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ELEVENTH AIR NAVIGATION CONFERENCE

Montreal, 22 September to 3 October 2003

Agenda Item 1: Introduction and assessment of a global air traffic management (ATM) operational concept

1.4 : The role of airborne collision avoidance systems (ACAS) technologies

EXPERIMENTATIONS CONDUCTED BY FRANCE INVOLVING GLIDERS EQUIPPED WITH TRANSPONDERS IN THE VICINITY OF ONE ACAS-EQUIPPED AIRCRAFT

(Presented by France)

SUMMARY

Every year, several losses of separation leading potentially to a collision, are reported in France, involving commercial air transport aeroplanes and gliders. In order to fully understand the potential impact of numerous transponders on ACAS II, some experimentations were conducted in 2001 involving gliders equipped with Mode A/C transponders in the vicinity of one ACAS II-equipped aeroplane.
The preparation of the experimentations highlighted technical, operational and regulatory issues. It is shown that the installation of Mode A/C transponders on board isolated gliders. On the other hand, ACAS is unable to correctly track the intruders in a cluster configuration of flight. It is assumed that this situation would be improved with Mode S transponders (experimentations are planned in 2003). In any event, the safest solution consists in implementing designated airspace classes or specific airspace zones, in order to protect the IFR published routes.

[1] English version provided by France.

1. INTRODUCTION

1.1 Every year, several losses of separation are reported in France, involving commercial air transport aircraft and gliders. As an indication, 22 "airprox" procedures involving this type of aircraft were investigated between 1993 and 1997. In the absence of appropriate airborne equipment enabling the detection of gliders, this kind of event shows the difficulty of applying the "see and avoid" procedure in accordance with the rules of the air.

1.2 Following a collision dated 12 February 1999 between an Airbus A320 and a glider, the French Bureau of Accident Investigations (BEA) recommended in its report in particular, that the DGCA took action in order that any IFR public transportation aircraft could be aware of the presence of an aircraft presenting a potential risk of collision. Three main objectives were defined:

1) the implementation of appropriate classes of airspace, or specific airspace ensuring the protection of IFR published routes;

2) the ACAS equipage of passenger-carrying aircraft in advance of the regulatory date for mandatory carriage in Europe; and

3) the mandatory carriage and utilisation of pressure-altitude reporting transponder for all aircraft flying above designated flight levels.

1.3 In order to take into account these recommendations, the air navigation services undertook some experimentations in 2000 and 2001 with the view to studying the impact of a cluster of gliders equipped with Mode A/C transponders on ground and airborne systems.

1.4 This note addresses only the impact on ACAS. The report containing all the results for ground and airborne surveillance is available upon request. Reference: Technical Review of STNA No. 62, May 2002 – Overflying a cluster of gliders: http://www.stna.aviation-civile.gouv.fr/gb/actualites_gb/revuesgb.

2. TRANSPONDER INSTALLATION ON-BOARD GLIDERS

2.1 A first series of experimentations was undertaken to evaluate the feasibility of transponder installation on-board gliders. In fact, considering the small available space inside the gliders, it was necessary to list the constraints of installation and certification for this type of aircraft. In particular, the addition of the transponder should not have required additional power supply. Another essential issue was the location of the antenna. Several configurations (internal, external) were evaluated including the impact of the radiations on the pilot in the configuration of an antenna inside the glider. The link budget integrity, in particular for close evolutions as well as the compliance with standards on the protection of human against electromagnetic radiations were analysed for this antenna configuration.

2.2 The results are as follows:

— The link budget is satisfactory only with external antenna;

— No need for additional power supply;

— The standards on the protection of human against electromagnetic radiations are quite satisfied; and

— At the time of the experiment only Mode A/C transponders were available. (No Mode S for general aviation).

3. PREPARATION OF THE ACAS EXPERIMENTATION

3.1 The aim of the experimentation was to verify the impact of a high density of transponders on ACAS. The main foreseen problems were identified in order to prepare the scenarios for the gliders:

3.1.1 Surveillance problems

3.1.1.1 Garbling: the replies from two or more close aircraft (within 1.6 NM) overlap and render their decoding extremely difficult. Therefore, the probability of detection is degraded and the number of false Mode C is increased. The TCAS antennas provide a much lower directivity than the ground radar: 4 quadrants for transmission only. This renders TCAS very sensitive to this phenomenon. However, the detection processor is able (theoretically) to decode three garbled replies. In addition, the “Whisper-Shout” technique should provide an improvement in the detection performance under these conditions. The experiment should therefore check that ACAS algorithms, which can efficiently decode up to three overlapping replies, function correctly in this situation (at least five aircraft in a garbling situation).

3.1.1.2 FRUIT (asynchronous overlapping reply), further to receipt of undesired transponder replies due to an interrogation emitted by another ACAS, or by surveillance radar.

3.1.2 Tracking problems

3.1.2.1 To track Mode A/C transponders, ACAS only use “Mode C all-call only” interrogations. Contrary to radar tracking, there is no Mode A interrogation of the transponder, which increases the difficulty of associating a plot with an existing track. It is obvious that the tracking process will encounter increased difficulties with aircraft flying at the same altitude. This constraint imposed some flight profiles where the gliders were at similar altitudes and some with the gliders vertically stacked.

3.1.3 Multi-intruder collision avoidance logic

3.1.3.1 Some simulations performed on the logic enabled to detect certain encounter geometries where the multi-intruder logic would be in default. The resolution would not be the best solution for the specific situation. Although the reproduction of such a configuration seemed difficult, one scenario was dedicated to this problem.

3.1.4 Traffic display for the flight crew

3.1.4.1 It was important to evaluate whether the display of numerous traffic was still readable and if the encounter with a cluster of gliders was not generating an excessive workload and stress affecting safety.

3.2 Several scenarios illustrating typical gliders operations have been defined in order to assess the issues listed above.

— string of 5 gliders: the ACAS-equipped aircraft is flying at a converging angle of 90 degrees then with a parallel trajectory;

— stack of 5 gliders: the ACAS-equipped aircraft is flying above, then 2 gliders quit the stack; and

— stack of 3 gliders: the ACAS-equipped aircraft (with a small offset), is facing the gliders in the middle in order to trigger a resolution advisory (RA).

3.3 These experimentations were conducted with an ATR42 as the ACAS-equipped aircraft, (flight inspection aircraft) and several gliders were equipped with Mode A/C transponders. (no Mode S transponder for general aviation was available at the time of the experimentation). In fact, for safety reasons, light aircraft were used but their flight profiles (speed and trajectories) were typical of actual gliders.

4. RESULTS FOR THE EXPERIMENTATION CONDUCTED FOR ACAS

4.1 The recorded data used for this analysis were the on-board data sent by TCAS to its display (IVSI). These data contain the list of traffic resulting from the detection and tracking by TCAS and enable the complete replay of what was displayed to the flight crew on the IVSI. The detailed analysis also enabled to assess the quality of the surveillance. However, it was not possible to distinguish the detection process from the tracking process. In order to positively confirm the aircraft trajectories, the three monopulse radar data had been recorded and analysed as well as flight crew reports.

4.2 For a cluster of aircraft, ACAS would always detect intruders although it never had the complete set. Generally speaking, the probability of display of intruder traffic was about 65 per cent when the aircraft were vertically spaced. Unfortunately, it fell down to 30 per cent when the aircraft are at the same altitude. In this latter case, only two tracks out of five are displayed without being aware if the two displays correspond to the same two aircraft. It is highly probable that these tracks were generated from different aircraft because there were numerous tracks with a short duration.

4.3 During the experimentation, two unexpected traffic enabled to draw further conclusions. The first aircraft crossed the zone (although it was declared with restricted access) and a traffic advisory (TA) was generated meanwhile the second aircraft was flying below the restricted zone. In both cases, TCAS perfectly detected the intruders, even when they entered the garbling situation created by the cluster. The scenario where two aircraft left the cluster also confirmed that the detection is excellent for traffic with trajectories diverging from that of the cluster, even when there is a local garbling geometry.

4.4 For the last trials, inappropriate successive RA were generated which proposed contradictory manoeuvres. The detailed analysis of the data indicated that the main cause for this inappropriate generation of RA is the lack of reliability of the altitude information of the tracks fed in the collision avoidance logic. The vertical profiles of these tracks show several deviations which failed the logic. The failure is rather in the tracking process than in the detection process since these profiles are more easily explained by switching plots than by erroneous Mode C decoding. The fact that unexpected traffic crossing the cluster are correctly displayed would support this assumption.

4.5 There had been several losses of traffic display although these traffics were in TA mode or even RA mode. This specific situation is a matter of concern because both the RA and the traffic disappeared without notice to the pilot such as “clear of conflict”.

4.6 It was not possible to draw any conclusion on the multi-intruder logic because the logic was provided erroneous tracks.

5. CONCLUSIONS OF THE EXPERIMENTATION

5.1 In presence of a high density of transponders in a garbling configuration, ACAS is unable to track correctly the intruders. The tracks are built upon plots issued for different aircraft thus showing erratic trajectories with false altitudes. This situation triggers unnecessary alerts which are not different from normal ones from a pilot’s perspective. There were even RA which were not usable, with proposed manoeuvre against intruder which suddenly disappeared. Such a situation would be extremely dangerous in “real life”.

5.2 Although imperfect, the traffic display provides the pilot with the information of the presence of a zone with a high density of aircraft; however, the data cannot provide the pilot with the appropriate information for the efficient surveillance and the visual acquisition of the intruders. The total number of intruders is never displayed and several vertical jumps are occurring in the trajectories.

5.3 For the traffic outside the high density zone, the conclusions are definitely better. The surveillance is not affected, the detection is excellent, and the logic performs as expected.

5.4 The results of the radar analyses (mono-radar and multi-radar) are rather pessimistic and consistent with the ACAS one.

5.5 In other words, the installation of Mode A/C transponders on-board gliders is acceptable for isolated gliders since it enables the ground or airborne surveillance. This can be seen as an improvement of the current situation. As far as clusters of gliders are concerned, the conclusions are rather extreme: on the one hand, the transponders enable the detection of a zone of high density, on the other hand, because of the garbling, they reduce the quality of surveillance in the zone. However, the surveillance is not affected outside the zone.

6. FUTURE WORK

6.1 One improvement in the experimentation would be to use Mode S transponders, which would likely produce better results typically in this garbling situation. In fact, all the traffic would be displayed without any altitude error. The surveillance would be very much improved not only for ground Mode S station but also for ACAS. It may happen that the collision avoidance logic would be so intensely solicited by the high number of intruders that it may fail.

6.2 Another possible, long-term, solution would be Automatic Dependent Surveillance — Broadcast (ADS-B) but it requires technical maturity and standardisation before any use in this context. In fact, the experimentation would necessitate the installation and certification of a Cockpit Traffic Display of Information (CDTI), enabling the display of all ADS-B equipped aircraft. In addition, the new operational use of ACAS would have to be defined.

6.3 In 2003, new experimentations are planned with an ACAS II equipped aircraft and several Mode S equipped general aviation aircraft with the view to evaluating the improvements provided by Mode S. The results will not be available by the time of the conference but will be made available as soon as possible.

6.4 If the installation constraints are not too stringent, transponders with ADS-B capability (Mode S extended squitter) would be used in order to test this technique for this type of operation.

7. ACTION BY THE CONFERENCE

7.1 The conference is invited to note the above information.

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