A new control law in flight guidance computers will reduce non-safety-critical TCAS RAs, Airbus says.

Softening Level-Offs

BY WAYNE ROSENKRANS | FROM MILAN

An altitude-capture software enhancement has been developed to eliminate the predominant cause of resolution advisories (RAs) from traffic-alerting and collision avoidance systems (TCAS II). It works by automatically adjusting the trajectory of at least one airplane converging with another during specific climb/descent scenarios.

Airbus TCAS Alert Prevention (TCAP) adds this functionality to the existing spectrum of defenses against midair collisions, said Christophe Cail, test pilot for the company. No changes to TCAS, human-machine interface or training are required.

Performance assessment with Eurocontrol's Interactive Collision Avoidance Simulator (InCAS^3) tool and Airbus simulation tools has enabled the company to estimate introduction of TCAP on new airframes and as retrofits beginning in 2011–2013, assuming that regulatory certification proceeds as expected, Cail said in November 2010 at Flight Safety Foundation's International Air Safety Seminar in Milan, Italy. Increasing traffic volume and wider use of reduced vertical separation minimums have been among factors drawing worldwide attention to the so-called side effect of the TCAS RAs generated in non-safety-critical scenarios. He called these "nuisance RAs during 1,000-ft level-off maneuvers."

Addressing this issue has been challenging because TCAS algorithms do not take into account pilot intentions, such as the intent to change an apparent collision trajectory by leveling off. The Airbus solution responds to safety

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recommendations from the French Bureau d'Enquêtes et d'Analyses (BEA) and Eurocontrol. In 2003, after investigating an incident involving an RA, the BEA recommended that the TCAS RA-triggering threshold be taken into account in the altitude-capture law of Airbus automation, he said. The same year, Eurocontrol proposed that Airbus modify its autopilot altitude-capture law by "an earlier reduction of vertical rate." Several airlines also requested a solution.

The specific types of RAs for which TCAP was designed are operationally undesired alerts in either of two simple encounter geometries. "More than 50 percent of all RAs [in Europe are] from these two geometries," Cail said. "The first is when one aircraft is climbing toward a flight level [FL] such as FL 100 [approximately 10,000 ft] and another aircraft [in cruise] is just at the adjacent flight level, 1,000 feet above, at FL 110." What typically has occurred is that, depending on the vertical speeds and the geometry, the climbing crew received first a traffic advisory (TA), then an RA directing them to "adjust vertical speed" while the TCAS aboard the aircraft in level flight directed that crew first to climb and then to descend back to the assigned flight level (Figure 1).

The other encounter geometry involves one airplane climbing toward a selected flight level, say FL 100, and the other aircraft descending to capture FL 110. "The relative vertical speed is higher, and the flight crews could get an RA," he said.

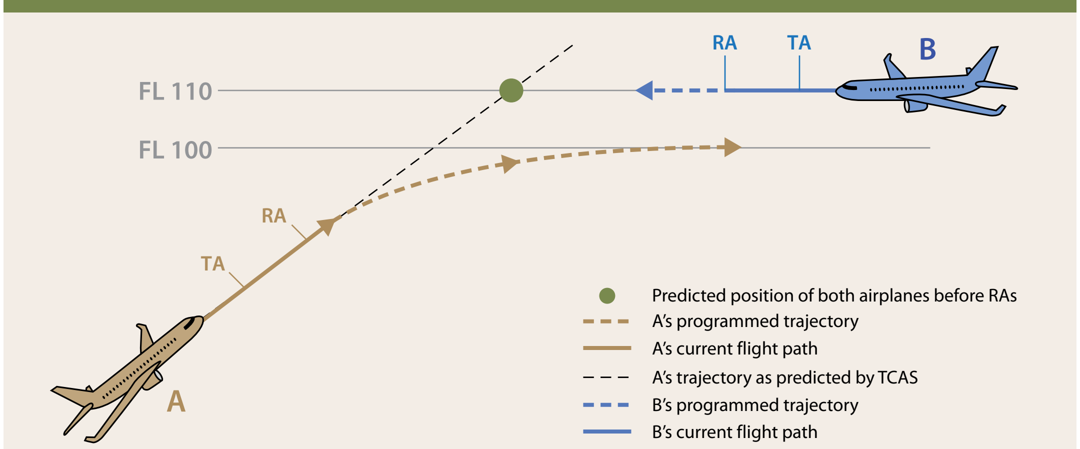
In 2010, Airbus assessed TCAP performance. "We avoided 100 percent of those operationally undesired RAs [in simulated cases]," Cail said. "We are very confident that in actual airspace, TCAP will be very efficient. [This research] has to be consolidated later on during a study in the framework of the Single European Sky Air Traffic Management Research project."

When trajectories of one TCAP-equipped airplane and one non-equipped airplane converged on altitudes separated by 1,000 ft per air traffic control (ATC) instructions, one TA and two RAs occurred on each flight deck. Only one TA occurred on each aircraft, however, when one was TCAP-equipped in the same simulated scenario. "So the benefit is also for non-equipped aircraft," he said.

The logic of TCAS explains why non-safety-critical RAs occur even with Version 7.1 software released in 2009 (*ASW*, 4/09, p. 34). "TCAS [logic] doesn't 'care' about the intention of the crew or what is in the flight management system of the aircraft," Cail said. For example, in aircraft between FL 100 and FL 200, if the computed time to collision is less than 30 seconds, the flight crews will receive an RA, he added.

"Usually, [the recommended intervention (*ASW*, 4/09, p. 19)] when an aircraft is close to its targeted flight level is … to manually select a new vertical speed instead of leaving the aircraft to follow its existing path," he said. "What happens

Operationally Undesired TCAS RA: Single Level-Off Maneuver



TCAS = traffic-alerting and collision avoidance system; TA = traffic advisory; RA = resolution advisory; FL = flight level

Source: Airbus

Figure 1

in reality is that [this intervention] is not always applied."

Because TCAS generates TAs — indicating the presence of another aircraft — before RAs, Airbus flight guidance computer system engineers developed a method of "softening" the trajectory, reducing the vertical speed of the TCAP-equipped airplane to avoid the need for an RA in these scenarios. "The principle was to introduce a new altitude-capture law that will 'soften' the capture in the presence of other traffic," Cail said. "We wanted to impact only the flight guidance computer, with no human-machine interface impact and no additional training."

Along with the prerequisite TA, three other conditions must be satisfied for TCAP to activate. "The autopilot and/or the flight director has to be engaged," he said. "The aircraft has to be converging toward its selected altitude [and the situation must meet] the 'TCAP availability threshold,' [designed to limit] activations only to TAs corresponding to the 1,000-ft level-off encounters."

The TCAP availability threshold is a vertical distance calculated using the equipped airplane's vertical speed, its distance to capture of the selected altitude and the altitude where the TA occurred. This distance is applied by the altitude-capture control law within the flight guidance computer, which factors in an intruder aircraft capturing the same altitude with conventional altitude-capture control law as one aircraft climbs and the other descends.

For instance, if while descending to capture FL 300, a TCAP-equipped airplane crosses FL 340 with a vertical speed of 6,000 fpm and convergence with an intruder aircraft triggers a TA, TCAP will activate given that the equipped airplane's position is lower than FL 365. But in the same scenario with a vertical speed of 2,000 fpm, TCAP activation will be inhibited given that the equipped airplane's position is not lower than FL 335.

"If, before the TA triggering, the [autopilot] is in open climb/descent mode or level change mode in descent, there will be an immediate reversion to altitude capture mode [ALT* on the Airbus flight mode annunciator (FMA)] with the new TCAP altitude control law active," Cail said. If the aircraft is already in ALT* mode with conventional altitude capture control law active when a TA occurs, ALT* will be maintained but with an automatic change from that law to TCAP control law, he said.

To retain the existing human-machine interface, the ALT* mode remains displayed on the FMA. There is no change to the autopilot/flight director/autothrottle engagement stages or other impact on the lateral trajectory or mode, he added.

"When the TA occurs, the ALT* with TCAP law remains until the end of the capture [even if the TA ceases, to avoid causing further TAs]," Cail said. "[In ALT* TCAP] control law, one or several vertical speed targets [are computed,] and the airplane will go from one [speed target] to another with a load factor of 0.15 g [i.e., 15 percent of standard gravitational acceleration]. As a pilot, you feel it [as sensory feedback by design]. At the end of the capture, [this mode] reverts to the normal ALT* parabola [trajectory profile] at 0.5 g." Airbus optimized this function during 100,000 simulated encounters, including other algorithms for "early TAs" that occur farther than 2,000 ft from the selected level-off altitude.

Cail used a typical operational scenario with and without TCAP to illustrate the benefits for non-equipped airplanes. One flight crew with TCAP receives the TA while in descent and 2,000 ft above the targeted flight level. "As soon as the airplane gets the TA, TCAP will take the first new vertical speed target," Cail said. "As soon as the aircraft crosses 2,000 ft above the targeted flight level, there will be a reduction of the vertical speed to 1,500 fpm."

In this scenario without TCAP, the flight guidance computer of the descending airplane is in ALT* mode and less than 2,000 ft from the crew's targeted flight level. "The crew gets the TA, and instead of continuing the capture that [would lead] to an RA, the pilot will [have to select a] vertical speed that is lower, a value between 1,200 fpm and 1,500 fpm," Cail said. "This function will increase the time to capture the altitude. This is one of the reasons [Airbus] wanted to activate [TCAP] only when relevant. The average increase in time is something like 40 seconds."

Airbus envisions TCAP reducing non-safety-critical RAs worldwide. Meanwhile, the RAs targeted by TCAP continue to occur despite appropriate maneuvers by pilots and appropriate instructions by ATC controllers, he said. Fewer RAs mean "less stress for the crew and less perturbation for the traffic because no avoidance maneuver will be done; it is unnecessary," he said.

With TCAP, flight crews will monitor the autopilot modes, airplane trajectory and altitude capture without the obligation to remember to manually intervene to adjust the vertical speed during the last 1,500 ft before capture, Cail added.

Airbus expects to obtain regulatory certification between 2011 and mid-2013, with timing dependent on the aircraft type. The company expects to fly TCAP-equipped test airplanes in early 2011, he said.