TCAS/ACAS - Archived 01/2008

Outlook

- Expect Honeywell to complete work under its contract with the U.S. Air Force to produce Traffic Collision Avoidance Systems for the C-130 aircraft
- Barring further information being made available, Forecast International will archive this report in January 2008

Orientation

Description. The Traffic Collision Avoidance System (TCAS) is an air-to-air anti-collision system. The International Civil Aviation Organization (ICAO) refers to this system as ACAS (Airborne Collision Avoidance System).

Sponsor

Department of Transportation (DoT)
Federal Aviation Administration (FAA)
Washington, DC
USA
(U.S. TCAS sponsor)

Status. TCAS I and II units are in full production.

Application. The TCAS I is a minimum-cost system targeted for the general aviation market, as well as regional airliners of 10-30-passenger capacity, while the TCAS II is intended for aircraft equipped with 30 or more seats. In addition to passenger carriers, cargo aircraft are now required to be fitted with a TCAS/ACAS unit.

Price Range. According to the FAA, the TCAS II costs between $80,000 and $200,000, and installation is estimated to cost $50,000 to $70,000.

Contractors

Prime

Honeywell Aerospace Electronic Systems	15001 NE 36th St, PO Box 97001, Redmond, WA 98073 United States, Tel: + 1 (425) 885-3711, Fax: + 1 (425) 885-2061, Prime

Technical Data

Design Features. TCAS is a three-level program: TCAS I, TCAS II, and TCAS IV. TCAS III was canceled in 1993 due to technical difficulties. It has been replaced by TCAS IV as a result of the maturation and widespread introduction of GPS technology.

TCAS I. TCAS I is a minimum-cost system targeted for the general aviation market, as well as regional airliners of 10-30-passenger capacity. It provides host aircraft with traffic advisories (TAs), but not resolution advisories (RAs). TAs contain range and bearing information about aircraft that present a potential conflict, or threat, for the host aircraft; RAs are command instructions to avoid the predicted conflict.

TCAS I acts only as a warning system, supplying pilots with TAs that disclose the range, approximate bearing, and altitude of traffic within four nautical miles. The concept is very similar to the Genave PWI (Proximity Warning Indicator), a device in use in the early 1970s that was unsuccessful because it generated too many unwanted alarms.

The FAA-approved TCAS I design has still not been fully determined. While the original concept was thought to entail a passive system, the FAA has recently shown that it prefers an active system. This is important because an active system is significantly more expensive, with average prices in the neighborhood of $50,000 (not including installation, approval, and training), versus the under-$15,000 price range that the FAA originally specified for TCAS I.

The difference between an active and passive system is that an active system transmits interrogation signals to elicit responses from other transponder-equipped aircraft. While the final rule covering TCAS-I (issued March 1989) stated that Mode S transponders are not required for TCAS I, most industry analysts believe that multiple interrogations of Mode A/C transponders would inundate the ATC system.

In recent statements, the FAA has said that it is willing to consider passive versus active TCAS units as long as the applying company can demonstrate that the passive system's capabilities provide a level of safety equivalent to that of active versions. The FAA further stated that it had not yet encountered a passive system that meets the safety intent of the rule. Interestingly, Foster AirData now offers a combined active/passive TCAS I, although it costs $80,000 uninstalled.

An example of a TCAS I that was scheduled to become available in fall 1990 was the Avion Sentinel II. The Sentinel II was based on a digital signal processor with a capacity of 50 million instructions per second, and with the collision-warning function taking up about half of the available processing power. Two blade-type antennas sensed secondary surveillance radar (SSR) interrogations and transponder replies. Range was cited as 20 miles, with returns within five miles being identified as threats. Bearing accuracy, at five degrees or less, was said to exceed TCAS II requirements. A weather radar display was used for data display. The company has since introduced the Sentinel II/A, which offers performance comparable to a TCAS II.

TCAS II. TCAS II is still the focus of current activity. It is an active system that performs the same function as TCAS I, but with greater accuracy. The TCAS II shows a vertical resolution advisory when a collision becomes imminent, and instructs the pilot on how to escape the threat.

When TCAS II-equipped aircraft encounter one another, the TCAS II units communicate via the Mode S link and coordinate the avoidance maneuvers that are to be suggested to the respective pilots. The FAA has mandated that TCAS II be installed on all U.S. aircraft and on foreign aircraft that fly into the U.S. on a regular schedule and are equipped with 30 or more seats. FAA-required performance parameters include a forward range of 15 nautical miles and rearward scanning capability of 14 kilometers (7.5 nm).

The normal equipment configuration for an airliner would consist of two antennas, dual processors, a dual Mode S transponder (equipped with two antennas), cockpit control panels, an audio system, and displays. The directional antenna on top of the fuselage must be compatible with the particular manufacturer's TCAS II unit.

However, if an omnidirectional under-fuselage antenna is used, a generic TCAS II antenna can be installed also. Honeywell claims that its TCAS II requires only one directional antenna located on top of the fuselage. The company claims that the antenna is capable of tracking aircraft 500 feet directly below the Honeywell-equipped aircraft. In contrast, AlliedSignal/King leans toward using two directional antennas, on the grounds that the omni-directional antenna cannot provide bearing data.

An AlliedSignal/King system is used for the purpose of demonstrating how a TCAS II works. Every second the system scans 15 nautical miles to the front of the aircraft and 7.5 miles to the rear. The observed air traffic is plotted on a dedicated traffic advisory display as a series of symbols, together with a plus or minus sign and numbers indicating the distance, in feet, of the detected aircraft above or below the instrumented aircraft. Up arrows indicate climbing aircraft, and down arrows indicate descending aircraft. Observed traffic not considered a threat is displayed as open white diamonds (with an adjacent altitude indication).

When an aircraft closes to within 45 seconds, the diamond changes to a yellow traffic advisory dot, and an audible alarm sounds ("Traffic, Traffic, Traffic"). When the intruder closes to within 30 seconds, a red square replaces the yellow dot, and the audible alarm follows with instructions such as "Climb, Climb, Climb."

It should be noted that most TCAS IIs (especially in retrofit applications) work only in the vertical plane. There is now some interest in the use of pitch cueing during a resolution advisory alert rather than the standard use of the vertical speed indicator (VSI). Fokker Aircraft is using this approach in its Model 100 transport, with the first deliveries having been those Model 100s ordered by American Airlines (first deliveries in 1991). Fokker is especially interested in fully integrating the cockpit, and pitch cueing is seen as providing the simplest, most instinctive instructions possible for alerting a pilot (testing has shown that pilots respond better to pitch cue alerts).

Furthermore, Fokker reasoned that since pilots fly to pitch angle rather than vertical speed, it made more sense to use its approach, especially since the pitch cue is normally located directly in front of the pilot, while the VSI usually is not. Boeing is also committing to pitch cueing in a retrofit of its 737, 757, and 767 families of aircraft. The Collins TCAS II has been integrated with the 757/767 Electronic Flight Control System, with resolution advisories being displayed in pitch cues as well as with vertical speed commands.

A limitation to the VSI approach is the fact that non-Mode S-equipped aircraft show up only as symbols, with no indication as to whether the aircraft is climbing or descending, or whether it is above or below the TCAS II-equipped aircraft.

Typical TCAS II equipment sets are as follows:

The Collins TCAS II consists of the TTC-920 control; the TTR-920 receiver/transmitter; the TPR-720 Mode S transponder; and the TRE-920 antenna, with display options including the XWI-711 radar display, the TVI-920 TCAS/VSI, and the TTA-920 TCAS traffic indicator.

The AlliedSignal/King TCAS consists of the TPA81A interrogator/processor, the ANT-81A directional antenna, the ITA-81A dedicated traffic display, the IVA-81A traffic/vertical speed indicator, the IVA-81B resolution/vertical speed display, and the TRA-67A Mode S transponder.

The Honeywell TCAS consists of an interrogator/computer; a directional antenna; an all-purpose flat-panel liquid crystal display (LCD); a transponder controller; and a Mode S transponder.

<u>TCAS III</u>. The FAA announced in September 1993 that it was abandoning all research and development on the TCAS III. The move to terminate was prompted by a report from Lincoln Laboratory that accurate horizontal-resolution advisories could not be achieved. TCAS III was supposed to add horizontal RAs to the TCAS II's vertical-only capability.

<u>TCAS IV</u>. The accurate 3-D position information made available by the fully operational Global Positioning System (GPS) satellite network has permitted TCAS IV to replace TCAS III in the evolutionary development of Traffic Control Avoidance Systems. TCAS IV-equipped aircraft would exchange flight data and be supplemented by improved aircraft position information provided by the GPS network. These features would permit horizontal as well as vertical resolution maneuvers to be made.

Rockwell Collins Avionics began an effort to make a prototype of the TCAS IV. The Rockwell Collins system would use Differential GPS to determine exact aircraft positions. For passive surveillance, it would incorporate Automatic Dependent Surveillance-Broadcast (ADS-B) in addition to the existing active Mode C and Mode S capabilities. Further news of this project is anticipated in the near future.

In a related government-sponsored development, the Department of Transportation, acting on behalf of the FAA, awarded the Rannoch Corporation a contract to develop a small, low-cost, cockpit-installed device for general aviation applications. This device would enhance flight safety by combining advanced TCAS and GPS technologies.

<u>CAS 100</u>. In July 2000, Honeywell Aerospace launched a next-generation TCAS called the CAS 100. The new CAS 100 prototype has been proven at 185 kilometers (100 nm) and is said to support the ADS-B system. Using a more sensitive receiver coupled with a phased-scan antenna system, the CAS 100 offers a greater bearing accuracy. The CAS 100 is reported to have a mean time between failures (MTBF) of an impressive 30,000 hours. Customers can choose either a TPA-100A processor or a TPL-100A processor. With its TPL-100A surveillance processor, which integrates the TCAS processor and the Mode S transponder, the

CAS 100 is up to 60 percent smaller than the typical traffic surveillance system. The TPL-100A processor also has built-in test equipment along with an LCD to show maintenance and modification status. Finally, the CAS 100 can be integrated with Honeywell's Enhanced Ground Proximity Warning System (EGPWS) to provide the best overall resolution of the situation, relative to both traffic and terrain.

Variants/Upgrades

Overall. While TCAS II parameters are basically set, TCAS I requirements are still somewhat fluid; thus, there is room for upgrades in the capabilities of both. For example, the FAA seems to have shifted the focus for TCAS I away from a passive system and toward an active system because of increased capability. Even TCAS II is still being tweaked, an example being Honeywell's 3-D display. There is also some controversy as to the range that TCAS II should have. (One hundred percent accuracy is possible only up to about the 14-mile mandated range, but targets have been acquired out to 100 miles.)

ADS-B is the first step to a GPS-reference air traffic management system that allows use of the free-flight concept. This concept would allow individuals to choose their own flight paths without being bound to specific corridors and being only superficially under air traffic control.

Skywatch. Introduced in June 1997 by BFGoodrich, the Skywatch is a low-cost system aimed at the lower end of the commuter/corporate/general aviation market. The system maintains TCAS-like features, with the exception that ranges are only displayed out to six miles. The logic is that as Skywatch is geared to slower aircraft, with consequently slower closure rates, a display range greater than six miles is unnecessary.

Skywatch is displayed via the monochromatic BFGoodrich WX-1000 Stormscope weather radar system. While losing the color warnings of a full TCAS, the gain is a display that shows both traffic and weather threats; an aural warning is retained to alert the pilot of a potential conflict. The system can interrogate Mode A and Mode C transponders only.

TCAS 2000. Honeywell has improved upon its TCAS 2000 by increasing the overall range and sensitivity of the unit. The upgrade will broadcast not only the position and altitude of host aircraft, but also its intent. A new feature will be the capability to self-update software via a portable or airborne data loader.

TCAS 4000. The TCAS 4000, manufactured by Rockwell Collins, is an improved version of its previous TCAS II. Range of detection has been doubled to over 100 nautical miles. Hardware and software developments exceed the FAA Version 7 standards, as well as incorporating features that will allow for upgrading to ADS-B. The TCAS 4000 may be displayed on either active matrix liquid crystal or conventional cathode ray tube (CRT) screens.

CAS 100. Honeywell's CAS 100 prototype has an increased range of 185 kilometers (100 nm), and supports the ADS-B system. CAS 100 offers a greater bearing accuracy and has an MTBF of 30,000 hours. Integrating the TCAS processor with the Mode S transponder, the CAS 100 is up to 60 percent smaller than the typical traffic surveillance system.

Program Review

Background. In June 1981, J. Lynn Helms, then-administrator of the FAA, made an announcement informing the public that the active civil aircraft fleet would double from 100,000 to 200,000 aircraft within nine years. Helms stated his determination to upgrade the ATC system to handle the onslaught. Helms' ATC upgrade solution was a threat alert element called TCAS I, and a collision avoidance element, TCAS II. He estimated that TCAS I would cost around $2,500 (with a little improvement in display information, perhaps $3,500).

TCAS II would have a ground link/cross link capability and provide TAs to TCAS I aircraft and RAs for the TCAS II host aircraft; he estimated the system cost of TCAS II to be $45,000 to $50,000. Helms described his personal participation in successful airborne tests of a brassboard system demonstrator, and stated his intent to have a threat and collision avoidance system in place before leaving office in December 1984.

In 1985, Dalmo Victor announced plans for a 12-month Limited Installation Program (LIP) of production TCAS II equipment on board revenue flights on Piedmont and Republic Airlines, starting in 1986. According to Dalmo Victor, the contract's value would reach $5.5 million by the time production and operational evaluation were complete.

In a later development, AlliedSignal/Air Transport Avionics announced that they had entered into a contract with United Air Lines for operational evaluation of the AlliedSignal CAS-80 (TCAS II) in B-737-200 and DC-8-71 aircraft in regular passenger service. In 1986, Piedmont announced the beginning of TCAS II evaluation in revenue service aboard a B-727-200.

The Military Side of TCAS

Some of the largest air fleets in the world are not equipped with TCAS as standard equipment. These aircraft constitute the fleets of the air forces of various nations, and range in size from single-seat fighters to massive cargo-carrying freighters. U.S. General Accounting Office (now Government Accountability Office) reports in 1994 and 1996 highly recommended the inclusion of TCAS in U.S. Air Force heavy aircraft.

By the end of 1997, AlliedSignal had begun development of a TCAS that would be used by tactical aircraft. The problems posed by such aircraft include close-in maneuvering and supersonic flight, but engineers were confident that these problems could be overcome. The biggest problem is related not to the software, but to the physical dimensions of the unit. TCAS II was too heavy and too large to be used by fighters. The size and weight problem appeared to have been overcome in February 1998 when the USAF contracted for the inclusion of tactical TCAS units on a pair of T-38 trainers.

The first C-5 equipped with the new TCAS was tested successfully in January 2000. With successful completion of the test, the C-5 modernization program was given a green light, allowing Lockheed Martin to start retrofitting the remaining 126 USAF C-5 aircraft. Once fitted with TCAS, the C-5s would be permitted to fly fuel- and time-saving air routes over the northern Atlantic. The retrofits were completed in October 2002.

Another large step toward equipping U.S. military aircraft with TCAS was taken in June 2001. At that time, the U.S. Air Force selected Boeing for its C-130 Hercules Avionics Modernization Program. Under this program, Honeywell will supply Boeing with TCAS. From 2004 through 2014, 519 C-130s are to undergo modernization. In addition to this large program, the U.S. military has also awarded contracts to Raytheon to supply TCAS units for installation on several C-21A and C-12 aircraft.

There are signs that foreign military forces are following suit. Lockheed Martin was awarded a contract in April 2000 to upgrade four ex-USAF C-130B aircraft for the Bangladeshi Air Force. Among the improvements are TCAS units. In December 2000, the Singapore Air Force brought into service a squadron of TCAS-equipped KC-135R air-to-air refueling tankers. About eight months later, in August 2001, Rockwell Collins was selected by Canada's Spar Aerospace Ltd to supply TCAS units in support of an avionics upgrade for Greece's C-130 modernization program. A total of 15 C-130s will be upgraded.

International Commercial Aircraft

The mandate that foreign carriers flying into the U.S. must be equipped with TCAS has caused a spurt of activity, as follows.

In April 1994, Rockwell Collins successfully installed and received certification for its TCAS II on board the Aeroflot Il-96-300.

The United Kingdom announced in May 1994 that it was taking steps toward mandating TCAS on aircraft. After a series of evaluation trials in which the system was found to be beneficial in operations in the high-density, 80-percent-controlled European airspace, the U.K. Civil Aviation Authority (CAA) directed that TCAS II equipment be installed in U.K. commercial aircraft. A competition for the installation of TCAS II on approximately 300 aircraft was held in June 1995.

During the same month, the Committee of Management of Eurocontrol recommended the mandatory introduction of the TCAS II on member-nation aircraft. The first phase of the two-phase program involved all turbine-powered fixed-wing aircraft of more than 30 seats and having a maximum gross weight of more than 15,000 kilograms. All equipment was to be installed by 2000. The second phase, applicable from 2005, covers aircraft with more than 19 seats and a gross weight of more than 5,700 kilograms. Besides dealing with smaller aircraft types, this phase also brings in cargo aircraft.

In the 1990s, Rockwell Collins, known as an extremely active company within Russia, successfully marketed a number of avionics systems to Russian companies and fleets. One of its first ventures was as the supplier and integrator of Western avionics for the Russian widebody Ilyushin Il-96M/T. In 1993-94, a TCAS was placed on a -96M/T for operational evaluations. Since that time, Rockwell has participated in numerous TCAS-related cooperative programs with Russian agencies, including the Russian State Research Institute for Aviation System (GosNIIAS).

In early 1998, Rockwell and GosNIIAS signed a co-production agreement centered on the Collins TPR-900 TCAS. Under the agreement, GosNIIAS will produce key components of the TPR-900, including the transmitter, receiver, power supply, and chassis. These modules will then be shipped to the U.S. for integration and testing.

In Europe, all aircraft with a weight of more than 33,000 pounds and operating in Europe were required to be equipped with ACAS II, which is TCAS II through software modification seven, by the end of March 2001. Starting in January 2005, the TCAS II requirement will extend to all turbine aircraft over 12,500 pounds maximum certificated takeoff weight, or with more than 19 passenger seats.

The USAF Awards a Contract in 2005

In June 2005, the U.S. Air Force awarded Honeywell International a contract to manufacture TCAS TPS-81A processors, 131 TCAS Mode S/IFF control panels, 85 TCAS APX-119/RT-1853 Mode S/IFF digital transponders, 75 TCAS displays, and 100 TCAS antennas for the C-130 System Program. Work under this contract is expected to be finished by November 2006.

Contracts/Orders & Options

Contractor	Award ($ millions)	Date/Description
Honeywell International	12.1	Jun 2005 – Honeywell International received a firm-fixed-price contract from the U.S. Air Force to manufacture and deliver 75 TCAS TPS-81A processors, 131 TCAS Mode S/IFF control panels, 85 TCAS APX-119/RT-1853 Mode S/IFF digital transponders, 75 TCAS displays, and 100 TCAS antennas for the C-130 System Program. Work under this contract was completed by November 2006. The Electronic Systems Center, Hanscom Air Force Base, MA, is the contracting authority. (F19628-02-D-0014)

Timetable

Month	Year	Major Development
	FY58	FAA begins RDT&E on means to prevent midair collisions
	FY79	Draft B-CAS Minimum Operational Performance Standard (MOPS)
	FY81	FAA announces shift from B-CAS to TCAS
	FY82	Design guidelines issued for TCAS I. Draft MOPS for TCAS II. Initial Piedmont 727 installation of Dalmo Victor TCAS II
	FY83	Initial installations of TCAS I
	FY84	TCAS II MOPS
	FY85	TCAS III (Enhanced TCAS II) MOPS
Mar	1990	AlliedSignal/King first TCAS manufacturer to receive an FAA Technical Standard Order authorizing production and shipment of TCAS equipment to airline customers
Sep	1993	TCAS III terminated by FAA
Jun	1995	U.K. CAA mandates TCAS II for U.K. fleet. 300 units ordered. Eurocontrol recommends two-phase program to install TCAS II on member-nation aircraft starting with 30-passenger-plus aircraft in 2000
Nov	1996	FAA evaluates TCAS IV GPS-based unit and TCAS II Version 7.0 software upgrade
Early	1997	FAA completes evaluation of TCAS II Version 7.0 software upgrade
Jan	1998	Federal Express becomes first U.S. cargo carrier to announce voluntary installation of TCAS on aircraft (total of 334 platforms)
Jan	2000	First C-5 equipped with the new TCAS successfully tested
Jul	2000	Honeywell Aerospace launches next-generation TCAS called CAS 100
Mar	2001	ACAS II Version 7.0 equipment scheduled for completion
Feb	2004	Honeywell receives contract from the USAF to provide Enhanced Traffic Collision Avoidance Systems (ETCAS) and other avionic equipment for 129 C-130 aircraft
Jun	2005	USAF awards Honeywell International a contract to manufacture various TCAS components

Month	Year	Major Development

Worldwide Distribution/Inventories

TCAS is used on military and commercial passenger/cargo aircraft worldwide.

Forecast Rationale

The Traffic Collision Avoidance System, or TCAS, is an airborne system designed to reduce mid-air collisions.

The TCAS was designed to increase cockpit awareness of proximate aircraft and to serve as a "last line of defense" for the prevention of mid-air collisions. TCAS operates independently of any ground-based air traffic control system.

Data is not sufficient to continue issuing this report. If new information is published in open source literature then a new report shall be generated.

Ten-Year Outlook

With no outlook forecast and the archiving of this report in January 2008, Forecast International has **omitted** the Ten-Year Outlook chart.

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