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United States General Accounting Office

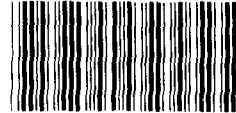
GAO

Briefing Report to the Honorable
J. James Exon, U.S. Senate

February 1988

AIR SAFETY

FAA's Traffic Alert and Collision Avoidance System



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United States
General Accounting Office
Washington, D.C. 20548

Resources, Community, and
Economic Development Division

B-222851

February 11, 1988

The Honorable J. James Exon
United States Senate

Dear Senator Exon:

This briefing report responds to your request that we obtain certain information about the Federal Aviation Administration's (FAA) proposed Traffic Alert and Collision Avoidance System (TCAS). From 1975 through 1986, 329 mid-air collisions have occurred in U.S. airspace, resulting in 777 fatalities. Of the 329 mid-air collisions, 29 involved commercial air carriers, while all but 6 involved general aviation aircraft. Two hundred ninety of the 329 mid-air collisions involved general aviation aircraft only. TCAS is designed to reduce the risk of mid-air collision by providing pilots with an independent airborne backup to FAA's ground-based system of air traffic control.

FAA plans call for three TCAS models. TCAS I, the least costly and least technically sophisticated model, is designed for use by small commercial and general aviation aircraft. TCAS I provides traffic proximity warnings to the pilot but cannot recommend collision avoidance maneuvers. TCAS II and TCAS III are intended primarily for larger commercial air carriers and are designed to provide the pilot with the threatening aircraft's position and to recommend collision avoidance maneuvers. FAA's highest priority throughout its mid-air collision avoidance program has been to provide increased protection to commercial passenger-carrying aircraft, giving special attention to large commercial aircraft. Although FAA also aimed to provide increased protection to smaller general aviation aircraft, it assigned this a lower priority. Accordingly, FAA's program has emphasized the development of TCAS II--the basic model that would be used by mid-sized to large commercial aircraft--and it is the furthest along in development of the three planned TCAS models.

TCAS III is intended to upgrade TCAS II's capabilities. FAA is encouraging the development of a TCAS II design that will permit an easy, low-cost upgrade to TCAS III capability. (Upgrade capability also is now required by recently enacted legislation.) TCAS II will recommend vertical avoidance maneuvers, while TCAS III is planned to recommend both vertical and horizontal avoidance maneuvers. In some situations, maneuvering horizontally rather than vertically

might more readily ensure the safe separation of aircraft, and in others, the opposite may be true. TCAS III also should more precisely determine whether another aircraft will become a threat, thereby providing the pilot fewer unnecessary warnings and collision avoidance advisories than TCAS II. Both TCAS II and TCAS III, however, require that the threatening aircraft be equipped with either TCAS or altitude transmitting equipment in order to provide the collision avoidance maneuvers.

As agreed with your office, this report provides information regarding (1) the safety benefits expected from TCAS, (2) commercial prospects for TCAS, and (3) FAA's plans for TCAS III development. The following summarizes our findings.

SAFETY BENEFITS

Two safety studies done for FAA by the MITRE Corporation have quantified reductions in the risk of near mid-air collisions (vertical aircraft separation of less than 100 feet and horizontal separation of less than 500 feet) expected from TCAS II and project even greater risk reductions once FAA implements complementary plans to require more aircraft to have altitude reporting transponders. These transponders will enable TCAS-equipped aircraft to locate and avoid an aircraft with altitude reporting equipment even if that aircraft is not equipped with TCAS. FAA will not perform similar studies to quantify TCAS I safety benefits but is in the process of doing so for TCAS III. FAA TCAS program officials believe that TCAS I has implicit safety benefits. However, they note that quantifying these benefits is difficult because, without recommended avoidance maneuvers, pilot judgment is the only basis for deciding whether collision avoidance action is needed, and for deciding on the type and timing of the action taken.

COMMERCIAL PROSPECTS

The prospects for commercial development and the use of TCAS I have been strengthened by FAA's proposed regulation, which would require TCAS I installation in small commercial jet aircraft, and by ongoing industry development efforts sponsored by the Navy. FAA's August 26, 1987, rulemaking announcement proposed that all small commercial jet aircraft with 10 to 19 passenger seats operating in U.S. airspace be required to install TCAS I within 5 years of the date the

rulemaking becomes final--expected to be in October 1988. While FAA does not intend to require that general aviation aircraft install the equipment, its rulemaking action has identified the initial commercial market for the unit, thereby strengthening industry's interest in TCAS I development.

Unlike its involvement in TCAS II and III development, FAA is no longer involved in the development of TCAS I. FAA believes that with the publication of TCAS I minimum operational performance standards in March 1987, industry can, without further FAA assistance, develop TCAS I equipment that will meet FAA certification requirements. FAA has, therefore, limited its future involvement in TCAS I to the testing and certification of the prototype units industry ultimately develops.

The U.S. Navy is sponsoring the development of a device similar to TCAS I for use on its training aircraft. This development could ultimately lead to the commercial availability of a TCAS I unit for civilian use. However, to date, no production-grade TCAS I model has been built, and, according to the manufacturer performing the Navy work, commercial availability within the 5-year installation time frame proposed by FAA will be difficult to achieve. The manufacturer estimates it will take at least 4 years to complete tests of the first production-grade Navy units. Efforts by that company to develop and obtain FAA certification of units for civilian use, and to plan for actual commercial production, must be accomplished thereafter.

Assuming it will not be required for private aircraft, the TCAS I unit cost will also be an important factor in determining the extent to which general aviation voluntarily installs it. FAA currently projects that a civilian TCAS I model will cost \$8,500 per unit and as much as \$2,400 to install it on existing aircraft (\$360 for installation during original aircraft construction).

The commercial prospects for TCAS II are more definite. FAA is now evaluating the operational performance of a prototype TCAS II unit in scheduled airline service, and FAA's two commercial industry/airline teams will soon begin similar operational tests using 14 production-grade units. FAA expects that TCAS II will be commercially available by early 1990. In November 1987, one of the airlines (Piedmont)

participating in operational testing of TCAS II placed an order for 81 units, which it expects will be installed and operating aboard its aircraft by 1991.

FAA has proposed that TCAS II be required on all large domestic aircraft and foreign jets with more than 30 passenger seats within 3 years of the final rule's effective date, and on all domestic and foreign jets with 20 to 30 passenger seats within 4 years of the final rule's effective date.

In addition to FAA's proposal, legislation recently passed by the Congress and signed into law by the President on December 30, 1987, requires that TCAS II be installed on all commercial aircraft with more than 30 passenger seats within 4 years of enactment (by December 30, 1991).¹ The law also requires that TCAS II be operable under both visual and instrument flight conditions, that its design be upgradable to TCAS III performance standards, and that FAA complete TCAS III development.

TCAS III DEVELOPMENT

FAA originally planned to end its involvement in the TCAS III program in April 1987 and give final development and testing responsibility to industry. However, because of legislative direction, FAA will now complete the research, development, and certification of TCAS III. The work remaining includes the refinement of the horizontal collision avoidance logic, resolution of technical questions concerning the unit's ability to determine an aircraft's bearing and attitude, completion of minimum operational performance standards and a safety study, and the testing of certified units in scheduled airline service.

In addition to the FAA Technical Center, the MITRE Corporation and the Massachusetts Institute of Technology's Lincoln Laboratory are performing developmental work on TCAS III for FAA. The FAA TCAS Program Office is determining the remaining milestones and resource needs. FAA estimates that TCAS III will require approximately another 5 years of

¹Public Law 100-223, The Airport and Airway Safety and Capacity Expansion Act of 1987.

research and development at a cost of about \$27 million. FAA has not projected when TCAS III will be available commercially, nor is there any current requirement that it be installed once it is available.

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This briefing report consists of five sections: section 1 summarizes the TCAS program's background; section 2 contains information on the program's status, including performance, schedule, and cost data; and sections 3, 4, and 5 contain information regarding the safety benefit expected from TCAS, the commercial prospects for TCAS, and FAA's plans for TCAS III development, respectively.

We obtained the information for this briefing report from discussions with and documentation provided by officials from FAA, the Air Transport Association, the Aircraft Owners and Pilots Association, the Air Line Pilots Association, the National Business Aircraft Association, MITRE Corporation, Massachusetts Institute of Technology's Lincoln Laboratory, the National Aeronautics and Space Administration's Ames Research Facility, and from relevant airline and industry program participants. We also reviewed studies, articles, and testimony pertaining to the TCAS program. Our audit work was conducted from June through November 1986 and April through December 1987.

As agreed with your office, we did not obtain official agency comments on this report; however, we discussed its contents with responsible FAA officials and they agreed with the information presented. We have incorporated their views and comments where appropriate.

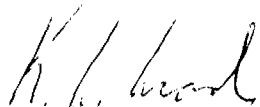
As arranged with your office, unless you publicly announce its contents earlier, we will not distribute this briefing report until 15 days after the date of this letter. At that time, we will send copies to the Secretary of Transportation; the Administrator, FAA; the House and Senate Appropriations Committees; the House and Senate Subcommittees on Aviation of the House Committee on Public

B-222851

Works and Transportation and the Senate Committee on
Commerce, Science and Transportation; and other interested
parties upon request.

Major contributors are listed in appendix I.

Sincerely yours,

A handwritten signature in cursive script, appearing to read "K. M. Mead".

Kenneth M. Mead
Associate Director

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ABBREVIATIONS

BCAS	Beacon Collision Avoidance System
FAA	Federal Aviation Administration
GAO	General Accounting Office
TCAS	Traffic Alert and Collision Avoidance System

SECTION 1

TCAS PROGRAM BACKGROUND

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- TCAS EVOLVED FROM YEARS OF DEVELOPMENT AND TESTING BY INDUSTRY AND FAA
 - THE SYSTEM OPERATES INDEPENDENTLY OF THE GROUND SYSTEM, ALERTING THE PILOT TO TCAS- OR TRANSPONDER-EQUIPPED AIRCRAFT
 - FAA PROPOSED THREE MODELS: TCAS I FOR GENERAL AVIATION AND SMALL COMMERCIAL JET AIRCRAFT AND TCAS II AND TCAS III FOR LARGER COMMERCIAL AIRCRAFT
 - AN FAA NOTICE OF PROPOSED RULEMAKING ON AUGUST 26, 1987, REQUIRES MOST COMMERCIAL AIRCRAFT TO BE EQUIPPED WITH TCAS
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The Federal Aviation Administration's (FAA) program to develop a workable mid-air collision avoidance device has been a long and controversial one. The development of the airborne Traffic Alert and Collision Avoidance System (TCAS) and the recent FAA proposal to require it on most passenger service aircraft represent the culmination of more than 30 years of FAA and industry effort.

Working through the Air Transport Association, the airline industry initiated the search for an airborne collision avoidance device in the 1950s. The airlines believed that such a device was needed for two reasons: to provide an independent backup to FAA's ground-based air traffic control system and to ensure safe aircraft separation in airspace outside the areas of FAA's ground-based air traffic control system. Developmental efforts intensified after two airliners collided in mid-air over the Grand Canyon in 1956.

By the 1970s industry had developed several collision avoidance devices. From 1972 to 1976 FAA tested models from three major commercial proponents of these systems while concurrently developing a mid-air collision avoidance technology of its own. Although tests of the commercial systems surfaced a number of technical problems, their most serious shortcoming was that converging aircraft would be warned of each other's proximity only if they were both equipped with like systems. Since no aircraft were equipped with the commercial systems, FAA concluded that a federal mandate would be necessary to ensure that enough aircraft installed them to provide an adequate level of protection.

Conversely, FAA's proposed system, then called the Beacon Collision Avoidance System (BCAS), was designed to recognize the proximity of all similarly equipped aircraft as well as those having only an operating air traffic control radar beacon transponder on board. Since over 100,000 aircraft (or about 65 percent of the existing air fleet at the time) already had these transponders, FAA believed that BCAS would offer adequate protection without the need to mandate its use by all aircraft--including general aviation aircraft.

With the support of the airline industry and potential aviation community user groups, FAA chose in 1976 to further develop BCAS rather than one of the three commercial alternatives tested. Controversy surrounded the 1976 decision largely because the technical problems associated with subsequent development of the FAA system proved more complicated and time-consuming than originally anticipated.

FAA's system--now called TCAS--evolved from the research, development, and testing done on mid-air collision avoidance since the 1950s, which included both the commercial systems and subsequent BCAS designs. Similar to earlier commercial designs, TCAS operates independently of FAA's ground-based air traffic control system. Unlike earlier commercial designs, however, TCAS can also detect and alert pilots to any nearby aircraft equipped with an air traffic control electronic transponder.

FAA plans call for three TCAS models in order to provide airborne protection from mid-air collisions to both general aviation and commercial aircraft. TCAS I, the least costly and least technically sophisticated model, is designed primarily for use by general aviation and small commercial jet aircraft. TCAS II and TCAS III are intended primarily for mid-sized and larger commercial aircraft. TCAS I will provide traffic proximity advisories but will not recommend collision avoidance maneuvers. TCAS II and III will provide proximity warnings and recommend collision avoidance maneuvers. TCAS II will recommend vertical maneuvers, while TCAS III will recommend both vertical and horizontal maneuvers. TCAS III also is designed to more precisely determine whether another aircraft will become a threat, thereby providing fewer advisories to the pilot that prove to be unnecessary than TCAS II.

On August 26, 1987, FAA issued a proposed TCAS rule for public comment, which would require TCAS II installation on all large domestic aircraft and foreign commercial jets operating in U.S. airspace with more than 30 passenger seats within 3 years of the final rule date. It would also require installation of TCAS II on all domestic and foreign jets with 20 to 30 passenger seats within 4 years of the final rule date. Interested parties had until December 24, 1987, to comment formally on the proposal, which is expected to be finalized in October 1988. In addition, legislation

signed into law on December 30, 1987, requires that TCAS II be installed on all commercial aircraft with more than 30 passenger seats within 4 years.

FAA's rule also proposes that all domestic or foreign commercial jets with 10 to 19 passenger seats be required to install TCAS I within 5 years of the final rule date. However, FAA has no plans to require that private general aviation aircraft install TCAS I. Unless owners voluntarily equip their aircraft, they will continue to rely on air traffic control advisories and "see and avoid" techniques in order to prevent mid-air collisions. Unfortunately, most mid-air collisions each year involve collisions between two general aviation aircraft.

SECTION 2

PERFORMANCE, SCHEDULE, AND COST

TCAS I

- PROVIDES TRAFFIC ADVISORIES BUT NO COLLISION AVOIDANCE MANEUVERS
- COMMERCIAL AVAILABILITY DEPENDS ON INDUSTRY DEVELOPMENT PROGRESS
- IS ESTIMATED BY FAA TO COST \$8,500 PER UNIT

TCAS II

- PROVIDES TRAFFIC ADVISORIES AND RECOMMENDS COORDINATED VERTICAL COLLISION AVOIDANCE MANEUVERS
- IN THE PROPOSED RULEMAKING, WOULD BE REQUIRED IN LARGE AIRCRAFT AND FOREIGN JETS WITHIN 3 YEARS OF THE FINAL RULE DATE; FAA ESTIMATES GENERAL COMMERCIAL AVAILABILITY BY EARLY 1990
- IS ESTIMATED BY FAA TO COST \$60,000 TO \$100,000 PER UNIT, DEPENDING ON PRODUCTION QUANTITY

TCAS III

- PROVIDES TRAFFIC ADVISORIES AND RECOMMENDS COORDINATED VERTICAL AND HORIZONTAL AVOIDANCE MANEUVERS
 - IS NOT SUFFICIENTLY DEVELOPED TO ESTABLISH COMMERCIAL AVAILABILITY DATE
 - IS ESTIMATED BY FAA TO COST \$70,000 TO \$90,000 PER UNIT
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To date, no TCAS models are available commercially. Therefore, costs, commercial availability dates, and performance characteristics are speculative and depend on a number of variables, including market size, design enhancement, and competition. Table 2.1 provides information obtained from FAA regarding estimated costs, planned installation time frames, and program status for the three TCAS models.

Table 2.1: Estimated TCAS Cost, Installation Time Frames and Program Status

	<u>Estimated user unit cost</u>	<u>Estimated installation cost</u>	<u>Required installation time frame (FAA proposed)</u>	<u>Aircraft passenger seating configuration</u>	<u>Program status</u>
TCAS I	\$ 8,500	\$2,400 ^a	Within 5 years of final rule date	10 to 19 seats	No FAA program
TCAS II	\$ 60,000 to \$100,000	\$7,200	Within 4 years of final rule date	20 to 30 seats	Prototype equipment flight tests
			Within 3 years of final rule date	Over 30 seats	
TCAS III	\$ 70,000 to \$ 90,000	Not available	None	Not determined	Horizontal collision avoidance logic under study

^aCost to install on existing aircraft. Cost to install during construction of a new aircraft is estimated at \$360.

TCAS I

Performance

TCAS I is a visual flight rule device that is designed to assist pilots in locating potential mid-air collision threats more rapidly, even in conditions of poor visibility. It will alert pilots to the presence of another TCAS- or air traffic control transponder-equipped aircraft and advise the pilot on which direction to look in order to see and avoid the aircraft. In addition to range and bearing information, TCAS I will provide the altitude of the other aircraft, provided the other aircraft has altitude reporting equipment onboard. However, TCAS I is not designed to recommend avoidance maneuvers. The avoidance actions taken are left to the judgment of the pilot and cannot be transmitted to or coordinated with the other aircraft.

Schedule

Although TCAS I minimum operational performance specifications were published in March 1987, no system has been built to date. In addition, FAA's development of TCAS I ended in March 1987. FAA will provide limited support in testing and certifying prototype units developed by industry but will leave the remaining development and operational testing necessary to bring TCAS I to certification and commercial production to the avionics industry. Although FAA has proposed a rule that TCAS I be required on small commercial jet aircraft within 5 years of its final rule date, neither industry nor FAA officials have estimated when TCAS I would actually become commercially available. (Section 4 contains details about TCAS I commercial prospects.)

Cost

In November 1985 FAA estimated that TCAS I would cost between \$4,000 and \$15,000 per unit. In September 1987, FAA refined that estimate to a per-unit cost of \$8,500, with additional installation costs of about \$2,400 for existing aircraft and \$360 for new production aircraft.

TCAS II

Performance

TCAS II is designed to alert pilots to the presence of another aircraft equipped with TCAS or an air traffic control transponder. TCAS II will also recommend vertical collision avoidance maneuvers when the other aircraft's altitude is known. To ensure that the recommended maneuvers do not themselves cause a collision, they are coordinated between the involved aircraft, provided that each aircraft is equipped with TCAS II or TCAS III units. However, recommended maneuvers cannot be similarly coordinated with aircraft equipped only with TCAS I or an air traffic control transponder.

Schedule

FAA and Piedmont Airlines are evaluating the performance of prototype TCAS II equipment in commercial passenger service. The National Aeronautics and Space Administration's Ames Research Facility is conducting human factors studies for FAA regarding the man/machine interface, and the MITRE Corporation is studying additional refinements to the collision avoidance logic. Testing completed to date has surfaced no major problems.

Production model TCAS II units with the coordinated maneuver capability have yet to be operationally tested in scheduled airline service. This testing is to begin in early 1988 and will be conducted for FAA by two commercial industry/airline teams (Bendix/King with United Airlines, and Sperry, Dalmo, Victor,

Incorporated with Piedmont and Northwest Airlines). However, on the basis of the operational testing conducted to date on prototype equipment, FAA believes that the limited installation program test results will confirm earlier tests and provide the hard data necessary to obtain final system certification.

FAA program officials expect that some additional refinements will be made to TCAS II as testing proceeds, and the ultimate unit price for TCAS II will be affected by any future design changes that result from these efforts. Major changes affecting system safety are not anticipated, however. FAA's TCAS program officials believe that TCAS II offers significant mid-air collision avoidance protection as currently designed and that its implementation should not be delayed awaiting future improvements. FAA's Administrator recently announced the accelerated development and installation of TCAS as one of his eight goals, indicating that the TCAS program has received his increased attention. An FAA Flight Standards Office official told us that TCAS II training programs are now approved for all three airlines participating in TCAS II operational testing and that, barring any unforeseen difficulties, he expects TCAS II to be certified for use under all flight conditions by early 1988.

FAA originally planned that TCAS II would be available nationwide by mid-1985 at the latest. FAA now estimates that TCAS II in-service evaluations will end in October 1988 and that TCAS II units will be commercially available by early 1990.

Cost

In November 1985 FAA estimated that TCAS II would cost between \$50,000 to \$60,000 per unit. On the basis of updated cost information from the two contractors participating in FAA's TCAS program, FAA now estimates that TCAS II will cost about \$100,000 per unit, but believes these costs could be reduced to about \$60,000 per unit with large production quantities. FAA estimates that each TCAS II unit will cost an additional \$7,200 to install.

TCAS III

Performance

Similar to TCAS II, TCAS III is designed to alert its pilot to the presence of any other TCAS- or air traffic control transponder-equipped aircraft. However, TCAS III will be capable of recommending horizontal as well as vertical collision avoidance maneuvers. To ensure that these maneuvers do not themselves cause a collision, they will be coordinated with the other involved aircraft, provided that it, too, is equipped with either a TCAS II or TCAS III unit.

Schedule

In August 1987 the FAA Administrator announced that FAA would fully develop TCAS III. FAA previously had planned to end its involvement in TCAS III development in April 1987 and leave all remaining development work to private industry. However, in light of concerns expressed by industry and potential user groups regarding the viability of such an approach, the Congress legislatively directed FAA's continued involvement. The FAA TCAS Program Office is now determining the additional work, funding, and time frames that will be required for TCAS III development, which will now include a full commercial airline evaluation of the unit's performance in scheduled passenger service. The MITRE Corporation and the Massachusetts Institute of Technology's Lincoln Laboratory are conducting development work for FAA in support of TCAS III.

Because development has not progressed far enough to permit reasonable estimates, FAA has not yet projected when TCAS III will become commercially available. However, FAA estimates that it will take about 5 years and around \$27 million to develop a certifiable, production-grade TCAS III unit. No requirement currently exists that TCAS III be installed once it becomes available.

Cost

A 1986 industry estimate projected a unit cost of \$100,000 for TCAS III, exclusive of installation costs. FAA now estimates that each unit will cost \$70,000 to \$90,000, exclusive of installation. FAA program officials believe that it is more realistic to use a range of possible unit costs for TCAS III rather than any one specific figure because the unit is at this time the least developed of the three TCAS models and a number of technical uncertainties and possible design options could affect its price. For instance, one of FAA's program goals is to encourage a TCAS II design that will permit an easy upgrade in the future to TCAS III capability at minimum cost. The ultimate unit cost for TCAS III could, therefore, depend on the technical feasibility and expense of such an option. By contract, both of the manufacturers participating in FAA's TCAS program are to demonstrate that the commercial-grade TCAS II units they provide for final operational testing can be upgraded to certifiable TCAS III capability.

SECTION 3

TCAS SAFETY PROJECTIONS

TCAS I

- NO SAFETY STUDY PERFORMED OR PLANNED

TCAS II

- SAFETY STUDY PROJECTS LARGE REDUCTION IN NEAR MID-AIR COLLISIONS
- FURTHER RISK REDUCTION EXPECTED AS MORE AIRCRAFT INSTALL ALTITUDE REPORTING EQUIPMENT

TCAS III

- SAFETY STUDY IN PROCESS
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System safety studies designed to scientifically quantify reductions in the risk of mid-air collision have been performed on TCAS II, the focal point of the TCAS system. These studies have projected a large reduction in near mid-air collisions (defined as vertical aircraft separation of less than 100 feet and horizontal separation of less than 500 feet) with the use of this model. The studies also projected an additional risk reduction if aircraft not equipped with TCAS were required to carry altitude reporting equipment. Near mid-air collisions were used as the basis of risk assessment in the studies because too few actual mid-air collisions involved commercial aircraft to provide a sufficient sample for analysis. According to FAA program officials, TCAS I provides implicit safety benefits, but similar studies quantifying risk reductions are not feasible because TCAS I lacks the capability to recommend avoidance maneuvers, making pilot judgment the primary basis for the collision avoidance action taken. A system safety study to quantify the risk reduction associated with TCAS III is in process now.

TCAS I

TCAS I is expected to enhance the safety of visual flight by helping the pilot to more quickly see and avoid other aircraft. However, no system safety study has been performed, nor is one planned, to quantify TCAS I risk reductions. According to FAA officials, safety benefits are implicit in the TCAS I ability to

identify the presence and general location of possible threatening aircraft so that the pilot can more quickly see them and avoid them, if needed. However, since TCAS I does not recommend avoidance maneuvers, any actions taken, and their timing, are based solely on the pilot's judgment. Accordingly, it is difficult to quantify the extent to which TCAS I contributes to the ultimate avoidance of a mid-air collision.

TCAS II

In December 1983 and June 1985, the MITRE Corporation completed system safety studies of TCAS II for overall and instrument flight rule conditions, respectively. We did not validate these studies or the assumptions used in them. The studies used the criteria for a near mid-air collision defined earlier in this section as their measure of risk. On the basis of this criteria, the December 1983 study estimated that the risk of experiencing a near mid-air collision at that time without TCAS II was 1 in every 100,000 flight hours. The study projected that with the introduction of TCAS II the risk would be reduced by almost 58 percent, to about 1 near mid-air collision in every 236,000 flight hours. The study also concluded that with a corresponding requirement for altitude reporting equipment on all aircraft not equipped with TCAS, the risk of near mid-air collision could be reduced by almost 95 percent, to about 1 chance in every 1,900,000 flight hours.

On June 16, 1987, FAA issued a notice of proposed rulemaking designed to increase the deployment of altitude reporting equipment. Under the proposed rule, all aircraft traveling within 30 miles of a primary airport in controlled airspace would be required to have altitude reporting equipment. The period for public comment on the proposed rule closed in September 1987. The final rule was due to take effect in December 1987 but still had not been finalized as of January 1988. FAA's proposal does not state the deadline for installing the altitude reporting equipment, and FAA officials told us that the installation time frame still has not been decided. However, Public Law 100-223, enacted December 30, 1987, requires FAA to finalize its proposed rule within 6 months (i.e., by June 30, 1988) and directs FAA to prescribe a deadline for the installation and use of altitude reporting equipment within 36 months of the legislation's enactment.

TCAS III

The MITRE Corporation is conducting a system safety study of TCAS III. Preliminary study results will not be available until September 1988. However, FAA's TCAS program officials believe that because TCAS III is designed to more precisely determine whether another aircraft will become a threat, in comparison with TCAS II,

it will provide fewer traffic and resolution advisories to the pilot that ultimately prove unnecessary.

SECTION 4

TCAS I COMMERCIAL PROSPECTS

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- TCAS I'S COMMERCIAL PROSPECTS ARE STRENGTHENED BY PROPOSED MANDATORY INSTALLATION AND NAVY INTEREST/DEVELOPMENT
 - ITS AVAILABILITY BY THE PROPOSED IMPLEMENTATION DATE IS UNCERTAIN
 - ITS HIGH UNIT COST MAY INHIBIT VOLUNTARY INSTALLATION BY GENERAL AVIATION
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One aspect of FAA's proposed TCAS rulemaking would require TCAS I installation within 5 years of the final rule date on all domestic and foreign commercial jet aircraft seating from 10 to 19 passengers. FAA has strengthened commercial interest in the development of TCAS I because, by including it in its proposed rulemaking, FAA has identified its initial commercial market. Unlike TCAS II and III, however, FAA has left the remaining development and testing of TCAS I to the avionics industry. FAA officials say that although FAA's development role in TCAS I ended in March 1987, the minimum operational performance standards published for TCAS I at that time enable industry to develop equipment that will meet FAA requirements. These officials say that with commercial efforts already under way to develop TCAS I for military and general aviation markets, the best approach is to let these efforts proceed without FAA interference.

The U.S. Navy is interested in TCAS I collision avoidance technology and has contracted for the development and testing of three TCAS I-type devices for possible use on Navy training aircraft. This should serve to further strengthen commercial interest in TCAS I development. However, although FAA believes that the development of collision avoidance equipment meeting the TCAS I specifications is well within the state of the art for avionics equipment manufacturers, it is not certain that industry's progress will match the 5-year installation deadline set for TCAS I in FAA's proposed rule. No production-grade TCAS I has been built to date and officials from the company doing the Navy development work doubt that a TCAS I device suitable for commercial aviation will be available from their company soon enough to meet the 5-year time frame for installation. These officials told us that, assuming no schedule problems occur, the company's tests of the first production-grade units for the Navy will not be completed for over 4 years (April 1991). Efforts to obtain FAA certification for

civilian application will not take place until after that time. Depending on what is required to obtain that certification, and considering the additional time subsequently needed to plan for and begin actual commercial production, these officials believe that the 5-year time frame will be very hard to meet.

FAA estimates that TCAS I will cost about \$8,500 per unit and that it could cost an additional \$360 to \$2,400 to install it on new and existing aircraft, respectively. Voluntary acquisition by general aviation will probably be limited by the expense, and FAA has no current plans to require that general aviation aircraft be equipped with TCAS I.

The Aircraft Owners and Pilots Association, which represents general aviation, is not opposed to the voluntary use of TCAS I by its members, and supports the increased use of altitude reporting equipment, which would make TCAS more effective. However, in the Association's opinion, the risk to its membership from mid-air collision is relatively minor when compared with other accident causes, and it is opposed to any proposal that would require general aviation aircraft to install TCAS I.

Unfortunately, although TCAS-equipped aircraft will be able to avoid general aviation aircraft equipped with altitude reporting equipment, most of the mid-air collisions that occur each year involve one general aviation aircraft colliding with another-- neither of which is likely to be equipped with TCAS.

SECTION 5

TCAS III DEVELOPMENT PLANS

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- FAA IS CONGRESSIONALLY MANDATED TO FULLY DEVELOP TCAS III
 - SUBSTANTIAL DEVELOPMENT WORK REMAINS
 - FAA IS DETERMINING ADDITIONAL RESOURCE NEEDS
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In August 1987 FAA announced its plans to fully develop TCAS III, including the operational test and evaluation of the unit in scheduled airline service. This decision reflected language the Congress included in FAA's fiscal year 1987 Appropriations Act requiring FAA's continued involvement with TCAS III. More recently, the Congress directed FAA to complete the research, development, and certification of TCAS III through a provision of Public Law 100-223, enacted December 30, 1987. Both the Congress and the aviation community were concerned that TCAS III might never be developed without continued FAA involvement.

FAA has evaluated the current horizontal and vertical collision avoidance capability of a TCAS III prototype in over 280 hours of flight testing on its own test aircraft. However, TCAS III collision avoidance logic is still being perfected and substantial work remains to be done. Technical questions also must be resolved concerning the unit's ability to determine a threatening aircraft's bearing and rate of bearing change, as well as to determine the bearing and attitude of the aircraft in which the unit is installed. Minimum operational performance standards must be completed for the unit, and a TCAS III safety study is still in process.

In addition, to ensure satisfactory operation under actual circumstances, FAA intends to test certified TCAS III units in scheduled airline service. This will be done as part of FAA's effort to demonstrate that TCAS II units can be upgraded to TCAS III capability. As such, FAA is requiring the manufacturers participating in its TCAS program to upgrade several proven TCAS II units to TCAS III configuration. The modified units will then be recertified and FAA will evaluate them in the laboratory. Once their TCAS III capabilities are proven in the laboratory, the units will be installed aboard FAA aircraft for actual flight tests. After the FAA flight tests, the modified units will be certified and installed on airline aircraft for evaluation in scheduled passenger service.

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