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Fact Sheet for the Honorable
J. James Exon
United States Senate

April 1986

AIR SAFETY

Federal Aviation Administration's Role in Developing Mid-Air Collision Avoidance Back-Up Systems

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UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

RESOURCES, COMMUNITY, AND ECONOMIC DEVELOPMENT DIVISION

April 22, 1986

B-222851

The Honorable J. James Exon
United States Senate

Dear Senator Exon:

Your June 5, 1985, letter requested that we obtain information regarding the Federal Aviation Administration's (FAA) actions in the development of mid-air collision avoidance back-up systems. Specifically, you asked for information regarding (1) whether a commercial air-based collision avoidance system has been available since 1975, (2) the difference between FAA's Traffic Alert and Collision Avoidance System (TCAS) and its predecessor, the Beacon Collision Avoidance System (BCAS), (3) the projected date for commercial availability of FAA's current TCAS system,[1] (4) the comparative costs and effectiveness of a commercial system versus FAA's system, (5) whether there has been any FAA misconduct or inefficiency regarding mid-air collision avoidance back-up systems, and (6) any GAO recommendations concerning the implementation of these systems.

As agreed with your office, we did not address the issue of whether there was misconduct or inefficiency within the FAA regarding mid-air collision avoidance systems because on July 1, 1985, the U.S. Merit Systems Protection Board's Office of Special Counsel referred allegations of FAA misconduct and inefficiency to the Secretary of Transportation for investigation and report. These allegations specifically concerned FAA's role in developing mid-air collision avoidance back-up systems and were investigated by Transportation's Office of Inspector General. The Inspector General's investigation was recently completed and the case summary was sent to the Special Counsel on January 30, 1986 (6VI-003). The Inspector General found no support for the allegations made.

On October 30, 1985, we briefed you on our examination. We agreed with your office that after performing some additional work, we would provide a document containing facts, without

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[1]TCAS was formerly known as the Threat Alert and Collision Avoidance System.

conclusions or recommendations, on your specific questions relating to FAA's role in developing mid-air collision avoidance back-up systems.

The facts for each of your questions are presented as individual sections in this report. We gathered the information from discussions with and documentation obtained from officials of the FAA; the National Transportation Safety Board; the Office of Technology Assessment; the Department of Transportation's Office of Inspector General; the Air Transport Association; the National Business Aircraft Association; the Aircraft Owners and Pilots Association; the Air Line Pilots Association; MITRE Corporation, and a former MITRE Corporation employee; Bendix Corporation; Sperry, Dalmo, Victor Corporation; Minneapolis-Honeywell Corporation--the manufacturer of a commercial mid-air collision avoidance system; and a former employee of FAA's Office of General Aviation who still favors the commercial system. We also identified studies and reviewed articles, testimony, and congressional hearings regarding mid-air collision avoidance systems.

The information provided in this document was discussed with responsible FAA officials, and they agreed with the facts as presented. As arranged with your office, unless you publicly announce its contents earlier, we will not distribute this fact sheet until 15 days after its publication date. If you have any further questions on the information provided, please contact me on 275-7783.

Sincerely yours,

Herbert R. McLure

Herbert R. McLure
Associate Director

Contents

ABBREVIATIONS

ACAS	Airborne Collision Avoidance System
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
AVOIDS	Avionic Observation of Intruder Danger System
BCAS	Beacon Collision Avoidance System
EROS	Eliminate Range Zero System
FAA	Federal Aviation Administration
RCA	Radio Corporation of America
SECANT	Separation and Control of Aircraft using Nonsynchronous Techniques
TCAS	Traffic Alert and Collision Avoidance System

SECTION 1

AIRBORNE COLLISION AVOIDANCE SYSTEM AVAILABILITY

QUESTION:	Has an air-based Airborne Collision Avoidance System (ACAS) been available since 1975?

RESPONSE:

By the 1970's, several different ACASs had been developed by private industry. However, according to FAA, none could have been adopted for national implementation without additional work to correct technical and operational problems identified during FAA-sponsored testing. Rather than pursuing ACAS development, FAA and user groups became interested in another technology--the Beacon Collision Avoidance System (BCAS). FAA officials said that unlike ACAS, BCAS used the Air Traffic Control Radar Beacon System (ATCRBS) equipment, in which FAA and over 100,000 aircraft in the airfleet had already invested. ATCRBS is the network of ground-based radar beacons and aircraft-installed transmitters the FAA uses to assure that aircraft are safely separated in controlled airspace. According to the FAA TCAS Program Manager, BCAS was chosen over ACAS primarily because FAA believed it offered a greater amount of immediate protection at less overall cost to the aviation community.

FAA believed BCAS was less costly and more effective because BCAS-equipped aircraft would have been alerted to any ATCRBS-equipped aircraft since it would obtain and monitor ATCRBS transmissions from them whether these other aircraft had BCAS or not. Conversely, FAA said that because ACAS was not compatible with ATCRBS, airplanes equipped with ACAS would not know of any

aircraft not similarly equipped, making it necessary for almost all aircraft to install ACAS before any were protected. Further, aircraft owners buying ACAS would have had to buy it in addition to the ATCRBS equipment already required by FAA.

The search for a workable ACAS had been in process since the 1950's. Working through the Air Transport Association, the airline industry began the search in 1955. The airlines felt they needed ACAS to act as an independent backup to FAA's ground-based air traffic control system, and to provide aircraft separation assurance in airspace outside the area of ground-based control. Efforts to develop an ACAS suitable for national implementation intensified after two airliners collided over the Grand Canyon in 1956.

From 1956 to 1969, the airlines, industry, and FAA explored the collision avoidance problem and developed a number of concepts. FAA formed its Collision Prevention Advisory Group in 1959, and in addition to monitoring industry efforts, began to develop several collision prevention concepts of its own. During 1970 and 1971, FAA monitored the development and testing of several approaches to collision avoidance proposed by industry.

In 1971, the Government Activities Subcommittee, House Committee on Government Operations, and the Subcommittee on Aviation, Senate Committee on Commerce, Science, and Transportation, held hearings on aircraft collision avoidance systems. During these hearings, industry and potential user groups testified in support of making airborne collision avoidance back-up systems mandatory. However, FAA testified that the various commercial systems available needed more thorough testing before any could be selected for national implementation. FAA agreed to test the various ACAS concepts being proposed.

From 1972 to 1976, FAA tested Minneapolis-Honeywell's Avionic Observation of Intruder Danger System (AVOIDS), McDonnell-Douglas'

Eliminate Range Zero System (EROS), and the Radio Corporation of America's (RCA's) Separation and Control of Aircraft using Nonsynchronous Techniques (SECANT). FAA concluded that the Minneapolis-Honeywell AVOIDS was technically and economically superior to the McDonnell-Douglas and RCA systems. However, FAA found that none of these systems were compatible with ATCRBS and all three developed electromagnetic interference with existing radar altimeters. According to FAA, the radar altimeters would have had to be moved to another radio frequency in order to eliminate this problem. FAA also said that ACAS required additional work to correct a false alarm problem it had in dense air traffic.

The FAA had started development of its BCAS in 1974. The shift away from ACAS to BCAS in 1976 was supported by the airline industry and potential user groups, including the Air Transport Association, the National Business Aircraft Association, the Air Line Pilots Association, and the Aircraft Owners and Pilots Association. Subsequently, however, it was found that BCAS developed interference problems in dense air traffic. After further corrective development, the evolved system was renamed TCAS. (See p. 7.)

SECTION 2
DIFFERENCE BETWEEN THE TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM AND THE BEACON COLLISION AVOIDANCE SYSTEM

QUESTION: What is the difference between FAA's Traffic Alert and Collision Avoidance System (TCAS) and its predecessor, BCAS?

RESPONSE: In June 1981, FAA announced that TCAS would be the national standard for airborne collision avoidance. TCAS evolved from the development and testing done to eliminate the interference problem that BCAS had. Essentially, this problem happened when the numerous data requests and replies generated by BCAS overlapped and became distorted in dense air traffic (known technically as synchronous garble).

According to FAA, TCAS eliminates the interference problem by using a totally airborne system of variable power levels, airborne directional antenna(s), and new selective address equipment (mode S). TCAS is designed to operate effectively in air traffic densities 10 times greater than those in which BCAS was expected to operate. FAA also said that BCAS was primarily designed for air carrier use and that TCAS design included a lower-cost, less-capable model for general aviation.

FAA plans call for three TCAS models in order to provide mid-air collision protection to both general aviation and air carrier aircraft. TCAS I, the least costly and technically sophisticated model, is expected to provide traffic proximity warnings but no recommended collision avoidance maneuvers. It is primarily designed for use by general aviation aircraft. TCAS II and TCAS III are intended primarily for air carrier, commuter, and

corporate jet aircraft. These systems provide the pilot with the threatening aircraft's position and recommended collision avoidance maneuvers. TCAS II only recommends vertical (climb or descend) maneuvers, while TCAS III recommends both vertical and horizontal maneuvers.

SECTION 3

TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM PROJECTED COMMERCIAL AVAILABILITY DATE

QUESTION:	What is the projected date for commercial availability of the FAA's Traffic Alert and Collision Avoidance System (TCAS)?

RESPONSE:

In June 1981 the FAA Administrator declared FAA's commitment to making TCAS operational nationwide by mid-1985, at the latest. However, FAA's TCAS Program Manager told us that the first TCAS equipment, designed for air carrier, commuter, and corporate jet aircraft, will probably not be commercially available until around 1990. The Program Manager also said that he does not know when TCAS I equipment to meet the needs of the general aviation community will become commercially available, and that availability would probably wait until the cost of the new technology comes down.

According to the TCAS Program Manager, the design/development and testing of TCAS I and III is being conducted by FAA's engineering group. He also said that the design/development and testing left to be done on TCAS II is now being conducted by two commercial industry/airline teams (Bendix Corporation/United Airlines and Sperry, Dalmo, Victor Corporation/Piedmont Airlines), with the FAA engineering group in a support role. System certification is the responsibility of a separate FAA office--the Office of Airworthiness.

FAA's primary emphasis is on TCAS II development for air carrier use. TCAS II is currently scheduled to start the second phase of its operational evaluation in April 1986.

The Air Transport Association believes that TCAS II offers the greatest potential for the early availability of an acceptable collision avoidance system. However, the Airline Pilots Association and the Aircraft Owners and Pilots Association say that only TCAS III, with its horizontal and vertical recommended avoidance maneuvers will adequately meet aviation needs. The Airline Pilots Asociation would like FAA to shift its emphasis from developing TCAS II to developing TCAS III and remain in the program until it has been proven suitable for use in scheduled airline service. The National Business Aircraft Association has expressed similar views, as has one of the airlines participating in TCAS testing.

Currently, FAA intends to end its developmental role in TCAS completely after TCAS II has been tested for operational and engineering acceptability in scheduled airline service. This date has slipped 14 months, to June 1988, partially due to a strike at one of the airlines participating in the test program and unforeseen equipment certification problems. After this last testing phase is complete, FAA expects industry to take over the program, bring TCAS II into commercial production, and ultimately produce TCAS I and III as well.

FAA's development of TCAS I and III is scheduled to end in December 1986 and April 1987, respectively. Program officials expect that all the engineering data necessary to develop minimal operational performance specifications for TCAS I and III will be completed by those dates. Program officials said that industry will be able to produce equipment that will meet FAA standards from the specifications.

The TCAS Program Manager told us there are no estimates of how long it will take air carriers and general aviation aircraft owners to use TCAS once it is commercially available. Program officials said TCAS acquisition will be voluntary, not mandated. However, they said that the two airlines participating in TCAS

testing are committed to the program and will probably equip with TCAS as soon as it becomes available. According to these officials, once one air carrier equips with TCAS, all the other airlines are expected to also equip because failure to do so might result in legal liability in the event of a mid-air collision.

General aviation pilots, however, may take a different view. Although most mid-air collisions involve general aviation aircraft, we were told by FAA program officials that, presently, general aviation is not very interested in acquiring TCAS equipment. Also, on November 23, 1985, the Aircraft Owners and Pilots Association testified before the Subcommittee on Investigations and Oversight, House Committee on Science and Technology, and questioned whether TCAS provides the greatest safety improvement for the investment. The Association's Vice President for Aviation Policy also told us that if general aviation aircraft owners were to purchase this equipment voluntarily, TCAS would have to provide a significant increase in flight safety at reasonable cost. He also said that the Association would oppose any legislation to mandate TCAS use. The Association has a membership of about 265,000 pilots.

In October 1985, the National Transportation Safety Board Chairman testified before the Subcommittee on Aviation, Senate Committee on Commerce, Science and Transportation. In his testimony, the Chairman said that FAA should evaluate its intentions not to impose a requirement for TCAS in large aircraft used in air carrier service. He said the effectiveness of TCAS in preventing mid-air collisions will not be realized until the systems are in widespread use, and that most likely will occur only through regulation.

SECTION 4

AIRBORNE COLLISION AVOIDANCE SYSTEM AND THREAT ALERT AND COLLISION AVOIDANCE SYSTEM COST AND EFFECTIVENESS

QUESTION:	What are the comparative costs and effectiveness of the ACAS and TCAS systems?

RESPONSE:

A meaningful comparison of cost and effectiveness cannot be made for ACAS and TCAS. Although the cost figures available suggest that ACAS is less expensive per unit, it is a considerably different system and would not meet current FAA requirements. Also, to be effective for any aircraft, almost all aircraft would have to have a working ACAS, unlike TCAS, which protects regardless of whether other aircraft are equipped. Therefore, although ACAS may have cost less per unit, the overall costs to the aviation community could be greater to obtain effective protection. The following sections provide information on cost and effectiveness estimates concerning the different systems.

Of the three ACASs tested in 1975, AVOIDS, EROS, and SECANT, FAA identified the Minneapolis-Honeywell AVOIDS as the most promising. However, a Minneapolis-Honeywell company official told us that the cost to make a nationally workable AVOIDS today is unknown, and would have to include any subsequent FAA system requirements changes.

In December 1975, ARINC Research Corporation, under FAA contract, estimated how much the air carrier, general aviation, and military versions of the Honeywell, McDonnell-Douglas, and RCA ACASs would cost the aviation community. Based on the ARINC data,

FAA compiled total 1-year cost estimates for each of the ACASs, and included this information in its report on the analysis, flight test and evaluation of these systems (FAA-RD-76-17, January 1976). The estimates were in 1975 dollars and did not include the additional cost of ground equipment required for EROS. The cost estimates are presented in Table 4.1.

TABLE 4.1
Estimated 1-Year ACAS Cost
To The Aviation Community
(1975 Dollars)

System	Air Carrier	General Aviation Performance		Military Performance	
		High	Low	High	Low
Honeywell/AVOIDS	$10,989	$ 8,381	$1,179	$15,200	$4,052
McDonnell-Douglas/EROS	11,693	9,264	1,875	15,991	4,655
RCA/SECANT	12,687	10,445	2,121	16,891	4,768

As noted earlier, FAA testing identified problems requiring resolution in each of these systems before national implementation would have been possible. The costs in Table 4.1 do not reflect the additional development and testing expense that would have been involved.

In December 1983, FAA's Office of Aviation Policy and Plans completed a cost study of TCAS II, and based on a production run of 800 units, arrived at an estimated average retail hardware cost of $66,828 and $82,237 per unit, in 1983 and 1987 constant dollars, respectively. The study stated that average rates for overhead and general and administrative costs were included in the figures, but that installation and check-out costs were not. The study also pointed out that the $66,828 and $82,237 figures were higher than the TCAS program manager's 1980 $45,000 estimate adjusted to $58,249 and $71,681 in 1983 and 1987 constant dollars, respectively. The study did not provide estimated costs for TCAS I or TCAS III models.

On November 23, 1985, the FAA Deputy Associate Administrator for Engineering testified before the Investigations and Oversight Subcommittee, House Science and Technology Committee. In his testimony, he estimated that the TCAS program would cost $42 million through its scheduled completion in fiscal year 1988, and he said that it was not feasible to determine the cost of TCAS equipment at that time. Instead, the following price goals were given for each of the TCAS models:

--TCAS I, $4,000 to $15,000;

--TCAS II, $50,000 to $60,000; and

--TCAS III, $70,000 to $90,000.

According to FAA program officials, these ranges are speculative, since TCAS is still under development, and they cannot be sure of what the costs will ultimately be. Industry officials involved in TCAS development also stated that TCAS costs are speculative at this time, but provided cost estimates for TCAS II and III. Neither of these industry officials had developed costs for TCAS I, and both expressed doubt that TCAS I would ever become a viable product from the market standpoint.

The cost ranges provided by one industry source generally corresponded with figures provided in FAA's November testimony. However, the estimates provided by the other industry official were higher--$75,000 for TCAS II and $100,000 for TCAS III, in 1986 dollars.

Some program officials and potential TCAS users also think that TCAS costs could exceed the ranges provided in the FAA November testimony. For instance, one TCAS program official said that TCAS II might cost $90,000 a unit by the time it is commercially available. The Aircraft Owners and Pilots Association

stated that by the time they are commercially available TCAS I, II, and III units might cost $20,000, $80,000, and more than $100,000 each, respectively.

We found no studies comparing the effectiveness of ACAS and TCAS. However, in 1976, the MITRE Corporation studied the hypothetical effectiveness various collision avoidance systems might have added to the ground-based ATC system in preventing 228 mid-air collisions that had occurred from 1964 to 1972, and 227 near mid-air collisions reported in 1975. Among other things, these studies considered existing ATC capabilities, planned ATC improvements, ACAS, and BCAS, the system TCAS evolved from.

In July 1976, MITRE personnel briefed FAA on the results of their two studies. The briefings concluded that, in connection with the ATC system, ACAS could have conceivably prevented all 228 past mid-air collisions that occurred over the 8-year period studied, and 173 of the near mid-air collisions they studied for 1975. The studies also concluded that BCAS and the ATC system could have conceivably prevented 120 mid-air collisions, and depending on the assumptions used, 6 to 52 near mid-air collisions. According to FAA, however, it is incorrect to compare the ACAS and BCAS figures and conclude that ACAS was a more effective alternative than BCAS. According to FAA, the high level of ACAS effectiveness is due to the MITRE study's assumption that ACAS was a nationally viable system, which FAA says it was not, and that all 240,000 or so domestic aircraft (air carriers and general aviation) would have been equipped with it. FAA said that in the evaluation of BCAS effectiveness, all domestic aircraft were assumed to have altitude reporting transponders and only the 2,200 or so air carriers were assumed to have BCAS.

Information we gathered from FAA and user groups indicates that it may not be realistic to assume a 100 percent domestic equipage rate for any mid-air collision avoidance back-up system.

Also, the analysts involved in the 1976 MITRE studies told us that the operating assumptions made in this type of analysis are not always realistic in the "real world" sense but, in the absence of other data, must be made in order for any analysis to take place. They said that the results of the 1976 studies were heavily affected by the assumptions that all aircraft had ACAS and only air carriers had BCAS, because most of the mid-air collisions and near mid-air collisions were between general aviation aircraft.

The MITRE studies also concluded that if only air carriers were ACAS-equipped, ACAS would not have prevented any of the mid-air collisons studied and fewer of the near mid-airs studied involving air carriers than BCAS. One of the analysts pointed out that more lives are lost when an air carrier is involved in a mid-air collision than when just general aviation is involved.

FAA also said that the MITRE study did not reflect that BCAS protection was effective immediately while ACAS protection was not effective until all (or most) aircraft were similarly equipped, or that the ACAS option would have cost 4 1/2 times as much as BCAS.

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