeeds in excess of the 250 knot speed limit for safe tactical/training operations. Flight operations which exceed the speed restriction are limited to:

a. Climbs and descents to traffic patterns authorized and/or designated training areas and low level navigation routes.

b. Low level training missions conducted in designated special operating areas on low level navigation routes or on designated flight routes.

c. Those instances where the safety of either crew or aircraft requires operations in excess of the limitation.

Senator Cannon. Does DOD permit military pilots to perform acrobatic or other maneuvers of that nature, severe maneuvers, in controlled airspace, absent control from the air traffic control system?

Mr. Whittaker. I don't know the answer to that, sir. I will provide that.

(The following information was subsequently received for the record:)

Insofar as the entire United States is controlled airspace above 14,500 feet MSL, the DOD does allow aerobatics off airways in controlled airspace, but only within tightly defined rules that go far beyond the restrictions contained in the FARs. Efforts have been ongoing for sometime to integrate these missions into the air traffic control environment as the air traffic control system develops sufficient capacity. Our efforts will continue.

Senator CANNON. Does DOD have a program to educate and familiarize its pilots with arrival and departure routes used by turbine-powered civil aircraft operating into the Nation's major airports?

Mr. McCOLL. Senator Cannon, the pilots who are operating under military command always follow very closely, to my knowledge, the actual departure and other instructions which are common to the civil fleet. In other words, the normal FAA rules are, in my experience, very conscientiously followed.

Senator CANNON. My question wasn't do they follow it. My question was does DOD have a program to educate and familiarize their pilots in this area? Obviously, some don't follow it or you wouldn't have had in midair in California, because the F-4 was operating in a well-known commercial corridor, in a controlled airspace corridor, and performing aerobatic maneuvers as well. My question was not do you abide by the rules, because it is obvious in this case rules may have been violated. But do you have an educational program for the pilots in that area?

Mr. McCOLL. Yes, sir; I would say it is common to all training programs today, especially since that tragedy, very great attention has been given to this matter to which you speak.

Senator CANNON. Will you review and make sure you are right, and if you are not, correct the record on that?

Mr. McCOLL. I will indeed, sir.

(The following information was subsequently received for the record:)

DOD PILOT EDUCATION PROGRAM ON AIR TRAFFIC CONTROL

Military pilots are required to participate in annual refresher training programs which concentrate on the air traffic control system and procedures as a whole. These programs are not limited to the area of arrival and departure routes used by turbine powered civil aircraft. Nevertheless, special emphasis is given to the procedures used in terminal areas for arrivals and departures. In addition, the interface of civil and military traffic is stressed. For example, FAA personnel participate in the training prorams at Andrews AFB and provide specific detai's concerning civil/military operations and how they are integrated into the entire air traffic control system. Other military installations have similar programs and liaison with FAA.

Senator CANNON. Your statement indicates that DOD will evaluate all promising airborne collision avoidance techniques during 1972. What form will that investigation take?

Mr. WHITTAKER. Mr. Chairman, we have an effort that we are mounting jointly with the Federal Aviation Administration in the interest of spreading our dollars as effectively as we can and of minimizing overlap. We have a program in the Navy under which the RCA Secant system has been and is continuing to be investigated, tested, and proven. We have, through the Army, a program to look at the Minneapolis Honeywell transponder PWI system. We are trying to do this both within our own agency as well as, shall I say, on a cooperative basis with the FAA.

In addition to that, the Air Force intends to devote attention to looking at the ATA time-frequency system.

Senator CANNON. Based on your Navy SECANT test, can you state whether the claims made for the SECANT system before this committee in December are valid?

Mr. WHITTAKER. I cannot state this at this juncture, Mr. Chairman, because the tests have not progressed to that point. I can say, however, that those in the Navy who have tested or who have been involved in the tests of the SECANT system, are optimistic as to its possibilities.

Senator CANNON. Now, how about your investigation of the CAS concept developed by McDonnell Douglas and others? Do your tests so far indicate that the claims made for that system before the committee in December are valid?

Mr. WHITTAKER. Again, our experience with the CAS system, the ATA system, is very limited, Mr. Chairman. Again, however, the evidence that we have been able to gather thus far, which is primarily documentation, is encouraging. The questions, sir, that trouble a number of us are the kinds of questions that we have stubbed our toe on in the Department of Defense in recent years, the problems of moving from a laboratory kind of hardware into a quantity-produced kind of hardware, the problems of producibility, the problems of reliability, the problems of the caliber of the service that would be required to support an item of this kind. This is not to say that we don't think that the CAS system isn't producible or isn't maintainable; we just don't have the information at our hand that would indicate how big a problem this is likely to be.

Senator CANNON. In the opinion of the DOD, is it practicable or feasible to determine and establish a national standard for CAS, PWI, for the United States during the current year?

Mr. WHITTAKER. No, sir; it does not appear feasible to us to do so.

Senator CANNON. Given the establishment of a national standard, how long do you think it would take to completely equip all U.S. military aircraft with the appropriate hardware?

Mr. WHITTAKER. Mr. Chairman, I believe that the Air traffic control radar beacon system installations have required a period, by the time they will have been completed the first of next year, will have taken something in the order of 6 to 8 years for installation. That was a forced draft kind of a program. It seems to us that the installation of CAS equipment could be completed in no shorter time and very likely it would take some time in excess of that. If an airborne collision avoidance system were to be mandated and were to be established as a national standard and were begun to be installed within the next 2 or 3 years, it seems clear to us that this type system would inevitably be with us for most of the rest of this century, and, therefore, it is awfully important, in our judgment, that the right kinds of decisions be made as to what is established as a national standard.

Senator CANNON. Senator Moss.

Senator Moss. Thank you, Mr. Chairman. Is the reason that DOD wants delay of the collision avoidance system implementation lack of money?

Mr. WHITTAKER. No, Senator Moss. It is essentially the lack, we believe, of all the returns—all of the information—that is needed to provide the basis for an appropriate decision. This decision, I might quickly add, is one that has got to be made, not by the DOD by itself, but it has got to be made by the Federal Avaiation Administration so that we will have a compatible system for not only military aviation, but also general aviation and commercial aviation.

Senator MOSS. Of course, any system that is settled upon has to be applicable to the military, as well as to transport and general aviation. But I am just trying to determine why DOD isn't willing to press ahead more rapidly. With a history of over 7 years' time-frequency applications to military aircraft, how can DOD claim today that they need more time to evaluate the time-frequency system?

Mr. WHITTAKER. Well, as I indicated, sir, there are several competing technologies that appear to have a certain degree of promise. There seems to us to be a great deal of additional work that has got to be done not only in looking at the technology that we are contemplating, but also looking again at this problem of converting that technology into a mass producible and supportable kind of a system.

Senator MOSS. Is the time-frequency system unacceptable?

Mr. WHITTAKER. I am not in a position to say whether it is unacceptable or acceptable to the Department at this point, Senator.

Senator MOSS. And you have no way of saying how long it will take before that decision is made?

Mr. WHITTAKER. The FAA in their testimony a short time ago talked about an interim report the first part of 1973, January of 1973. I would be less than candid if I didn't say I felt that was optimistic as a schedule. It is a very complicated question that still has not been resolved.

Senator MOSS. Obviously, it would take some time since you have had about 7 years of experience with time-frequency and haven't come to a decision yet on that. The Air Force has great monetary losses from midair collisions, as well as the loss of life. Doesn't that plead for speed rather than delay in implementing some system?

Mr. WHITTAKER. Yes. We certainly agree that the program should move as expeditiously as it possibly can. I think in all candor the program has not moved as expeditiously in recent years as it perhaps should have. But we are now attempting with the FAA and under their leadership to move forward more vigorously.

Senator MOSS. Wouldn't it spur even greater action if we had some deadlines set up?

Mr. WHITTAKER. My concern, Senator, is that were deadlines to be established, I have the feeling that this would constitute a de facto decision on the time-frequency system, which I admit looks like a very interesting candidate, but by no means the only one and the only possibility.

Senator MOSS. I agree with you there is great urgency and we need to move along.

Thank you, Mr. Secretary.

Senator CANNON. Thank you very much, Mr. Secretary.

Our next witness is Mr. Dan C. Ross, president of Ross Telecommunications Engineering Corp.

STATEMENT OF DAN. C. ROSS, ROSS TELECOMMUNICATIONS ENGINEERING CORP., WASHINGTON, D.C.

Mr. Ross. Mr. Chairman and members of the committee, the opportunity to appear before the Aviation Subcommittee of the Senate Commerce Committee is greatly appreciated, and I hope that my testimony and accompanying papers will be of service to the members and staff of the committee and to the executive departments concerned with aviation.

I am Dan C. Ross, president of Ross Telecommunications Engineering Corp. and of CATV General Corp., Washington, D.C.

My background includes service in the Signal Corps and Infantry, advanced degrees in engineering from Purdue and Johns Hopkins, service on the faculties of those universities and of the U.S. Military Academy, and 16 years as an engineer and executive with IBM before starting RossTEC in 1969.

My experience in ATC systems engineering and related areas began in 1953, when I served as a member and later as manager of the systems planning group on the SAGE air defense project, the first computer/communications/control system of national scope. In 1955–68, I organized and managed IBM's system studies and developments in air traffic control.

My colleagues and I have been active in ATC, communications, surveillance, and navigation in several areas:

1. Use of information systems and technology in air defense and ATC, as major components of such systems and as tools for system research and development;
2. Study of the requirements of the overall ATC system and of the position data acquisition subsystem;
3. Satellite communications;
4. Signal processing for satellite navigation; and
5. Development of solutions to the problem of position data acquisition for aircraft, ships, and vehicles.

Experience as a student of the ATC problem and as a contributor to its solution has led me to certain conclusions in the areas noted above and in the area of collision avoidance systems. My purpose in testifying before this committee is to present some of these conclusions in the hope that they will be constructive. The extent and the complexity of the interaction between several related problems is such that only the key points can be mentioned in the time available here. Additional points are outlined in the documents provided for the record, and these points can be amplified through questions here or in later meetings, if desired or required.

S. 2264 contemplates early implementation of an air-derived collision avoidance system (ACAS) of a type which requires cooperating equipment in all aircraft sharing the same airspace. Advocates of ACAS, over 15 years ago, proposed another design which used radar techniques and which required equipment in only one of a pair of approaching aircraft; that design was abandoned when shown to be impractical. We must also consider another design, GCAS, based on ground-derived measurements and centralized monitoring and control, essentially a variation and extension of the present ATC system.

None of the major organizations responsible for aviation operations feel that ACAS has been developed and proven to the point that operational specifications can be written now and mandatory dates set for implementation prior to 1976—not even the Air Transport Association, which has provided the major support for ACAS. The statement of the National Business Aircraft Association before this committee fairly states the situation:

In spite of the professional work that the airlines have accomplished in evaluating the available techniques, * * * the fact remains that [ACAS] as presently developed cannot in our opinion include sufficient numbers of aircraft to warrant its designation as a national standard, * * * .

* * * the basic requirement against which the air carriers developed their system and which led to its present configuration is tailored for air carrier operations.

* * * It is not a total requirement developed against the total background of the Air Traffic Control system with its mix of aircraft monitored by ground-based radars and controllers. * * *

It is also important to note that no responsible organization claims that ACAS can be more than a supplement to the centralized ATC system; ACAS can certainly never replace ATC nor substantially reduce the extent of the ATC system. In fact, the simplest and most effective way to proceed is to improve and extend the ATC system by including the GCAS function. GCAS would practically eliminate all near misses and collisions of controlled aircraft without requiring years of unnecessary delay and great technical and operational risk. It is clear that GCAS would be much more economical than ACAS. Note that ATA estimates that ACAS would cost the airlines about $200 million.

The most significant problem of ACAS is not its cost but its complexity and attendant risks. In order for ACAS to operate effectively, the airborne equipment must look far enough ahead to give adequate warning to the pilot or autopilot, and, in dense traffic situations, must take account of all aircraft involved in any potential collisions. Separations and velocities must be measured accurately in three dimensions, and previously planned maneuvers of all aircraft involved must be considered. If the equipment in one aircraft determines that an unplanned maneuver is necessary, this change in plan must be quickly communicated to all other aircraft involved and confirmed before the maneuver is actually executed. Such a countermand of at least one and perhaps several flight plans carefully made and followed by the various pilots, controllers, computers, and supervisors cannot be permitted unless the measurements and decisions made by the ACAS equipment are extremely accurate, reliable, and complete. That such a sophisticated set of operations could be done routinely and economically by all of general aviation with proven reliability sufficient to meet the demanding requirements of the major carriers and of the public is a farfetched idea.

The measurements needed for collision avoidance must be accurate, and the way to obtain accuracy is to use one system of large aperture (miles, not feet) for each major airport, not two (or more) measuring systems of an aperture dicated by the dimensions of small aircraft. The way to obtain reliable and accurate decisions that can be executed quickly with a minimum of unplanned maneuvers is to make such decisions on the ground. In GCAS, all of the necessary data is readily available, and the personnel are equipped and trained for the primary purpose of collision avoidance. If the current ATC system has deficiencies, they must be corrected, not further complicated by the introduction of ACAS.

Improvement of the ATC system to provide a real-time GCAS function over all airspace with significant traffic is a natural and logical extension of the current system, and much of the work required in this direction is underway. The most important ATC subsystem requiring major change to permit inclusion of the GCAS function is position data acquisition. Radar is not adequate for this purpose because of a number of inherent technical problems: lack of identity of aircraft with the radar reflections they produce, weak reflections from small aircraft, interfering reflections from other sources, et cetera. The beacon transponder is self-interfering and lacks precision. Use of such inadequate data sources as the prime input to ATC computers forces the allocation of large fractions of the ATC system capability to the sorting and correlating of input data.

Introduction of a properly designed system of position data aquisition would free most of this wasted capacity to serve the conflict detection, resolution, and communication functions required for GCAS. Several candidate systems are known that can clearly offer great improvement over current radar and beacon techniques; at least one of these can provide an effective solution to the problem of position data acquisition.

The class of multipoint systems is particularly important; these are systems in which pulses from aircraft are received at several ground locations (say, four points in the vicinity of a major runway) and the aircraft position is found from the time of arrival of the pulses or from their propagation intervals. Some of these multipoint systems can be made free of interference by using time-division control in which each aircraft is assigned a long (1,500 microseconds) time slot, a control technique that is similar to that used by the designers of ACAS.

Appended for the record is a detailed list of requirements that the position data subsystem ought to meet, particularly if the GCAS function is to be included in the ATC system. The Government, via DOD, FAA, and NASA, ought to proceed expeditiously to do the experiments, analyses, simulations, estimates of implementation costs, et cetera, required to compare the candidate design approaches in the light of the requirements imposed on the position data subsystem. Much of the data needed for the matrix of capabilities versus requirements and designs is already available; the rest can be determined by experiments and analyses that can use the experience gained on closely related projects in DOD and NASA. This work can be completed in a few months of staff and contract effort, and is a necessary prerequisite for systems engineering decisions.

The most important requirements on the data acquisition subsystem stem from the need to integrate general aviation into the ATC system in a convenient and economical manner. This need must be met soon, in view of the fact that most airline midair collisions are with general-aviation aircraft typically operating VFR at altitudes less than 10,000 feet and at low rates of closure. Midair collisions of airlines with general aviation are currently occurring at the rate of about three per year. In most of these cases, the general aviation flight is unknown to the ATC system and unseen by the airline crew in time for effective action. Other reasons for emphasis on general-aviation requirements are its traffic statistics representing over 80 percent of the active aircraft, and over 60 percent of the flights, takeoffs, landings, and peak traffic aloft.

A system that satisfies the requirements imposed by general aviation must be simple and easy to understand, operate, and maintain. These criteria are just as important to the airlines since they are certainly not interested in unnecessary expense and complexity. GCAS can come as close to meeting the criterion of simplicity as any system of collision avoidance could, and it is inconceivable that any effective ACAS could ever be objectively regarded as simple.

$200 million would buy all of the airlines avionics and the ground receivers, transmitters, and computers needed at 350 airports to implement an effective position data system for general use and meeting all of the requirements appended herewith. The avionics package used by general aviation in such a system would cost about $500 per aircraft installation. Such an implementation is a major and necessary step toward the inclusion of an effective GCAS function in ATC.

I respectively suggest that it would be unwise to pass S. 2264 in its present form, and that it would be better to expedite GCAS implementation via improvement and extension of the ATC system, with particular emphasis on position data acquisition and on the integration of major segments of general aviation into the system at the earliest possible instant. In taking such crucial and urgent steps, it is essential to keep in mind an important principle of systems engineering, paraphrased from the wisdom of William of Ockham: Complex system solutions ought not be engineered if simple solutions suffice.

Thank you for allowing me this opportunity, and be assured of my desire to assist this committee if I can.

Senator CANNON. Thank you very much, Mr. Ross, for a very fine statement.

How would a ground-based collision avoidance system vary from the present air traffic control system envisioned for the 1980's?

Mr. ROSS. The main difference would be the degree of real-time response required in such a system. In other words, the kind of system I have in mind when I use the term "ground-derived collision avoidance system" is essentially a system very much like the present air traffic control system, except that we would include frequent, accurate, up-to-date, and fully identified position data on almost all aircraft for almost all the time. The decision can then be made at any time by the ATC system itself to take whatever action is necessary to avoid an impending collision.

Senator CANNON. What system requirements would be necessary for the type of system you are talking about, and how would it alter the basic ATC system, and what could it be expected to cost?

Mr. ROSS. Well, of course, the central computer system itself would have to be programed to include the collision avoidance functions, but more important than that, from the point of view of the total development effort required, cost et cetera, would be the necessity of improving the position input data system.

As I pointed out in my prepared statement, this is really that area of the system that is most in need of improvement, and this improvement is really necessary to accomplish a ground-derived collision avoidance function.

Senator CANNON. On the cost item, the $200 million figure that you used, is that——

Mr. ROSS. With regard to the $200 million figure, I was thinking approximately in the following terms. The radio equipment and ancillary coordinate conversion computers that would be required in each major airport would probably cost between $250,000 and $750,000 per installation. Let's say $500,000 on the average. The reason for the variation stems from the fact that each airport installation is a different problem unto itself due to different coverage problems caused by terrain, buildings, et cetera. The number of receivers and transmitters required in each area would vary from one airport situation to another.

The second point would relate to the cost of a device for installation in airline aircraft and the upper ranges of general aviation aircraft; for instance, the business aviation type of aircraft. Such an installation should not cost more than $1,000 to $1,500. It would certainly be less expensive than the present beacon transponder. So, that should give you a good measure of the cost.

To summarize, I was getting my $200 million figure by essentially allowing something in the order of $20 million or less for airline and business aircraft avionics, and the balance for the installation of the ground equipment required at something like 350 airports.

Senator CANNON. The developers of time-frequency CAS state that airborne CAS will not create maneuvers which will increase the dangers of midair collisions and will not complicate nor change the basic operation of the air traffic control system on the ground. Your testimony seems to disagree with that.

Mr. ROSS. I think that is an optimistic statement to say that these maneuvers would not interfere with air traffic control.

My statements are aimed at a situation where we have mixed traffic in a dense airspace, several aircrafts are involved in potential collisions at any given time. I am sure the statements of the developers of air-derived collision avoidance systems are true in a two-aircraft situation in airspace that is not particularly crowed. But I am dubious about such statements in general. Let me put it this way: I feel that the proof has not been shown that the air traffic control system would be unimpaired by introduction of an air-derived collision avoidance system in a dense situation in mixed airspace.

The type of study that is required to establish the required proof has only recently begun; the FAA has started a project at O'Hare which involves simulation of actual traffic in that dense terminal area, including the general aviation traffic. I think when that kind of an experiment is completely finished and the analyses and results are in, then we could have a better idea as to what interaction there would be between a proposed air-derived collision avoidance system and the air traffic control system.

Senator CANNON. Senator Moss.

Senator MOSS. Thank you, Mr. Chairman.

I am sorry that I was not able to be here to hear all of your testimony, Mr. Ross. I did have a chance to glance through it and read it, not carefully, but read it.

On your last page, you suggest it would be unwise to pass S. 2264 in its present form, that it would be better to expedite GCAS implementation by improvement and extension of the ATC, air traffic control system.

Since midair collisions occur most frequently in noncontrolled areas, do you think it is an adequate answer to the problem to say we simply ought to improve and extend the air traffic control system?

Mr. Ross. Yes, Senator Moss, I do. Essentially what I am saying is that the gaps in the air traffic control system need to be filled in.

Senator Moss. I guess we all agree to that, that they need to be filled in. Would it be feasible to have air traffic control over all of the airspace of the country?

Mr. Ross. Essentially all, yes.

Senator Moss. And that is what you mean, then, extend it so far that everything would be under control all the time?

Mr. Ross. That's right. I am assuming that a position data acquisition subsystem can be developed in relatively short time that can be installed at essentially every airport, including the general aviation airports, and that the coverage so obtained would essentially supply the position data, identity, et cetera, that would be needed for air traffic control throughout essentially all the Nation's airspace, with the exception of certain low-altitude areas in the en route volume. Even those could be filled in by scheduling the installation of the position data subsystem at a tertiary airport that happened to be in one of these important en route gaps. By adding in a few secondary and tertiary airports, you could in fact provide complete service to the entire en route traffic control volume so far as position data, identity, altitude, et cetera, are concerned.

I think that these improvements can all be done with very much less money and very much less delay and very much less technical risk than to provide an air-derived collision avoidance system.

Senator Moss. Of course, Senator Cannon and I come from the part of the country where there is a long distance between the airports, and there is a lot of area that would have to be covered if you had control of all of the airspace nationwide. It seems to me that is an immense task, that would be more expensive and probably more difficult to establish than to have the black box on the airplane. But if you have positive control all the time, then you think it could be directed so you wouldn't have this threat of a midair collision.?

Mr. Ross. I do. With reference to the mountainous part of the country, let me point out that you also have the advantage in that part of the country of having some relatively tall peaks on which to put sensor equipment, which thereby gives you fantastic range, so you could cover the en route area rather easily in the western part of the country.

The problems, of course, would be in the canyon areas and the valley areas in between these locations, and if there wasn't any particular degree of air traffic in those valleys, then they, of course, would have to wait their turn in the implementation program, and those valleys that had substantial air traffic would be filled in earlier. But I believe that a position data subsystem can be developed that will meet the requirements of the entire country, and that this can be done very much more quickly and with less risk and expense than the air-derived approach.

Senator Moss. Thank you.

Thank you, Mr. Chairman.

Mr. Ginther. The present air traffic control system for the 1980's, both NAS and ARTS III, is based on data acquisition by radar. Does the system you are contemplating mean that the FAA would have to abandon the radar data acquisition concept that it now has?

Mr. Ross. If you are going to solve the position data subsystem problem, you are going to have to take a different approach than we have now.

However, that does not mean that one would not want to continue to use radar. I would postulate quite the opposite. It seems to me that radar is the only technique we know of and are likely to invent at any time in the next decade that gives us the ability to track an aircraft that is unequipped for any reason, as during an evolutionary phase of system implementation, or an aircraft that is equipped but for some unfortunate circumstance is temporarily out of order. So radar will continue to be a valuable tool throughout the foreseeable future, even assuming we had complete implementation of a truly excellent position data subsystem.

However, I would also add that despite the continuous need for radar, I see no real need to feed the radar data into an air traffic control computer. I would visualize the radar continuing to be used as an assist to controllers by superimposing the radar data on the display along with the processed data from the computer so that the controllers could use it when they needed it. I would also suggest the use of separate luminance controls on the processed data from that used with the radar data.

With regard to the beacon transponder, I would see it being phased out. However, it is entirely possible to design the position data subsystem in such a way that you could make use of substantial parts of the existing beacon transponder system. Furthermore, during the evolutionary phase, it is possible to design that interaction in such a way that the operation of the beacon transponder system would be improved while it is still being used.

Mr. Ginther. Are you really saying that the ARTS III program and the NAS program are obsolete if your concept is adopted?

Mr. Ross. No, I wouldn't say that. What I am thinking about is a natural evolution of the system. The only comment I would make on that point is we could have started this very much earlier. It really wasn't necessary to wait until 1972 to develop a proper position data subsystem.

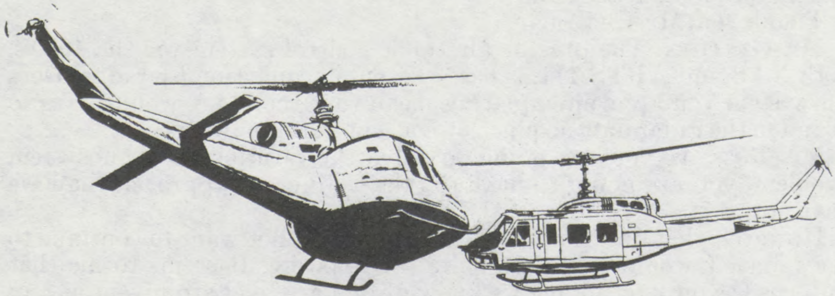
But, nevertheless, we are here and it is 1972, and there is no reason why we shouldn't start now.

Senator Cannon. Thank you very much, Mr. Ross.

The committee will stand in recess subject to the call of the Chair.

(Whereupon, at 3:55 p.m., the hearing was adjourned, subject to the call of the Chair.)

ARMY MIDAIR



COLLISIONS

PREPARED BY THE U. S. ARMY BOARD FOR AVIATION ACCIDENT RESEARCH ■ FORT RUCKER, ALABAMA

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ARMY MIDAIR COLLISIONS

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Report No. 71-1

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ARMY MIDAIR COLLISIONS

I. ABSTRACT. This report contains analyses of 56 Army midair collisions which occurred during the period January 1963 to November 1969 and conclusions and recommendations based on the analyses.

II. SUMMARY. Analysis of 56 midair collisions experienced by the Army revealed that multiple cause factors were present in each accident. It was found the pilots must shoulder the majority of the responsibility for midair collisions. However, it was also found that other factors contributed to the crew errors which resulted in collisions. The full extent that other factors contributed could not be accurately determined because of the tendency of aircraft accident investigation boards and reviewing officials to accept pilot error as the cause of accidents, without seeking other contributing factors.

General problems encountered in training areas stem from the aircraft saturation within high density areas. Corrective actions to eliminate the problems must be oriented toward reducing aircraft densities in specific training areas. This can be accomplished either by a reduction in the number of aircraft operating in a specific area or through the expansion or relocation of existing facilities.

The most common trend revealed by analyses of accidents in tactical areas was the failure of aviation units to enforce adherence to published regulations. In most cases, adequate operational procedures were established in unit SOP's, field manuals, and technical manuals. Adherence to approved procedures would have prevented most of the midair collision accidents.

Inadequate command, control, and supervision were present in 50% of the midair collisions studied. It was determined that increased command attention must be directed toward the fundamentals of good airmanship, i.e., see-and-be-seen. In addition, new approaches must be taken to improve aircraft visibility and detection. Prominent among these are installation of proximity warning devices, installation of aircraft high intensity lights, and the installation of improved communication systems in air traffic control towers.

III. INTRODUCTION. Initially, this study was originated to establish a profile of Army midair collisions. This profile (Annex III) was based on data contained in 56 midair collision accident reports, involving 113 aircraft. Information from the reports was analyzed to determine common factors found in midair collisions. Analysis of the initial study generated the following unanswered questions:

1. Why are numerous midair collisions occurring in the training and troop lift/tactical environments?
2. Why are numerous midair collisions occurring during daylight hours in periods of excellent visibility?
3. What is the impact of inadequate command and control and lack of supervision?
4. What is the degree of violation of instructions or procedures and the principles of good airmanship?
5. What action can be taken to eliminate aircraft density around focal points which seem to attract aircraft at random times? (Focal points could be navigation aids, on-going operations, airfields, etc.)

To answer these questions, further analyses of the 56 reports were accomplished. These analyses revealed that conclusions and recommendations resulting from the study of midair collisions during training missions are not applicable in all respects to midair collisions occurring in a troop lift/tactical environment. For this reason, the study is presented in two parts. Detailed findings and conclusions are contained in Annex I (training) and Annex II (troop lift/tactical).

IV. CONCLUSIONS.

1. Conclusions and recommendations drawn from midair collisions during training missions are not applicable in all respects to midair collisions occurring in a troop lift/tactical environment.
2. Training environment conclusions are:

a. There is an ever-present possibility of crews being inattentive in a training environment. Student aviators in the early stages of flight training concentrate more on flying the aircraft and devote less attention to the see-and-be-seen concept. The aviator's failure to keep his head on a swivel increases the probability of midair collisions.

b. Student pilots flying in traffic patterns under the jurisdiction of air traffic control towers often develop a false sense of security. They frequently fail to clear themselves before executing maneuvers in high density areas.

c. Deficiencies in equipment and insufficient number of personnel were contributing factors to nine of the 12 midair collisions which occurred while aircraft were operating in stagefield/airfield traffic patterns.

d. The full impact of supervision and command control shortcomings as cause factors was not fully explored by aircraft accident investigation boards due to the tendency to accept pilot error as the only cause for accidents.

e. Investigation boards and reviewing authorities made a relatively small number (27) of recom-

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This UH-1B was one of two which collided and crashed during training, killing all four occupants and destroying both aircraft.

mendations for the 25 training accidents. An apparent trend prevailed for boards to find that only the crew or crewmember was at fault when other factors were present that indicated other deficiencies.

f. Some student pilots failed to take advantage of time provided for crew rest, resulting in fatigue factors.

g. A small percentage of student pilots have a history of unsafe flying practices which may well develop into major contributing factors for midair collisions.

h. Aircraft visibility restrictions contribute to the pilot's failure to see other aircraft in time to avoid collisions.

i. Ten of 13 collisions could have been prevented if a functioning proximity warning device had been installed aboard each aircraft involved.

j. Insufficient use of the Operational Hazard Report (OHR) system may be attributed to a lack of knowledge about its intent and the aviator's fear that the information contained in the report might impinge on his personal reputation or professionalism.

k. Aircraft without distinctive conspicuity markings are more apt to be involved in midair collisions.

l. The intensity of the Grimes anticollision light is not sufficient to insure that student pilots see other aircraft in time to avoid collisions, especially during full daylight hours.

m. The see-and-be-seen concept is still the primary method available for preventing midair collisions.

n. Command emphasis in the form of constant evaluation of air traffic density, revision of air traffic control regulations, and strict control of aircraft operations is mandatory if a reduction in the number of midair collisions occurring in training environments is to be achieved.

o. A rapid turnover of key personnel contributes to a higher number of midair collisions.

p. Formation flight midair collisions do not occur when tightfisted command and control procedures culminate in detailed briefings, maintenance of prescribed separation between the aircraft, and adherence to safe flying practices.

q. Violations of regulations and published SOP's contribute greatly to midair collisions.

r. The fluctuating concentration of aircraft, varying between moderately saturated to highly saturated over such areas as stagefields, airfields, and navigational facilities, increases the probability of midair collision mishaps.

3. Troop lift/tactical environment conclusions are:

a. Loss of visual contact between aircraft during night operations contributes to midair collisions.

b. Aircrews are more susceptible to midair collisions during prime recovery periods following missions.

c. Cumulative fatigue resulting from excessive flying hours contributes to midair collisions.

d. Inadequate command, control, and supervision constitute a serious problem area. It is not uncommon to have two or more of these elements involved in one midair collision.

e. Supervisory deficiencies receive little or no attention by aircraft accident investigation boards and reviewing officials. The primary emphasis is concentrated on real or assumed faults of the aircrew.

f. The present system for disseminating changes to SOP's, NOTAM's, and other information to individual aviators is inadequate. Aviators often learn about changes in operational procedures and policies through mistakes and experience.

g. Violation of instructions, procedures, and principles of good airmanship are involved in most midair collisions.

h. Midair collisions increase as aircraft inventory increases in a combat zone.

i. Diversion of attention and preoccupation of crews due to concentration on ground actions in combat areas contribute to collisions.

j. There will be no appreciable change in aircraft density in the vicinity of focal points, i.e., landing and pickup zones, tactical areas of operation, base camp heliports, etc., in low intensity warfare operational areas. The concept of providing airmobility to enhance ground operations results in large numbers of Army helicopters and fixed wing airplanes, as well as numerous aircraft of other services and nations, using the airspace above the ground forces.

k. Broad use of the Operational Hazard Report system can become a very effective tool in the prevention of midair collisions by identifying potential focal points.

V. RECOMMENDATIONS.

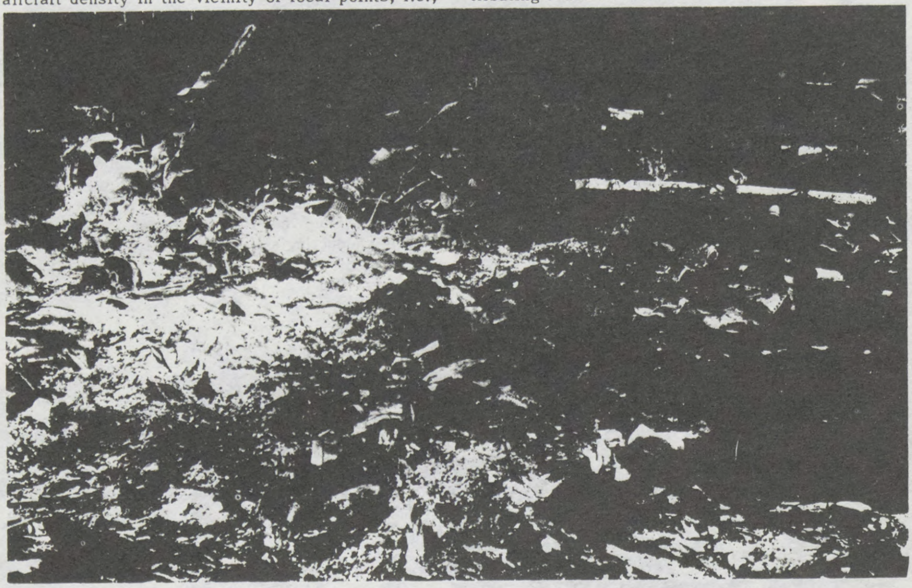
1. Recommendations for the training environment are:

a. Use of buddy riders to increase the number of eyes available for outside surveillance.

b. Increased emphasis on the necessity for student pilots to always clear themselves before executing maneuvers.

c. Command emphasis in the form of constant evaluation of air traffic density, revision of air traffic control regulations, and strict control of aircraft operations.

d. Greater efforts by aircraft accident investigation boards to identify and substantiate all contributing cause factors for each accident.



Charred remains of CH-47C which collided with fixed wing aircraft at 3,000 feet during tactical mission and tumbled end over end to ground, killing all five occupants.

e. Aircraft accident investigation boards and reviewing officials must develop positive and viable recommendations to prevent recurrence of all cause factors associated with every accident.

f. Command insistence that student pilots take full advantage of time provided for crew rest.

g. Greater command emphasis on the detection and elimination of marginally safe students at an early stage of flight training.

h. Elimination of design restrictions to visibility for future aircraft procured for training and modification to eliminate restrictions to visibility for training aircraft in the current inventory.

i. Installation of proximity warning devices in all aircraft.

j. Continuing command emphasis on an education program to promote use of the operational hazard reporting system.

k. Conspicuous markings for all training aircraft in noncombat areas.

l. Use of high intensity strobe lights to increase aircraft conspicuity during daylight operations.

m. Continuous command action to insure the use of the see-and-be-seen concept.

n. Continued command actions to offset the effects of a rapid turnover of key training personnel.

o. Continuous and tight supervision over all formation flights to insure maintenance of at least two rotor discs separation between aircraft.

p. Command emphasis to insure that aviators at all levels know and understand published directives and unit SOP's concerning formation flying.

q. Radar vectoring of traffic in high density areas.

r. Assignment of and adherence to prescribed routes and altitudes in training areas.

2. Recommendations for the troop lift/tactical environment are:

a. Development and use of techniques to avoid loss of visual contact resulting from flare illuminations at night.

b. Improved planning and closer coordination between aircraft crews in fire support teams.

c. Continuing emphasis on increased alertness and aircraft separation during prime recovery periods after missions are flown.

d. Increased command emphasis on adhering to recommended limitations for daily and monthly crewmember flight hours to prevent cumulative fatigue.

e. Command emphasis in the form of constant surveillance of air traffic density, revision of air traffic control regulations, and strict control of aircraft operations. Particular attention must be given to aircraft density during unit buildups in low intensity warfare areas of operation.

f. Deliberate efforts by aircraft accident investigation boards to identify and substantiate all possible cause factors contributing to each accident.

g. Improvements in the publication and dissemination of flight directives, flight information, and SOP's.

h. Continuous command emphasis on adherence to published regulations and SOP's.

i. Command emphasis on continuous alertness of all aircrewmembers to detect other aircraft in the vicinity of their aircraft.

j. Command emphasis on improved selection of landing zones, pickup zones, and staging areas.

k. Command emphasis on an education program to promote full use of the operational hazard reporting system.

l. Increased supervision to prevent close formation flying in violation of published regulations.

m. Prohibition of unplanned formation flights.

n. Elimination of formation flying that is unnecessary to accomplish missions.

o. Improved planning and better supervision while conducting and executing airmobile operations.

Midair collisions most often result in catastrophic accidents, such as this OH-13 which collided with another OH-13 during training.

ANNEX I
(training)

Question: Why are numerous midair collisions occurring during daylight hours in periods of clear visibility?

FINDINGS:

1. Twenty-five midair collisions occurred in the training environment. Analysis revealed that 23 midair collisions occurred during periods of excellent visibility.

2. Aircraft density and the false sense of security of aviators while flying in traffic patterns under the jurisdiction of a control tower were the two major factors in these mishaps, as shown below:

Situation	No. of Mishaps	% of Sampling
Flying in a high density area	24	96%
Flying under jurisdiction of a control tower	12	48%

3. In a training environment, there is the ever-present possibility of crews being inattentive. Student aviators, in the early stages of flight training, concentrate more on flying the aircraft and devote less attention to the see-and-be-seen concept. This increases the probability of midair collisions due to the reduced chances of the aviators detecting other aircraft in time to avoid collisions.

4. In 13 of the 25 training midair collisions, one or both aircraft were flown solo. Only one pair of eyes was available for outside surveillance in 32 of the 50 aircraft involved. The following table shows the numbers of aircraft and occupants:

No. of Aircraft Involved	No. of Occupants Aboard Each Aircraft
21*	1 (solo)
12	2
11	2 (1 was under hood)
6	3 or more

*The average flight experience of solo students involved in midair collisions was 52.1 hours.

CONCLUSION: Careful consideration should be given to the use of buddy riders and their value in preventing midair collisions. This would increase the number of eyes available for surveillance outside the aircraft.

Question: What is the impact of inadequate command and control and lack of supervision?

FINDINGS:

1. Prior to 1966, the number of midair collisions did not appear significant due to the scattered and isolated pattern of occurrences. Following are the numbers of collisions by calendar year:

Year	Number of Mishaps
1963	1
1964	3
1965	2
1966	8 (high)
1967	3 (low)
1968	7 (high)
1969	1 (low)

The increased frequency of midair collisions subsequent to 1965 clearly indicates that command emphasis in the form of constant surveillance of air traffic density, revision of air traffic control regulations, and strict control of aircraft operation is a mandatory requirement. The large number of collisions during calendar year 1968 is attributed to the rapid turnover of key personnel at the aviation training bases. Command actions were initiated in 1967 and again in 1969 which appreciably reduced the number of midair collisions for those two years. Some of the positive actions taken were:

a. Radar vectoring of traffic in areas of high density.

b. Assignment of prescribed routes and altitudes.

c. Overall command emphasis in the elimination of midair collision mishaps.

2. Following are the locations of the 25 midair collision mishaps occurring in a training environment:

Location	Number of Mishaps
Fort Wolters, Texas	10*
Fort Rucker, Alabama	8*
Fort Stewart, Georgia	2*
Fort Benning, Georgia	2
Other CONUS Locations	1
Republic of Vietnam	2**

*Twenty of the 25 midair collisions occurred in ultrasaturated training areas.

**The two collisions in the Republic of Vietnam occurred in a training environment.

3. The 12 training midair collisions which occurred while aircraft were operating in stagefield/airfield traffic patterns revealed that the tower operations and deficiencies in equipment and personnel actions listed below were present and contributing factors in nine accidents.

a. Tower operators did not exercise positive control of air traffic in their area of responsibility.

b. The communications equipment installed in some towers does not provide transmitting and receiving capability with all aircraft operating in the vicinity of the airfield.

c. The design and location of towers used to control air traffic, particularly at training stagefields, restricts the visibility of air traffic controllers.

d. There were cases where inadequate manning of the control tower with fully qualified air traffic controllers resulted in these personnel being unable to control all the aircraft operating in the vicinity of the airfield.

4. Additional supervisory errors present pertaining to airfield/stagefield areas were:

a. Effective control measures such as establishment of traffic patterns and distribution of traffic pattern diagrams had not been initiated.

b. Standing operating procedures were not published in many instances. SOP's were inadequate to insure separation of aircraft operating in the local area in many accident reports reviewed.

5. Analysis of the 25 training collisions revealed the following additional information:

a. Thirteen collisions occurred in authorized training areas.

b. Six midair collisions occurred over navigational facilities.

c. Only three of the 25 accident investigation reports stated that adequate regulations were published.

d. Nine accident reports stated that a detailed survey of the local training areas should be conducted to prevent recurrences.

6. Formation flying:

a. Primary phase of training: A significant finding was that no mishaps occurred during formation flying in this phase of flight training. This can be attributed to tightfisted command and control, adequate briefings, and adherence to safe flying practices.

b. Advanced phase of aviation unit training: Two midair collisions occurred during formation flight, resulting in the loss of four aircraft and 24 fatalities. Both occurred in an advanced stage of training just prior to unit deployment and involved the No. 2 and No. 3 aircraft in flights of four aircraft. Although responsibility for maintaining proper separation between aircraft under VFR conditions rests with crewmembers, command supervision was determined to be an established factor in both collisions because:

(1) Radio silence was imposed for training reasons and hand signals were being used.

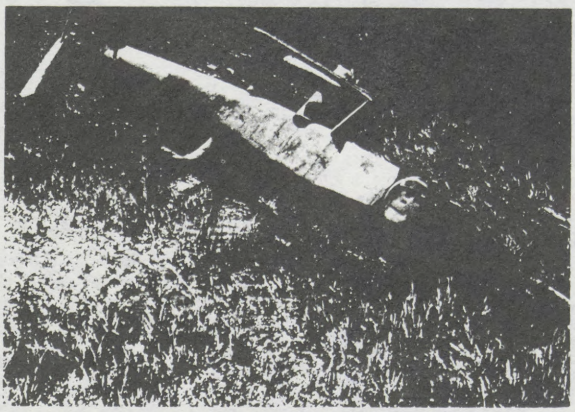
(2) A UHF (primary) radio had been removed from one of the aircraft prior to flight.

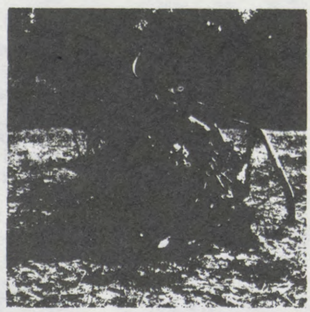
(3) SOP's were not adequate to govern formation flights.

(4) An aircraft commander executed flight maneuvers without first notifying the crews of every aircraft in the flight of his intentions. (A pilot error cause factor would be valid in these mishaps if the aircraft were not part of a formation of aircraft under the command and control of a flight leader. Strict discipline and immediate response to the commands of the leader are mandatory during formation flight. Therefore, responsibility for the safety of all aircraft in the flight rests with the flight leader.)

(5) Training missions were conducted in marginal weather, with reduced visibility.

(6) Established safeguards for avoiding pilot fatigue were not adhered to. The crewmembers





AH-1G crashed inverted in marsh and water after collision with OH-13 in photo above. Two occupants were killed and one survived with major injuries.

of two aircraft had exceeded the maximum recommended flight time for a 30-day period.

CONCLUSION: All aspects of command, control, and supervision as accident cause factors were not fully explored by accident investigation boards. The tendency was to accept pilot error as the only cause of the accidents. Investigation boards made only 27 positive recommendations in the reports of investigation of the 25 midair collisions occurring in the training environment. The recommendations included improvement of training areas, regulations, and local SOP's. This is a small number of recommendations, considering environmental conditions in which the accidents occurred. Five of the recommendations made were disapproved by approving authorities. It was noted that a trend prevailed for accident investigation boards to find the crew at fault when other causative factors were present. This is substantiated by the fact that accident investigation boards submitted less than one recommendation per accident that would reduce hazardous environmental conditions.

Question: What is the degree of violation of instructions or procedures and the principles of good airmanship?

FINDINGS:

1. Violation of published regulations and SOP's occurred in nine of the 25 training midair collisions. The following violations occurred:

a. Prescribed traffic patterns were not followed.

b. Proper separation was not maintained.

c. Deviations from designated flight routes.

d. Communication radios not tuned at designated times.

e. Noncompliance with control tower instructions.

2. Crewmembers did not insure that there were no other aircraft operating in the area prior to executing maneuvers in a high density area in 13 of the 25 midair collisions occurring in the training environment. Nine midair collisions occurred when one aircraft descended on top of another and four occurred when one aircraft climbed into another. Five of these collisions involved aircraft on approach to the same runway/lane.

3. Crewmember fatigue was an established causative agent in two accidents and present in two others. Ample time was provided for crew rest. The student pilots did not take advantage of this time. Fatigue of any crewmember impinges on the basic principles of good airmanship.

4. One or both student aviators involved in three midair collisions had histories of unsafe flying practices prior to the accidents. This fact was revealed through a review of instructor pilot statements and individual flight records of the students. The unsafe flying practices of these three students were prime contributing factors to the midair collision accidents.

CONCLUSIONS:

1. Student aviators must devote more attention outside the aircraft, rather than concentrating entirely on flying the aircraft and monitoring gauges.

2. Detection and elimination of marginally safe student aviators at an early stage of flight training should receive greater command emphasis.

Question: What action can be taken to eliminate aircraft density around focal points which seem to attract aircraft at random times? (Focal points could be navigation aids, on-going operations, airfields, etc.)

FINDINGS:

1. During the day, aircraft density continuously shifts throughout training areas. Although entire training areas remain areas of high aircraft density, concentrations of aircraft in certain sectors fluctuate from moderately to extremely high saturated areas. Stagefields, established airfields, and navigational facilities are generally in the highly saturated areas.

2. Time of day appeared to have no significance. A greater number of midair collisions occurred, however, during launching and recovery periods, as shown below:

Period of Day	Number of Mishaps
0700-0900 hours	4
0900-1100 hours	5
1100-1300 hours	4
1300-1500 hours	3
1500-1700 hours	8
After 1700 hours	1 (night)

3. An aircraft design deficiency was a contributing factor in three midair collisions involving TH-55's. These mishaps resulted in five fatalities and the loss of four aircraft. The 4-inch metal doorframe of the TH-55 restricts visibility on both sides of the aircraft. This problem, first noted during December 1966, was brought to the attention of appropriate authorities by the training command using the aircraft. The design deficiency remains uncorrected.

4. Conspicuity was reported as a possible contributing factor for 12 of the 25 collisions due to:

Inadequate anticollision lights	7*
Aircraft without distinctive markings	3
Sun	2

*Investigations revealed no evidence that anticollision lights were not in use by either aircraft involved.

5. Installation of proximity warning devices was recommended by boards investigating four of the 13 collisions which occurred in training areas while aircraft were in the vicinity of navigational aids/facilities. Consideration was given to airspeeds, altitudes, locations, and phases of flight to determine how many of the 13 collisions could have been prevented by the warning provided by a proximity

warning device. This analysis disclosed that 10 of the 13 could have been prevented if a functioning proximity warning device had been installed aboard each aircraft. The aircrewmembers involved in these 13 collisions were unaware of the presence of another aircraft.

6. During 1967, the Federal Aviation Agency (FAA) adopted a reporting program for near midair collisions (NMAC) which granted immunity to those involved. An analysis of 2,230 NMAC reports received by the FAA resulted in the compilation of 700 recommendations which would improve operating conditions and assist in preventing midair collisions. The Operational Hazard Report (OHR), DD Form 2696, used by the military services, offers no such immunity. AR 95-1 states that the originator's signature on the OHR is desirable, but not mandatory. Analysis of midair collisions revealed that the OHR is seldom used to report potential midair collision causative agents. An aviator's reluctance to use the OHR may be attributed to his lack of knowledge of its intent and purpose, or his fear that information contained in the report might impinge on his personal reputation or professionalism.

CONCLUSIONS:

1. Serious consideration must be given to eliminating design restrictions to visibility for all future Army aircraft procured for training. Current Army training aircraft should be modified to eliminate design visibility restrictions.

2. Proximity warning devices should be a requirement for all aircraft.

3. Operational Hazard Reports, DD Form 2696, are not being effectively used to identify existing and potential hazardous focal points. The OHR is a very effective tool for preventing midair collisions. Corrective measures must be instituted to eliminate hazards to safe flight that are identified in Operational Hazard Reports.

4. Currently authorized anticollision light systems are inadequate for a training environment. Serious consideration should be given to the use of high intensity strobe lights to increase aircraft conspicuity during daylight training operations.

5. The see-and-be-seen concept is the primary method available for preventing midair collisions.

ANNEX II
(troop lift/tactical)

Important! most occurred with their own aircraft

Question: Why are numerous midair collisions occurring during daylight hours in periods of clear visibility?

FINDINGS:

1. Thirty-one midair collisions occurred in the troop lift/tactical environment. Twenty-three occurred during periods of excellent visibility. This is not unusual because the majority of combat missions flown in the Republic of Vietnam are conducted under these conditions. Following are the conditions and numbers of collisions for each:

Condition	Number of Collisions
Excellent visibility	23
Night/reduced visibility	5
Day, weather/dust	3

Four of the five night collisions involved UH-1B/C armed helicopters. Two factors evident in these mishaps were:

a. Loss of visual contact with other aircraft after flare illuminations.

b. Loss of visual contact between aircraft of the light fire team while conducting fire support missions.

2. The 31 collisions involved a total of 63 aircraft. Seven aircraft were assigned to other services:

Service	Number of Aircraft
Army	56
Air Force	5
Marines	1
Vietnamese Air Force	1

There was no established trend as to locations where a midair collision between an Army aircraft and an aircraft from the other services occurs. As many took place in the vicinity of focal points as there were in operational areas.

3. Time of day appeared to have no great influence on midair collisions. A greater number occurred between 1500 hours and 1900 hours. This is a prime recovery period to base camp heliports after missions are flown.

Time of Day	Number of Collisions
0500-0700 hours	3
0700-0900 hours	5
0900-1100 hours	2
1100-1300 hours	3
1300-1500 hours	2
1500-1700 hours	6
1700-1900 hours	5
After 1900 hours (night)	5

4. Fatigue was an established factor in five of the 31 collisions, according to the aircraft accident

investigation reports. Further analysis revealed that the pilot in command of 37 of the 56 Army aircraft involved had flown in excess of 90 hours during the 30-day period prior to the accident. Of these 37, 29 aviators had exceeded 100 flight hours. Their total flight time for the 30-day period prior to the accident ranged from 101 to 167 hours. There was little or no mention of chronic flight fatigue, living conditions, mission requirements, or the stress of operating in a hazardous combat environment in the reports.

5. The constant requirement for formation flying is evidenced by the fact that 16 of the 31 collisions occurred while formation flying was in progress by one or both aircraft involved.

CONCLUSIONS:

1. There will be no appreciable change in aircraft density in the vicinity of focal points, i.e., landing and pickup zones, tactical areas of operation, base camp heliports, etc., in low intensity warfare operational areas. The concept of providing airmobility to enhance ground operations results in large numbers of Army helicopters and fixed wing airplanes, as well as numerous aircraft of other services and nations, using the airspace above the ground forces. The majority of midair collisions that occur in Vietnam will occur during daylight hours and there will be no severe restriction to visibility.

2. Flight time accumulated in excess of 100 hours per 30-day period is accepted by commanders and aircraft accident investigation boards. This problem can best be summed up by one of the flight surgeon's statements: "Chronic flight fatigue is cumulative and occurs due to incomplete physical and mental recuperation between repeated missions."

3. A requirement exists for adherence to flying hour limitations recommended by Army regulations. Personnel who exceed these maximum limits must be monitored by flight surgeons and aviation unit commanders to insure detection of complacency which could cause the aviator to become prone to accidents.

Question: What is the impact of inadequate command and control and lack of supervision?

FINDINGS:

1. Inadequate command, control, and supervision were present in 27 of the 31 collisions. This is a serious problem area. It was not uncommon to have two or more of these factors present in each midair collision. Following are the most common factors:

a. Laxity in flight control during formation flying.

b. Inadequate planning and proper execution of airmobile exercises.

c. Selection of inadequate landing zones, pickup zones, and staging areas.

d. Absence of adequate published and approved SOP's and directives and inadequate dissemination and enforcement of existing rules and procedures.

e. Absence of or insufficient coordination between different services.

f. Inadequate, or absence of, air traffic control facilities and ATC regulations.

2. Midair collisions between aircraft involved in formation flying accounted for 52% of the 31 mishaps. It is, therefore, necessary to elaborate on this category separately. Twelve of the 16 midair collision mishaps occurred between aircraft within a formation. The remaining four mishaps involved an aircraft not in formation flight with another aircraft which was in a formation. All collisions involved the No. 1, 2, and 3 aircraft, regardless of the size of the formation. Following are the factors revealed by this analysis:

a. Positive control was not maintained. This is evidenced by the flight leader permitting unnecessarily tight formation flying in violation of published regulations.

b. Conducting missions in marginal weather.

c. Conducting formation flights unnecessary to accomplish missions.

CONCLUSIONS:

1. Supervision appeared as a significant causative factor in the 31 midair collisions analyzed. However, these deficiencies received little or no attention by accident investigation boards and reviewing officials. Primary emphasis appeared to be concentrated on aviator factors.

2. The present system for disseminating changes to SOP's, NOTAM's, and other information to individual aviators is inadequate. Aviators often learn about changes in operational procedures and policies through mistakes and experience.

3. Contrary to common beliefs, statistics derived from this study showed the danger area for a midair collision in formation flying centers around the No. 1, 2, and 3 aircraft.

Question: What is the degree of violation of instructions or procedures and principles of good airmanship?

FINDINGS:

1. Crew error was listed as an established cause factor in the reports of 24 of the 31 collisions. Analysis of the 31 reports disclosed that violations of instructions/procedures and principles of good airmanship were present in all cases. Following are the four most prominent violations:

a. Aviators did not clear themselves and/or maintain a careful watch for other aircraft.

b. Adequate separation was not maintained between aircraft in formation flight.

c. Published regulations and SOP's were not followed.

d. Aviators did not maintain visual contact with other aircraft.

2. Five of the formation flight collisions occurred as the result of spur of the moment decisions to fly formation without prior planning. These five mishaps resulted in 18 fatalities, 11 serious injuries, and eight destroyed aircraft. Flights of this nature are in complete disregard for normal margins of safety and good airmanship.

CONCLUSIONS:

1. There is a need for aviators at all levels to know and comply with directives and SOP's pertaining to formation flying.

2. Formation flying that is not necessary for mission accomplishment must be eliminated.

3. Unplanned formation flying must be eliminated.

Question: What action can be taken to eliminate aircraft density around focal points which seem to attract aircraft at random times? (Focal points could be navigation aids, on-going operations, airfields, etc.)

FINDINGS:

1. Midair collisions increased as the aircraft inventory increased in the combat zone. Following are the numbers of collisions by calendar year:

Calendar Year	Number of Collisions
1963	0
1964	1
1965	3
1966	4
1967	7
1968	8
1969	8*

*Includes only the number of collisions through 29 October.

2. Focal points:

a. Navigation facilities. Two midair collisions occurred over navigation facilities; one when the facility was being used as a check point and the other when an aircraft collided with an Air Force aircraft over a navigation facility while the Air Force aircraft was making an instrument approach.

b. Ten midair collisions occurred in the vicinity of airfields, heliports, pickup zones, and staging areas. Cause factors included:

(1) Violations of published procedures.

(2) Regulations governing traffic patterns and air traffic flow around congested areas were not published.

(3) Inadequate communications.

c. On-going operations. Nineteen collisions occurred in operational areas. Aircraft density in these areas is generated by existing combat situations. Paramount cause factors in areas of on-going operations were lack of command and control, observation aircraft flying without a trained observer, and significant ground action present.

(1) Eight occurred during combat assaults with significant ground action present. In five cf these reports, it was stated that ground action was distracting and diverted the attention of the crewmembers.

(2) Five occurred between Army aircraft and aircraft of another service with no significant ground action present.

(3) Six occurred after missions had been completed and the aircraft were en route to home bases.

3. It was significant that armed helicopters were involved in 10 of the 31 collisions. This degree of involvement is high with respect to the number of armed aircraft in the tactical zone. Some of the factors revealed by analysis of collisions involving armed helicopters were:

a. Preoccupation of aircraft crews due to significant ground action.

b. Failure to maintain visual contact between aircraft on the same fire support mission.

c. Lack of command and control procedures between armed helicopters and other elements of troop lift flights.

d. Operation of armed helicopters during the hours of darkness without external lighting.

e. Conducting unnecessarily close formation flights which were not required for successful completion of missions.

CONCLUSIONS:

1. There will be no appreciable change in aircraft density in the vicinity of focal points, i.e., landing and pickup zones, tactical areas of operation, base camp heliports, etc., in low intensity warfare operational areas. The concept of providing airmobility to enhance ground operations results in large numbers of Army helicopters and fixed wing airplanes, as well as numerous aircraft of other services and nations, using the airspace above the ground forces. The majority of midair collisions that occur in Vietnam will occur during daylight hours and there will be no severe restriction to visibility.

2. Immediate command attention must be given to strengthening command and control procedures in areas of on-going operations. Measures must be initiated which will insure control of the number of aircraft within an operational area, coordination between all combat elements within the area (including the other services), and individual command and control of organic elements.

3. There is a vital need for controlling agencies of focal points, such as airfields, heliports, and navigational facilities, to insure the establishment of and compliance with the best possible traffic regulations and procedures.

4. All phases of armed helicopter operations must be analyzed to develop corrective measures for reducing the high susceptibility of armed helicopters to midair collisions.

ANNEX III
(midair collision profile)

The aircraft involved will be of the UH-1 type and the collision will occur between two aircraft during daylight hours with the visibility at 10 to 20 miles. There will be 2.4 crewmembers per collision aircraft or 4.8 crewmembers per mishap. There will be 5.03 fatalities (both crew and passengers) in each mishap. The aircraft will be involved in some form of training operations. The crews will have performed 2.7 hours of flight prior to the collision and will have been on duty 5.1 hours of the duty day. The aircraft involved will not be in formation. Neither will they be climbing, nor turning, but will simply converge. They will be in radio communication with each other. The collision will occur between the altitudes of 1,001 feet and 2,000 feet absolute. The two aircraft will not necessarily be using the same navigation facility, and the experience level (flight time) of the aviators in command will not be a factor. The collision will take place in an area of known high density traffic. Inadequate command and control or a lack of supervision will be present in 50% of the mishaps. And some degree of violation of instructions or procedures, or the violation of the principles of good airmanship will exist.

PREFACE

While engaged in training, a light observation helicopter was on the downwind leg of a heliport traffic pattern in late afternoon, flying south. The pilot entered a left turn to the eastbound base leg and his helicopter collided with an OH-13 which entered traffic by a straight-in approach to the base leg. Both helicopters crashed, killing the pilots. Visibility was 15 miles and the sun, behind the pilot of the OH-13 and to the right of the other pilot, did not obstruct the visibility of either pilot. This training environment accident occurred because neither pilot saw the other helicopter in time to initiate evasive actions to avoid collision.

During a right echelon formation of four UH-1H's in a combat area, the pilot of the No. 3 helicopter flew too close to the No. 2 helicopter and the main rotor blades collided. The No. 2 helicopter was crash landed, with extensive damage. The No. 3 helicopter fell to the ground and exploded, killing the crew of four. This tactical environment accident occurred because the No. 3 pilot attempted to fly excessively close formation in violation of established rules.

The above excerpts, taken from Army aircraft accident investigation reports, vividly portray the results of midair collisions. There are a few midair collisions recorded wherein only minor damage to one or both aircraft occurred. These are exceptional since most midair collisions are catastrophic, resulting in destruction of the aircraft involved and the death of the occupants. Midair collisions have long been one of the gravest hazards to safe flight. As aircraft density increases in both the combat and noncombat environment, the potential for the occurrence of midair collisions increases correspondingly, requiring of the crew and controller a greater degree of alertness and care in aircraft operations. Because of density, aircraft speed, and persistent hazy conditions, it may well be that aviation in general has passed the point where timely visual detection of other aircraft by the aircrew (see and be seen) is sufficient to insure against the midair collision.

One of the first teaching points voiced by instructor pilots to their students is: ''Keep your head on a swivel to prevent collision with aircraft and other hazards to flight.'' The basic tool used by aviation safety officers to prevent midair collisions is the see-and-be-seen philosophy. This fundamental rule is essential to safe operation of Army aircraft. Yet, it is a fact that aviators inadvertently violate instructor pilots' orders or ignore the see-and-be-seen philosophy and do not see aircraft operating in their vicinity. How many times have you been advised by radar operators that a target is at your -- o'clock position and, even after the warnings, been unable to find the other aircraft? I believe the answer is, unfortunately, frequently! It is evident that the see-and-be-seen philosophy is inadequate to prevent midair collisions in training and operational areas which are saturated with military and civilian aircraft.

Technological advancements have proven beneficial in improving the crashworthiness of aircraft and in numerous other areas of the aircraft accident prevention field. Proximity warning devices are presently available which alert aviators of other aircraft in their vicinity. The proximity warning device has been installed in a limited number of Army aircraft. Aviators flying TH-13T helicopters with the proximity warning device installed will respond to any warning received and initiate evasive action necessary to prevent a midair collision. However, they can have confidence in the system only if they know that all other aircraft which may be in the immediate area are similarly equipped. It is apparent that a strong case exists for the installation of proximity warning devices in all Army aircraft. The monetary savings brought about by the prevention of one midair collision involving two UH-1 helicopters would go a long way toward equipping the Army aircraft fleet with proximity warning devices.

Certain constraints make it difficult to modify the Army's aircraft fleet with the proximity warning device in the foreseeable future. It is, therefore, mandatory that all aviators and crewmembers increase their alertness and initiate actions to prevent midair collisions. Aviation unit commanders must also initiate action to insure that conspicuity marking of their aircraft is properly maintained. The commander must be alert and recognize indicators that reflect aviators' inattentiveness to regulations and unit standing operating procedures directed toward accident prevention. Aviation staff officers must consider the probability of midair collisions while planning airmobile operations. Sightseeing in the area of airmobile operations landing zones must be eliminated.

As aircraft and cockpit sophistication increase, requiring more head-in-the-cockpit time, the requirement for rapid and effective scanning of areas outside the aircraft increases. Installation of proximity warning devices holds the only promise for assisting aircrews to avoid collisions, but these devices can only assist. There will always be a requirement for each member of the Army aviation team to be alert, keep his head on a swivel while airborne to see other aircraft in his vicinity, and take necessary actions in his sphere of responsibility to prevent catastrophic midair collision accidents.

EUGENE B. CONRAD
Colonel, Infantry
Director

STATEMENT OF ARTHUR A. LAVINE, PRESIDENT, LEXco

INTRODUCTION

The most critical period for obstacle collision avoidance by aircraft is during low altitude flight operations, i.e. during takeoff and landing of all aircraft, at high altitude flight when flying close to mountain terrain, and extended low level flight encountered in crop duster operations. It is during such operations that the ability to penetrate and survive extended flight operations at low level (100 feet down to ground) rests not only on the capability of terrain clearance and avoidance of gross obstacles in the flight path such as other aircraft, trees, poles, towers and buildings, etc., but also on the ability to sense and avoid high resolution type obstacles (power lines, guy wires, telephone lines, birds, and suspension bridge cables). These high resolution obstacles are randomly scattered over the countryside.

The resolution limitation of the human eye coupled with the inability to discriminate wire obstacles from background clutter often result in an inability of the pilot and vehicle to react in time to avoid collision.

Radar devices, like the human eye, are also unable to resolve and display these high resolution cable type obstacles, and do not give the universal protection required.

In answer to the obstacle collision threat for *all* material obstacles within the collision threat zone of an aircraft regardless of obstacle size, LEXco. proposes the use and adoption of its laser collision warning and avoidance system.

LEXco.'s system establishes a truncated field of view elliptical cross section cone in space forward of the vehicle. The cone angles and length of the cone (from apex to truncation) are a function of the vehicle velocity and the maximum vehicle clearance dimensions required. Any obstacle outside this cone does not pose a collision threat. Any obstacle which enters the cone will result in collision if an avoidance maneuver is not executed in time.

In LEXco.'s system when an obstacle enters the field of view cone (collision threat zone), it is sensed and displayed in parallel by an audio alarm and a television screen.

In obstacle free flight the pilot flies in a normal visual contact flight mode. When a threat enters the collision threat zone the audio alarm alerts the pilot to the television screen and he decides upon and executes an avoidance manueuver while observing the continuous screen display.

The system incorporates:

1. A 25 megawatt water cooled ruby Laser transmitter with 20 nanosecond pulsewidth pulsed at 1.5 pulses per second for illuminating obstacle within the collision threat zone.

2. A pulsed image intensifier and Kerr cell (optional) to range gate out background clutter and near field backscatter. The range gate is varied as a function of minimum allowable reaction range (velocity dependent).

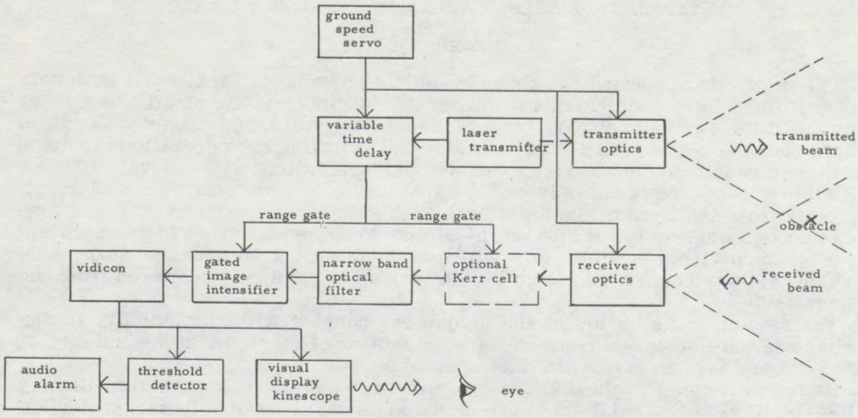


Figure 1. Schematic of LEXco.'s Laser System.

3. A vidicon sensor for high resolution (246 line vertical × 738 line horizontal) short time response (0.67 second) acquisition.
4. A television display (246 × 738 line) with long persistence (0.5 second) phosphor for continuous (1.5 per second) display.
5. A threshold detector and audio alarm.
6. Associated power supplies, timing circuits and electronics.
7. Transmitter and receiver optics whose field of view (cone angle) are varied as a function of velocity.
8. A narrow band optical filter centered at the laser transmitter frequency to eliminate solar reflections off background.
9. A slewing servo for utilizing the system for turning maneuvers.

System weight is less than 40 pounds. System volume is less than 2.3 cubic feet. Power requirements are less than 600 watts.

All subsystems of LEXco.'s collision warning and avoidance system incorporate test proven concepts. No breakthroughs are required. Tests to date have demonstrated the ability to acquire, range gate, and yield sufficient signal-to-noise ratio for a high resolution sensing and display of a ¼ inch diameter steel cable in both sunlight, rain and smog conditions.

The components used in those tests were well below optimum, and test substantiated theory demonstrates that more than adequate field of view, resolution, range gating, signal-to-noise ratio (background plus system greater than 46:1) for acquiring ⅛ inch diameter cable at 6,000 feet range with sufficiently short response time to avoid collision.

U.S. Patent No. 3,390,271 covering this system was issued to LEXco.'s founder on 25 June 1968.

The high resolution television display on the raster representing known cross-field dimensions (the vertical dimension is twice the aircraft height, while the horizontal dimension is twice the aircraft wingspan) at the known range entrance pupil enables immediate recognition by the pilot of all obstacles regardless of size within the collision threat zone, their interrelation, and in turn enables the pilot to execute the optimum avoidance maneuver (right turn, left turn, climb above, descent and clear below, deceleration or acceleration).

Since all obstacles are viewed realistically (trees are displayed as trees, cables as cables, poles as poles, birds as birds, etc.) and are displayed as a two dimensional pattern in shades of grey, the pilot can reject random noise patterns and discriminate noise from signal in the display. Since background is time/range gated out, only obstacles which pose the threat of collision remain on the black background within the display field. This eliminates the requirement for complex display logic inherent in other systems, and utilizes the natural and trained ability of the pilot to react for collision avoidance maneuvers.

The realistic two dimensional continuum display in LEXco.'s system results in essentially a zero false alarm rate and 100% obstacle recognition and avoidance.

LEXCO.'S SYSTEM CONCEPT

The LEXco.'s laser system (see fig. 1) consists of a ruby LASER transmitted with variable beamwidth optics, variable field of view and focal length receiving optics, a Kerr cell (optional), a narrow-band filter, an S–25 photocathode image intensifier coupled with a vidicon, a variable time delay and high voltage pulser, a visual display kinescope, and a threshold detector and audio alarm.

The ruby Laser fires 20 nanosecond pulses through the transmitted optics at a pulse repetition frequency of 1.5 pps. This illuminates the required field of view. Everything within the field reflects the incident pulse sequentially in time as a function of range.

The return power is focused by the receiver optics through the narrowband filter and Kerr cell (optional) onto the photocathode of the range gated (pulsed) S–25 image intensifier tube coupled with a vidicon.

The function of the narrow-band filter is to cut down the background noise (basically solar reflected power) while allowing transmission of the ruby LASER power.

The Kerr cell (optional) and the image intensifier is opened at 0.2 usec and abruptly closed at the allowance range (i.e. range for executing an obstacle avoidance maneuver). The Kerr cell (optional) and image intensifier which are open for approximately 12 μsec prevent the integration of solar background power on the photocathode of the vidicon during the time difference between range gate open time and the readout frame time of the vidicon. Since the photocathode of the image intensifier is partially transparent to light and since the photo emissive character of the phosphor of the image intensifier is real although down a factor of 5×10^{-4} from that of the image intensifier photocathode, the Kerr cell whose closed transmittance is 10^{-2} can be used in conjunction with the gated image intensifier to enhance the signal-to-noise ratio. The gating pulse rise and fall times are 50 nonosecond (25 ft.).

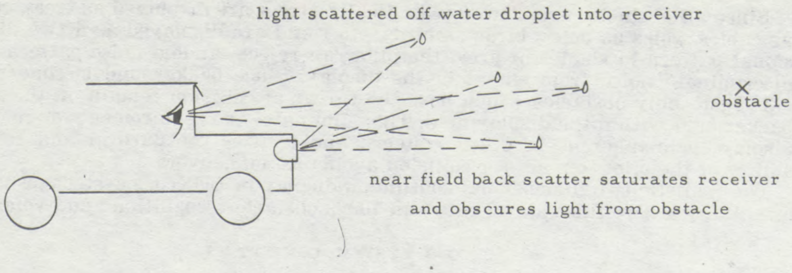
This elimination of near field back scatter saturation of the receiver greatly enhances the bad weather operation characteristics regardless of wavelength used.

In LEXco.'s LOTAWS near field back scatter is time gated out, only allowing light reflected from greater than 80 ft. into the receiver.

The ground speed servo has dual functions:

1. To adjust the beamwidth, the field of view, and the focal length of the optics for operation in the correct aircraft velocity regime.
2. To adjust the length of the pulse controlling the Kerr cell (optional) and open time of the image intensifier photocathode. This yields proper range gating for variations in aircraft velocity.

The vidicon video output is fed in parallel to a visual display kinescope and a threshold detector—audio alarm. The display consists of a television picture of an obstacle within the field, along with the range to target and viewing field. When a signal exceeds the threshold detector level, an audio alarm is actuated.



In LEXco.'s system near field back scatter is time/range gated out, only allowing light reflected from greater than 80 ft. into receiver

auto driver in fog analogue illustration of near field back scatter saturation problem and time/range gating solution

Advantages of LEXco.'s laser aircraft collision warning and avoidance system

1. LEXco.'s laser system acquires, resolves, and displays not only gross obstacles but also high resolution obstacles (such as power lines and birds) to enable collision avoidance. Neither radar nor the human yet can do this.

2. LEXco's system yields realistic TV display of actual obstacles within the collision threat zone (both within the field of view and the allowable reaction range). This enables the pilot sufficient time to decide upon and execute an *optimum* avoidance maneuver. In contrast competing laser systems indicate only the one dimensional placement of obstacles. These competing laser systems do not indicate the nature of the obstacle within the collision field. Thus only one automatic avoidance maneuver can be programed, which may not be the optimum avoidance maneuver and may still result in collision.

3. The amount and quality of the realistic data displayed on LEXco.'s laser system enables essentially a *zero* false alarm rate and 100% collision avoidance, while competing systems can exhibit avoidance maneuvers from stray electronic noise in the system and still not give complete collision protection from real obstacles.

4. Pilots prefer (and from safety considerations rightly so) a system which supplies a realistic display enabling the pilot to control his own survival and that of his payload, rather than an automatic system in which he is blind to high resolution obstacles in which a fixed (not necessarily an aptimum) maneuver is triggered on real obstacles or noise in the electronics.

5. LEXco.'s realistic display is updated every ⅔ of a second which enables the pilot to continually close his control loop during an avoidance maneuver.

6. The pilot is not slaved to his TV display but is only alerted to it when an audio alarm alerts him to an obstacle entering the collision threat zone in range and field.

7. LEXco.'s system operates effectively in fair weather and foul weather because of transmitter bandwidth and near and far range gating. The near range gate eliminates near field backscatter saturation of the receiver from light scattered of fog, while the far gate gates out background clutter.

8. The system has low weight and volume, and low average power is required.

9. The system was developed at private expense and is protected by U.S. Patent No. 3,390,271.

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