AIRBORNE COLLISION AVOIDANCE SYSTEM

(ACAS) PROGRAMME[1]

BACKGROUND

Since 1955 the international aviation community has sought an effective airborne collision avoidance system (ACAS). In the mid 1970s, research centred on the use of signals from airborne Secondary Surveillance Radar (SSR) transponders as cooperative elements of a collision avoidance system, independent of the ground ATC system. In 1981 the FAA announced its decision to proceed with a concept called the Traffic Alert & Collision Avoidance System (TCAS) based on the use of airborne SSR transponder message formats. Trials followed during the 1980s and, on 30 December 1993, the use of TCAS became mandatory in US airspace for certain classes of aircraft.

In parallel to the development of TCAS equipment, the International Civil Aviation Organisation (ICAO) has been developing standards for Airborne Collision Avoidance Systems (ACAS) since the early 1980s.

In 1994, the 4th Meeting of the European Civil Aviation Conference (ECAC) Ministers of Transport (MATSE 4), and the 82nd Session of the EUROCONTROL Permanent Commission called for the development of a policy concerning the carriage and operation of ACAS, as well as the development of a European implementation schedule. The ACAS policy and ACAS II implementation schedule, subsequently proposed by the EUROCONTROL Agency, were adopted by the EATCHIP Project Board in November 1995, and endorsed by ECAC Transport Ministers at the MATSE 5 meeting in February 1997.

PURPOSE AND DESCRIPTION OF THE SYSTEM

Safety is of the highest priority in aviation. The purpose of ACAS is quite simply to reduce the risk of mid-air collision. It is independent, airborne equipment, which provides a 'last-resort' method of preventing mid-air collisions or near-collisions. ACAS

1 Adaptado de John Law, http://www.eurocontrol.int/dgs/publications/skyway/2000/v5n18/p30.html e safety managemet http://www.eurocontrol.int/safety/gallery/content/public/Acas.pdf

provides a different functionality to ground-based Short-Term Conflict Alert (STCA) safety net which is nevertheless complementary to ACAS.

Extensive ACAS/TCAS safety analyses and system safety studies have been performed, principally in France (CENA), the United Kingdom (DERA and NATS) and the United States. In the European airspace environment, when compared to the current risk of mid-air collision, an ACAS II could be expected to reduce the risk of collision by a factor of 3, or a factor of 2 in airspace where the air traffic control system has a Short-Term Conflict Alert (STCA) functionality. A further benefit, but one which has not been quantified, is that contributed by the associated traffic display, which enhances flight crew situational awareness of nearby traffic.

Two types of ACAS have been implemented, but the European ACAS mandate is for ACAS II only:

- ACAS I provides Traffic Advisories (TAs) but no international implementation is planned at ICAO level;
- ACAS II provides TAs, and Resolution Advisories (RAs) in the vertical plane.

Only TCAS, manufactured by three US companies, complies with ICAO ACAS standards, these being TCAS I for ACAS I standards, and TCAS II for ACAS II standards.

SYSTEM IMPROVEMENTS

There were two extensive TCAS II operational evaluations which started in the United States in June 1990, and in Europe in March 1991.

As a result of these evaluations, changes were made to improve TCAS II operational performance. In 1993 these improvements were introduced in the TCAS II Version known as 6.04A. Operational evaluations continued, and further necessary performance improvements were identified. This led to the development of TCAS II Version 7, which includes many modifications appropriate to the European airspace environment. It will improve TCAS II compatibility with the ATC system (including flight operations in the forthcoming Reduced Vertical Separation Minimum (RVSM) environment). TCAS II Version 7.0 first became available in 1999.

SYSTEM OPERATION

ACAS interrogates the SSR transponders of all aircraft in the vicinity by means of antennas. On the basis of the replies received, the system tracks the slant range, altitude and bearing of these aircraft. From several successive replies, ACAS calculates the time to reach the Closest Point of Approach (CPA) with an intruding aircraft by dividing range by closure rate. This time value is the main parameter for issuing alerts and the type of alert issued to the pilot by ACAS depends on this value. ACAS also computes time to reach co-altitude.

ACAS II can issue two types of alert:

- Traffic Advisories (TAs), which are intended to assist the pilot in the visual search for intruder aircraft, and alert him to a potential resolu- tion advisory;
- Resolution Advisories (RAs), which are vertical avoidance manoeuvres recommended to the pilot. When the intruder aircraft is also fitted with an ACAS system, both ACASs coordinate their RAs through the Mode S data link in order to select complementary RAs.

ACAS is designed to work both autonomously and independently of the airborne navigation equipment and ground systems used for the provision of air traffic services.

SYSTEM COMPONENTS

Figure 1 shows the block diagram of the TCAS II system. TCAS II is composed of:

- a computer unit - which performs airspace surveillance, intruder tracking, threat detection, avoidance manoeuvre determination and the generation of advisories;
- a TCAS control panel - incorporated into that of the Mode S transponder;
- two antennas - one fitted above the fuselage and another below. The top antenna is directional to enhance intruder surveillance. These antennas are separated from the transponder's antenna. Interrogations are transmitted on 1030 MHz and replies received on 1090 MHz, the same frequencies used by Secondary

Surveillance Radar (SSR). TCAS operation is linked to the transponder's operation in order to avoid self-tracking;

- a connection to the Mode S transponder - to issue complementary, coordinated resolution advisories, when both aircraft are equipped with TCAS;
- a connection to the altimeter - to obtain pressure altitude, and/or connect with the on-board Air Data Computer (ADC), if fitted;
- a connection to the radar altimeter - to inhibit RAs when the aircraft is in close proximity to the ground and determine whether aircraft tracked by TCAS are on the ground;
- loudspeakers - for aural annunciations;
- screens - to display relevant data.

Additionally, other data relating to aircraft performance are also taken into account, such as landing gear and flap status, operational performance ceiling, etc.

However, TCAS II is not connect-ed to the autopilot nor to the Flight Management System (FMS). TCAS II remains independent and will continue to function in the event of failure of either of these systems.

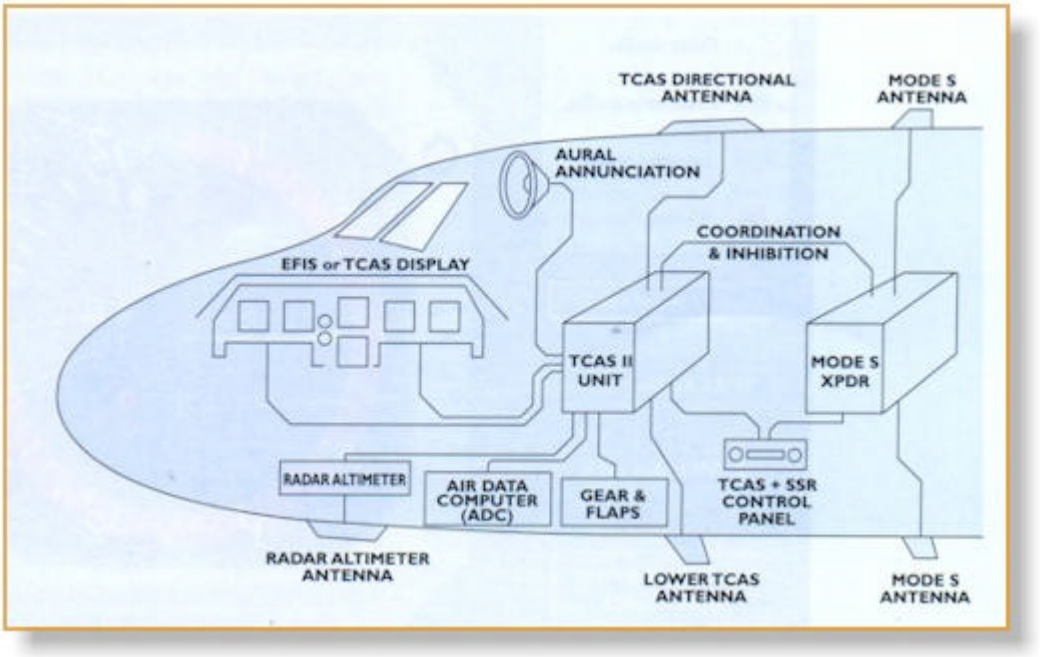
COCKPIT PRESENTATION AND TRAFFIC DISPLAY SYMBOLS

The cockpit presentation provides information on adjacent traffic, TA and RA displays, and aural annunciations.

The traffic information display system is designed to aid visual acquisition of an intruder. It indicates the relative horizontal and vertical position of other aircraft in the vicinity. Targets are displayed on the TCAS traffic display by different symbols:

- a hollow blue or white diamond - for non-intruding traffic;
- a solid blue or white diamond - for non-intruding traffic within 6 NM and 1200 ft;

- a solid amber circle - for intruders (triggering a TA);
- a solid red square - for threats (triggering an RA).



In a representative 'non-glass' cockpit, traffic targets and advisories are shown on a liquid crystal display, which is combined with the Instantaneous Vertical Speed Indicator (IVSI). The display range can commonly vary from 4 NM to 30 NM ahead of own aircraft. The own aircraft is shown as an arrowhead or aircraft-like symbol coloured white or blue, with a 2 NM radius circle around the own aircraft symbol.

An RA is shown by the display of a red arc, which indicates the range of vertical speeds to be avoided. A green arc, shown next to the red arc, indicates to the pilot that he should manoeuvre the aircraft to reach the required vertical speed, shown in the green arc, while limiting the altitude deviation. If there is more than one threat, two red arcs may flank the range of the required vertical speeds.

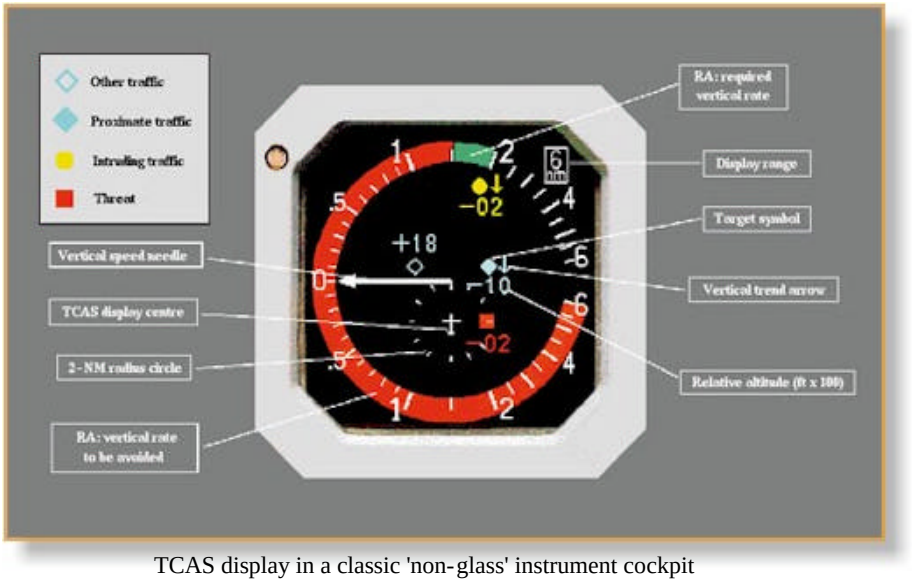
In addition, loud speakers located in the cockpit alert the crew to TCAS advisories generated by means of aural annunciations.

ACAS PROGRAMME - ACAS II IMPLEMENTATION

So where does the EUROCONTROL ACAS Programme fit in? Well, the ACAS Programme is one of the EATMP stand-alone programmes. Perhaps unusually for an EATMP Programme, the ACAS Programme objectives are not in any way related to capacity improvement, but purely to improved safety. It should be remembered that the safety objective of the EUROCONTROL ATM 2000+ Strategy is "to improve safety levels by ensuring that the number of ATM-induced accidents and serious or risk bearing incidents do not increase and, where possible, decrease". The ACAS Programme contributes directly to the achievement of this objective. It carries out activities to ensure the coordinated and harmonised introduction of ACAS II in accordance with the ACAS Policy and implementation schedule agreed by the ECAC States.

ACAS II implementation requires the mandatory carriage and operation of ACAS II for flight in the airspace of ECAC Member States. There are two phases.

Phase 1 requires that, with effect from 1 January 2000, all civil fixed-wing turbine-engined aircraft, having a maximum take-off mass exceeding 15,000 kg or a maximum approved passenger seating configuration of more than 30, be equipped with ACAS II. This includes passenger and cargo aircraft and applies equally to all aircraft flying in ECAC European airspace, whether they are registered within ECAC, or elsewhere.



TCAS display in a classic 'non-glass' instrument cockpit

.However, Phase 1 implementation has been affected by practical implementation issues, involving supply, installation, and certification of the TCAS II Version 7 equipment which is required to meet the ACAS II mandate. An ACAS II implementation transition period was therefore established from

1 January 2000 until 31 March 2001. Beyond this date, apart from special flights (test flights, for example), there will be not be any exemption to the ACAS II mandate.

Phase 2 extends the mandate to smaller aircraft. It takes effect from 1 January 2005, when all civil fixed-wing turbine-engined aircraft having a maximum take-off mass exceeding 5,700 kg or a maximum approved passenger seating configuration of more than 19, are to be equipped with ACAS II.

Not surprisingly, given the complexity of the equipment and the modifications required to the aircraft, TCAS II installation is expensive. The average cost could be estimated at around USD 150,000. Of course, many other factors can cause this cost to rise sharply, particularly if the aircraft was produced in low volume, or is no longer supported by the manufacturer.

Since the ACAS mandate affects a very large number of aircraft, the overall cost of the aircraft operators' retrofit programme is high. While it is recognised that fleet sizes are constantly changing, the number of aircraft required to be fitt-ed with TCAS II to meet Phase I of the ACAS II mandate is around 7,000, split approximately equally between those aircraft registered within the European Civil Aviation Conference (ECAC) States and those from outside Europe.

OPERATIONAL ENVIRONMENT

Analysis of TCAS II encounters between aircraft is carried out by sophisticated TCAS simulation using recorded radar data and, when available, data from on-board TCAS recorders. The current, ongoing operational monitor-ing and analysis of TCAS II events, which is coordinated by the EUROCONTROL Experimental Centre on behalf of the ACAS Programme, has demonstrated that TCAS II is an efficient airborne collision avoidance system. However, a special effort must be made to ensure appropriate flight crew training. Only the correct use of TCAS II by pilots will result in the desired

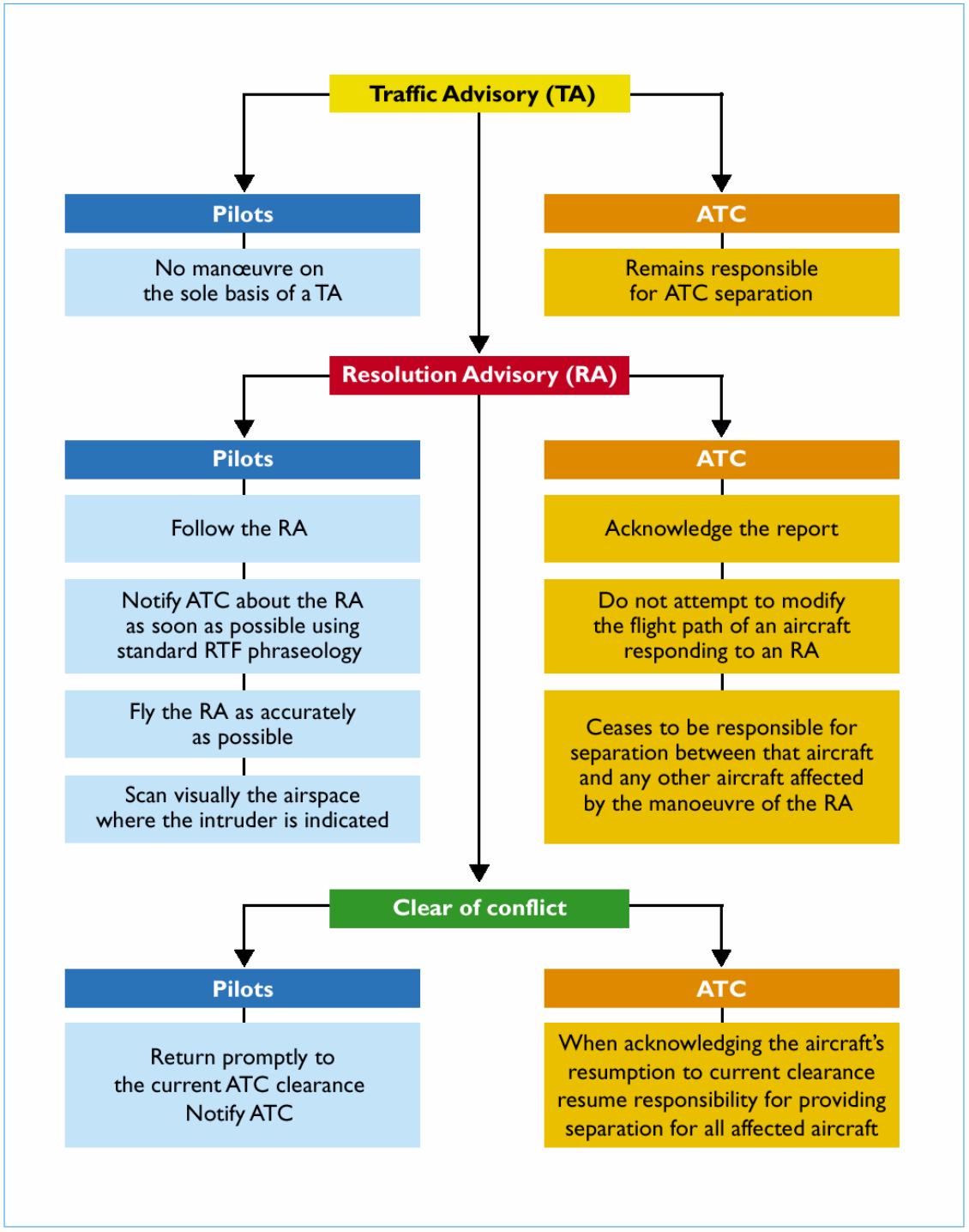
improvement in flight safety, and the integration of ACAS into the air traffic control environment. Of course, controllers do not use ACAS, but they do need to take it into account when providing aircraft with an ATC service. In Europe a comprehensive training course and computer training tool, using real TCAS encounters, based on recorded radar data and data from on-board TCAS recorders, has been made available for both the initial and refresher training of European controllers.

IMPLEMENTATION PROGRESS

The Programme is currently focusing on Phase 1 implementation. In tracking the implementation progress, and identifying problems before they become crises, the ACAS Support Unit (ASU) has been in contact with 1,300 aircraft operators, not to mention maintaining constant contact with industry, national CAAs, the JAA and the FAA.

There have inevitably been, and still are, many specific implementation problems which we are addressing. Not surprisingly, with all the possible combinations of equipment across so many aircraft types, there have been technical interface problems. The degree of cooperation between the regulatory authorities, aircraft and TCAS manufacturers, aircraft operator associations, and, of course, the aircraft operators themselves has been quite remarkable. Nonetheless, the ACAS II implementation schedule is extremely challenging. If it is to be achieved successfully, it will require continued major effort by all those involved within the aviation community.

Interaction ATC and Pilots during an ACAS event



Inappropriate Response to RAs Seriously Degrades ACAS Safety Benefits

Appropriate response to RAs

Aircraft Operators should strongly encourage pilots to follow RAs whilst explaining ACAS constraints and limitations.

Pilots should be made aware of:

- the potential benefits of reducing rates of climb/descent when approaching their cleared Flight Levels;
- the importance of telling ATC that they are following an RA as soon as possible.

Finally, it should be made clear to pilots that ACAS traffic display is not designed as a means to maintain separation.

Air Navigation Service Providers should make controllers aware of the importance of not interfering with a manoeuvre in response to an RA.

ACAS Implementation Monitoring

The monitoring should be continued

- To identify ACAS/ATC compatibility problems: a high incidence of RAs at specific locations may indicate a potential airspace design or safety issue;
- To monitor ACAS system performance;
- To monitor specific technical issues.

ACAS Training

ACAS Training should be reinforced for both Pilots and Controllers

- ACAS should be included for both ab initio and continuation training;
- Training for ATCOs and pilots should ensure that the responsibilities of pilots and ATCOs are made clear during an RA event;
- Training should be delivered to civil and military pilots and ATCOs.

Available Training Material & Tools

- ICAO - ACAS Performance-Based Training Objectives.
- JAA TGL11 - Guidance for Operators.
- ACAS Training Brochure (Eurocontrol ACAS Programme).
- ACAS Operator in the European RVSM Environment (Eurocontrol ACAS Programme).
- RITA (Replay Interface of TCAS Advisories). RITA is a dynamic graphical tool showing TCAS occurrence from both pilots and controllers perspective. Available on www.eurocontrol.int/acas