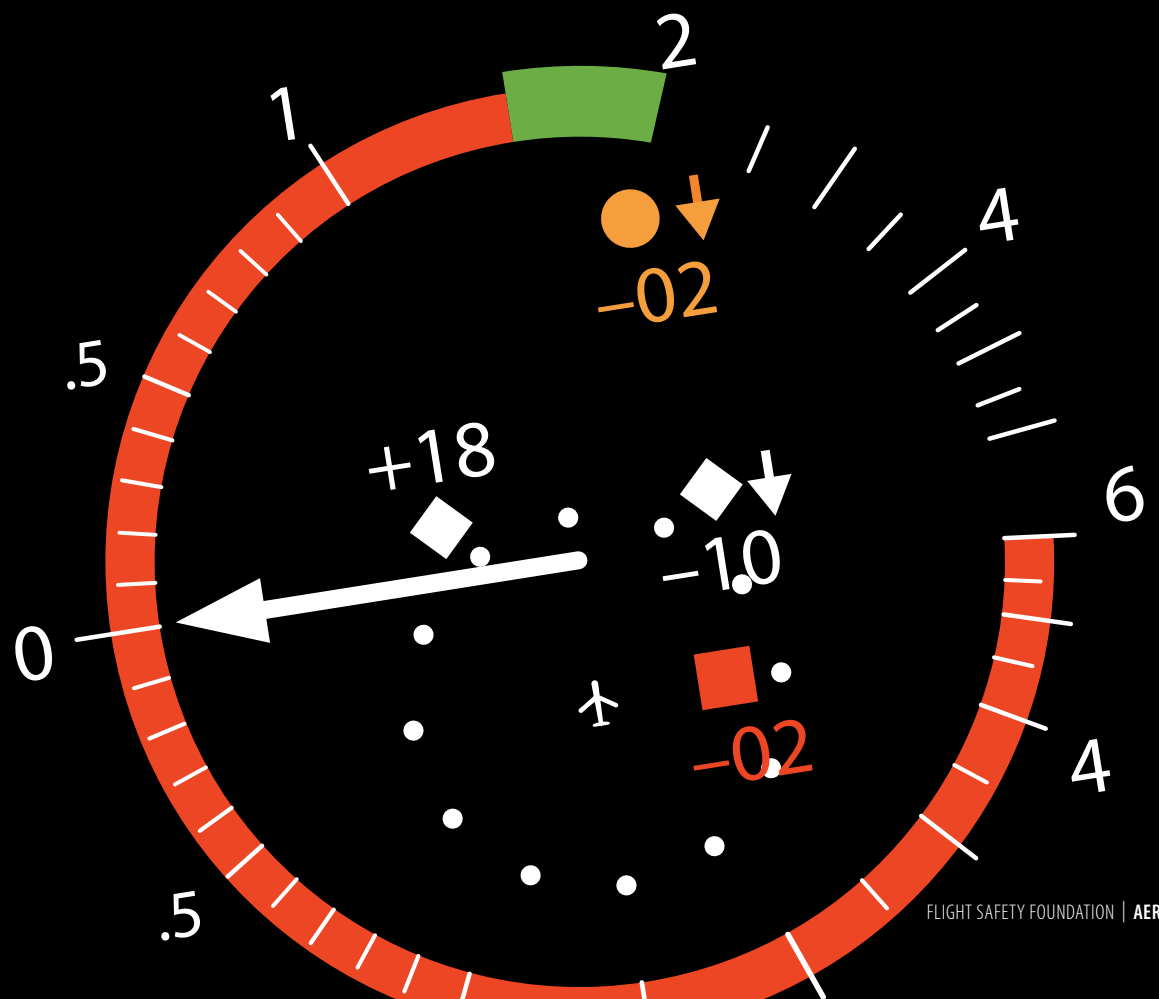
Separation

Imminent approval of software upgrade promises safer TCAS II collision avoidance system logic.

Traffic alert and collision avoidance system (TCAS II) Version 7.1 — a software upgrade developed by European and U.S. specialists — is expected to clear one of the last technical hurdles on its five-year path to operational readiness during April. Possibly by mid-2010, the upgrade installed in new TCAS II equipment will fix two serious problems in today's collision avoidance system logic and make other minor improvements. Strategic decisions on whether civil aviation authorities will recommend or require retrofitting Version 7.1 logic are pending.

One problem is that Version 7.0 logic does not reverse some resolution advisories (RAs) when a reversal is required to resolve the threat of collision between two equipped aircraft while both are climbing or descending within a vertical distance of 100 ft of each other. The other problem is flight crews with vertical speed TCAS II displays maneuvering in the wrong vertical direction after receiving one of four "Adjust Vertical Speed, Adjust" (AVSA) RAs. AVSA RAs, now considered ambiguous by many safety specialists, advise a pilot to reduce the aircraft rate of climb or descent to 0, 500, 1,000 or 2,000 fpm for collision avoidance, and they lack any upward or downward aural annunciation.

AVSA RAs have accounted for nearly two-thirds of all RAs in European airspace, occurring mainly in geometries involving level-off at 1,000-ft altitude increments as assigned by air traffic control (ATC). Pilot training solutions — for example, re-emphasizing that the



Anxiety

BY WAYNE ROSENKRANS

proper response to any AVSA RA is a reduction in vertical speed while maneuvering toward level flight — alone have not worked, European specialists say.[1]

Version 7.1 solves the first problem with a significant software code change that monitors compliance with RAs and enhances the reversal logic, allowing reversals when the aircraft are vertically within 100 ft. Version 7.1 solves the second problem by replacing AVSA RAs with a "Level Off, Level Off" RA. Independent validations by computer simulations with actual air traffic data from several European sources, Boston and New York have demonstrated safe and effective software performance.[2]

A Eurocontrol recommendation in July 2008 urged the industry to aggressively pursue this software upgrade when revised U.S. and European technical standard orders (TSOs) for TCAS II take effect. "As TCAS II Version 7.1 provides further significant reduction in the risk of midair collisions, it is therefore strongly recommended that TCAS II Version 7.1 is implemented as rapidly as possible," Eurocontrol said.[3]

The organization's policy position is that until all current TCAS II–equipped aircraft and new aircraft are Version 7.1 compliant, there will be no short-term reduction in the unacceptable risk of midair collisions to the Version 7.0–compliant aircraft in Europe, a risk equivalent to one midair collision every three years. Forward fit plus retrofit delayed not more than two years would reduce this risk by a factor of four (*ASW,* 10/08, p. 53), Eurocontrol said.[4] Some European specialists say that no hardware modifications should be necessary, and they have proposed that International Civil Aviation Organization (ICAO) standards require TCAS II Version 7.1 equipage by Nov. 30, 2010, for new aircraft and by March 31, 2013, for existing aircraft.[5]

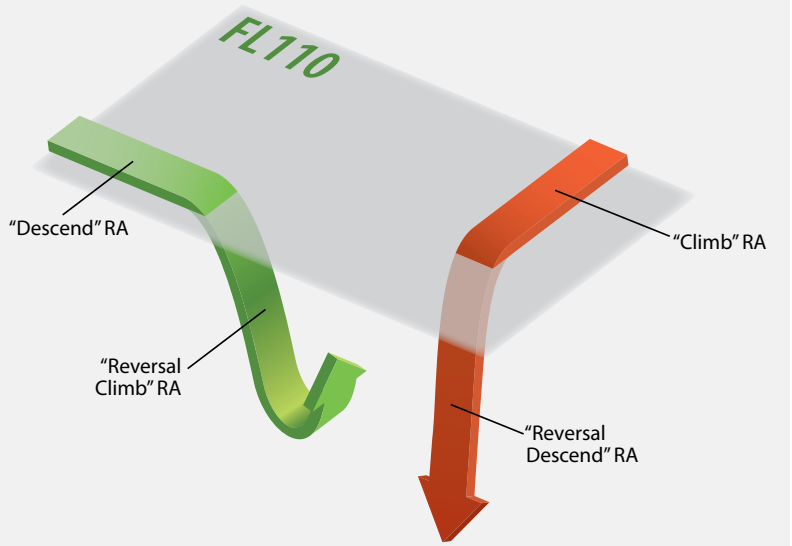
In December 2008, John Marksteiner, the U.S. Federal Aviation Administration (FAA) representative to an ICAO aeronautical surveillance working group, said that it would be premature for ICAO to consider a timeline for mandatory worldwide carriage of TCAS II Version 7.1 without further study.[6] He cited several issues as still unresolved, including different risk levels in the United States and Europe, possibly time needed for manufacturers to develop new equipment and retrofit packages, and an unknown scope of hardware upgrades.

He raised other questions to consider. Will standard cost-benefit analyses show that requiring Version 7.1 retrofit is justifiable instead of clarifying the meaning of AVSA RAs and improving pilot compliance with Version 7.0 RAs through training? How effectively could midair collision risk be mitigated without Version 7.1 compliance by training pilots to climb and descend at less than 1,500 fpm in the last 1,000 ft before level-off at the assigned altitude/flight level? Would analysis of RAs, based on pilot reports and monitoring of downlinked Mode S RA data, enable civil aviation authorities to identify "RA hot spots" in their airspace and mitigate the Version 7.0 shortcomings — with procedural changes, for example?

After TSO revisions for the Version 6.04a-to-Version 7.0 logic upgrade were issued in 1999, the European Joint Aviation Authorities in January 2000 mandated TCAS II Version 7.0 carriage by all civil turbine-engine aircraft with more than 30 passenger seats or maximum takeoff mass of more than 15,000 kg (33,070 lb). U.S. Federal Aviation Regulations (FARs) for these aircraft currently require Version 7.0 or equivalent logic but allow version 6.04A Enhanced if that logic was installed before May 1, 2003, and can be repaired to conform to its original minimum operational performance standards.[7]

U.S. and European TSO revisions expected during 2009 will establish the dates when newly identified or manufactured TCAS II equipment must be Version 7.1 compliant. Steve Plummer, designated federal official representing the FAA at the March 12 meeting of RTCA Special Committee 147 (SC-147), offered no details but said that the FAA is now evaluating what the appropriate strategy should be for implementing Version 7.1, working on harmonizing rule-making strategy with the European Aviation Safety Agency (EASA) and, like others, proposing Version 7.1–related

TCAS II Version 7.1 Solution to Pilot Error



TCAS = traffic alert and collision avoidance system; RA = resolution advisory; FL = flight level

Note: Current TCAS II logic allows only one climb/descend sense reversal, and reversing an ongoing RA is not permitted while the aircraft are maneuvering within a vertical distance of 100 ft of each other. The illustrated enhancement in the new Version 7.1 logic is that if the aircraft with the red flight path descends contrary to a "Climb" RA, immediate reversal RAs will be generated for pilots of both aircraft.

Source: Eurocontrol Safety Issue Rectification Extension Plus Project

Figure 1

language for ICAO standards and recommended practices. The RTCA meeting included representatives of its counterpart on TCAS II standards, the European Organisation for Civil Aviation Equipment (EUROCAE) Working Group 75 (WG-75).

Last-Minute Modification

The TCAS II Version 7.1 revision to minimum operational performance standards was published by RTCA as RTCA/DO-185B in June 2008 and by EUROCAE as Document ED-143 in September 2008. A post-revision validation process led to a delay in completing the TSOs, however, when a minor discrepancy came to light between the pseudocode[8] and state charts.[9] In one multi-aircraft scenario — that is, involving more than two aircraft — run on a standard computer simulation program, the RAs did not agree. This led to more development, testing, multi-site verification and validation of modifications issued as Change 1 to this standard.

Change 1 eliminates the corrective green arc in TCAS II display symbology for a weakening RA for the aircraft in the middle of a multi-aircraft encounter, according to an SC-147 working group report presented by Andrew Zeitlin of The MITRE Corp. Center for Advanced Aviation Systems. Validations by Eurocontrol and Massachusetts Institute of Technology (MIT) Lincoln Laboratory confirmed that the modifications were safe and effective, Zeitlin said.

On April 21, SC-147 is scheduled to approve Change 1 to RTCA/DO-185B. Probably later in the second quarter, the RTCA Program Management Committee is expected to approve this change, in turn enabling the FAA to issue TSO C119c, "Traffic Alert and Collision Avoidance System (TCAS II) Airborne Equipment, TCAS II With Optional Hybrid Surveillance." Parallel work in Europe included EASA's March 12 issuance of Notice of Proposed Amendment No. 2009-03 similarly updating European Technical Standard Order ETSO-C119b.

FAA Monitors RAs

The FAA has been deploying monitoring systems at 20 U.S. sites that collect data on TCAS RAs for analysis of both safety and air traffic management. As of March, the systems were operational in Boston, Los Angeles, New York and Philadelphia, said Neal Suchy, the FAA's TCAS program manager during Version 7.1 development.

This FAA analysis first has focused on business jets operating below Class B airspace and RAs occurring during multi-aircraft encounters, he said. Three more California sites — Ontario, Long Beach and Oakland — are scheduled to be deployed by the end of May, and the FAA also expects to monitor TCAS II performance near Louisville, Kentucky, using automatic dependent surveillance-broadcast technology in the nation's first Next Generation Air Transportation System (NextGen) environment.

During development of Version 7.1, Eurocontrol contractors used TCAS II computer simulations to validate the performance of the AVSA RA–related enhancements. They first were compared with Version 7.0 using aircraft

encounter data from Europe. The effort comprised safety aspects, human factors aspects and operational aspects.

After reviewing the European results, however, RTCA SC-147 specialists wanted to confirm that AVSA-related enhancements would not disrupt FAA terminal control area operations or induce a conflict with a third-party aircraft flying near a TCAS II-equipped aircraft, given the country's dense mixes of air carrier and general aviation traffic operating under different flight rules. In response, a Eurocontrol analysis identified 92 initial AVSA RAs among a total 992 RA encounters from Boston-area data recorded by MIT Lincoln Laboratory, with 81 AVSA RAs suitable for detailed study.

These RAs occurred during six months of 2006 within a 60-nm (111-km) radius of Boston Logan International Airport, and the Eurocontrol contractors received both FAA radar data and RAs downlinked by MIT from a Mode S transponder sensor. About half of the recorded AVSA RAs involved two aircraft; the remainder involved three to seven aircraft in the surrounding traffic.

This analysis found that the AVSA-related changes in TCAS II Version 7.1, assuming that all aircraft in the airspace were equipped alike, would generate one "Level-off, Level-off" RA about once every three days in the Boston airspace compared with an average of 18 RAs of all types recorded every three days. The new "Level-off, Level-off" RA did not induce a conflict with any third-party traffic, and the likelihood of such a conflict was deemed "extremely remote."

Eurocontrol contractors next looked at three months of 2007 FAA radar data from recorded aircraft encounters that occurred within a 60-nm radius of John F. Kennedy International Airport. They did not have downlinked Mode S transponder data available from this airspace, so RA data were extrapolated based on an assumption that the aircraft were fitted with TCAS II operating in RA mode as required by current FARs.

Pilot-Friendly Benefits

Eurocontrol, its research contractors, other European aviation organizations and the FAA expect introduction of the "Level-off, Level-off" RAs in TCAS II Version 7.1 to be welcomed worldwide. The Version 7.0 logic had been designed with an expectation that pilots of converging aircraft would become comfortable ensuring initial separation solely by simultaneously modifying their present climb/descent rates rather than climbing, descending or leveling off. In such scenarios, however, today's TCAS II may direct one flight crew to reduce climb rate from, say, 2,500 fpm to 1,000 fpm in about three seconds, Eurocontrol noted. Unlike that scenario, intuitively simple "Level-off, Level-off" RAs will be of shorter duration and typically involve less altitude change.[10]

"In the same geometries, the Version 7.0 logic can post increasingly stronger AVSA RAs, possibly up to a positive RA, in quick succession if the vertical convergence rate is not decreasing as fast as expected, which constitutes a complex RA sequence," said the Eurocontrol report on New York airspace simulations. "With [Version 7.1 logic], this complex sequence can be replaced by a single Level-off RA, as it is more efficient in rapidly reducing the vertical convergence."

For ATC, one of the main safety benefits of Version 7.1 will be that pilots receiving RAs will not continue in the same vertical direction, Eurocontrol said. A conclusion from its analysis of Boston data was that "TCAS II Version 7.0 issued RAs that left both aircraft evolving in the same vertical direction and, despite appropriate pilot responses, the target vertical separation of 350 ft was not achieved at their closest approach."

Notes

1. Arino, Thierry; Chabert, Stéphan; Drévillon, Hérve. "Decision Criteria for Regulatory Measures on TCAS II Version 7.1." Eurocontrol Mode S Programme, DSNA and Egis Avia Safety Issue Rectification Extension Plus (SIRE+) Project. July 17, 2008.
2. Arino; Drévillon. "Operational Performance of CP115 in New York Airspace." Dec. 4, 2007.
3. Arino; Chabert; Drévillon.
4. Eurocontrol. "TCAS II Version 7.1." <www.eurocontrol.int/msa/public/standard_page/ACAS_Upcoming_Changes.html>.
5. Loscos, Jean-Marc; Mallwitz, Roland; Potier, Eric; Woods, Ray. "Update to ACAS Mandatory Carriage." An ICAO working paper presented in Montreal to the Aeronautical Surveillance Panel Working Group of the Whole. Document ASP-WGW/1-WP/12. Nov. 24, 2008.
6. Marksteiner, John. "ACAS Carriage Considerations." An ICAO working paper presented in Montreal to the Aeronautical Surveillance Panel Working Group of the Whole. Document ASP-WGW/1-WP/17. Dec. 5, 2008.
7. Eurocontrol ACAS [Airborne Collision Avoidance System] Programme; Sofréavia; CENA. "European Maintenance of TCAS II Version 7.0: Project EMOTION-7 Final Report." Report no. ACAS/03-003. January 2003.
8. *Pseudocode* is an informal structured language that programmers use to convey to other people high-level descriptions of computer programming algorithms.
9. *State charts* in RTCA/DO-185B are tables showing a transition, code location, trigger event, true/false status of conditions and output action in the collision avoidance system logic.
10. Arino; Drévillon. "Operational Performance of CP115 in Boston Airspace." March 9, 2007.