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Working Group 4

Airborne Surveillance and Separation Assurance Processing

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Collected ASSAP Comments on Ken Carpenter's Traffic Display Paper
(comments are included as MS Word markups in the margin)

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Standards for traffic displays that include TCAS tracks

(Prepared by Ken Carpenter)

Reference

“Standards for traffic displays that include ACAS tracks”, SCRSP/WGA WPA/10-25, April 2006

1 Introduction

- 1.1 Flight deck traffic displays that show both aircraft tracks based on ADS-B and TCAS tracks are being developed, and some have been deployed. This raised the question, in the ICAO SCRSP, whether there is any guidance that ICAO should give on the display or use of the TCAS tracks, and whether any standards would be appropriate. The Reference was the last in a series of SCRSP papers of the same title containing proposed standards for discussion.
- 1.2 SCRSP WGA agreed an early version of the paper as a starting point for consultation and coordination, and made its own input. The paper has been circulated to various groups, including SC186, and some comments have been received. SC186 (neither the CDTI group nor the ASSAP group) has not sent in definitive comments on the paper, although they have had it for some time. In truth, it is a little difficult to see why they should be very interested since the requirements expressed in the paper are specific to TCAS.
- 1.3 At its meeting in May 2006, SCRSP WGA considered a proposal to refer the paper to the Operations Panel. SCRSP took the view that the questions raised in this paper are technical, and that primary responsibility (within ICAO) for this subject should remain with the Aeronautical Surveillance Panel (ASP – the new name for SCRSP).
- 1.4 SCRSP WGA did not make any further changes to the material at its meeting in May, leaving it unclear how the matter was to be progressed in practice. It is now proposed (belatedly, one might suggest) that SC147 is the best forum in which to develop these proposed standards further.
- 1.5 By and large, the paper discusses standards relating to what TCAS data should be displayed rather than standards relating to the display. The exceptions relate to the use of TCAS symbology. It is assumed and accepted that the SC186 CDTI group is the group responsible for developing display standards for CDTIs. However, the standards suggested here relate specifically, and solely, to TCAS, and they are not proposed as “display standards”.
- 1.6 The suggested draft standards are attached. The presentation differs from that in the Reference, because the earlier version was based on a distinction between statements in SARPs and statements in Guidance Material that is now out of date, and of little consequence for SC147. Section 3 provides a brief summary of the high level issues, highlighting the most contentious points.
- 1.7 The familiar terms ‘ASAS’ and ‘ASAS track’ are used freely in this paper, but all that is implied is the existence of an airborne surveillance application system that produces tracks that are displayed on the flight deck, and used in some currently undefined way. No assumption is made concerning the information available to the airborne surveillance function, nor concerning its quality. ADS-B is not assumed.
- 1.8 SC147 is asked to review the proposed material, to make comments and to pass its comments to the ASP working group.

2 Background

- 2.1 The material in this section is intended as an introduction for readers who are not domain experts. Comments from SC147 and SC186 are very welcome, but the section can safely be ignored in their internal discussions.
- 2.2 Traffic displays that show more than the familiar TCAS tracks are being developed on two fronts: ASAS, and TCAS hybrid surveillance. Some ASAS are already in operational service. The MOPS for TCAS hybrid surveillance were approved on 5 October 2006.
- 2.3 ASAS
- 2.3.1 SC186 is developing MOPS for ASAS.
- 2.3.2 There are some who argue quite strongly that we should not assume that a flight deck traffic display (a CDTI) is essential to the exploitation of airborne surveillance data, but most people simply take it for granted that there will be such a display. SC186 is considering how such displays can be used to support multiple applications, including that of the TCAS traffic display.
- 2.3.3 The reasons for issuing the standards and guidance proposed here relating to traffic displays that display TCAS tracks would be to ensure that the TCAS function is protected, and that the TCAS data are not used inappropriately. Here, “inappropriate” means other than as intended for the TCAS function. In particular, TCAS tracks are not sufficiently accurate to provide a basis for horizontal manoeuvres; and they should not be used as part of a separation mode (whether provided by a controller or the flight crew), because such use would create a common failure mode between separation provision and collision avoidance. Whether these considerations justify ICAO material needs to be discussed, but it is taken for granted in this paper.
- 2.3.4 Thus, the standards and guidance suggested here relate to TCAS, and neither to the use of airborne surveillance data based on ADS-B, nor to the design of airborne surveillance based on ADS-B (or any other source), nor to the display of ADS-B data. It is simply assumed that there is a flight deck traffic display that is showing tracks based on a source other than TCAS, and that these tracks are used in some way that goes beyond aiding see-and-avoid or providing situational awareness.
- 2.4 *Hybrid surveillance*
- 2.4.1 The potential advantages of TCAS hybrid surveillance are that it will reduce the RF interference caused by TCAS, and will improve the quality of the TCAS traffic displays by providing and displaying tracks for some aircraft that would not currently be tracked by TCAS because of the operation of TCAS interference limiting.
- 2.4.2 ADS-B data received via the extended squitter will be validated (initially and at intervals) against active TCAS range and bearing measurements. Subsequently, pseudo-range and pseudo-bearing measurements will be calculated from the ADS-B data and passed to TCAS. TCAS will then track the intruders and show them on the traffic display, tracking the pseudo-range and pseudo-bearing in the same way as it currently tracks active range and bearing measurements.
- 2.4.3 The tracks presented on the traffic display will be shown as TCAS tracks whether they are based on active TCAS interrogations or passive monitoring using ADS-B. Flight crew will not know the individual source for each track and the use of the displays should not change. Although the displays should be more complete, in the sense that more aircraft are available for display, tracks will exist only for transponder equipped aircraft that are within the TCAS active interrogation range. Furthermore, active interrogation by TCAS will have validated every track that is displayed.
- 2.4.4 It seems that the result of TCAS hybrid surveillance, from the operational and flight deck perspective, is no more than an improved TCAS display, more suited to supporting situational awareness. Nothing more can be done with it because there is no distinction between the passive ADS-B based tracks and the active surveillance tracks. Were it desired to use the passive ADS-B tracks in some more positive way, it would be necessary to distinguish them from the active TCAS tracks, and it would probably be desired to show every ADS-B track, whether or not TCAS can validate it. It would cease to be a TCAS traffic display, and would become a more general traffic display that includes TCAS tracks.

3 Proposed standards

- 3.1 The draft standards presented in the Reference distinguished between standards in SARPs and specifications in a manual. However, it is no longer fashionable to propose technical requirements for SARPs. It is now suggested that the Annex 10 SARPs could be limited to a Recommendation and a Note, perhaps as follows:

“The ACAS installation should include a traffic display that shows airborne traffic in plan view. The intruders shown on the display should include the proximate traffic identified in paragraph 4.3.3.2 [of the SARPs] and all potential threats and threats.”

“Note: When the traffic display shows only traffic tracked by ACAS, the specifications contained in RTCA DO-185A and its successor documents are to be followed. When the traffic display shows tracks derived from a surveillance system other than ACAS as well as ACAS tracks, the specifications contained in the ACAS Manual are to be followed.”

Then the Manual (which already exists) would contain all the stuff attached to this paper, in which the former distinction between SARPs and Manual has been removed. The wording of this Recommendation and Note does not matter at this stage.

- 3.2 Previous versions of this paper have included values for the acceptable probabilities for defined errors. The precise values were never intended seriously, and this was stated. However, their presence has proved to be a distraction, and has taken attention away from the main issues, which, at this stage, are whether such material is merited, what its nature should be and how the values for the acceptable probabilities should be determined. The numbers have been replaced by the letters “*TBD*”.
- 3.3 The provisions suggested in the attachment are summarised below. There is more explanation in the attachment. SCRSP considered the ideas sufficiently realistic to be exposed to a wider audience, but on the basis that the purpose of the paper is to promote debate in order to reach a consensus.
- i) Although there are two distinct sources of aircraft tracks, only one track should be displayed for each aircraft.
 - ii) The frequency of two errors is limited: displaying only one track when there are two aircraft; and displaying two tracks when there is only one aircraft.
 - iii) The system is required to decide whether or not a pair of tracks relates to a single aircraft. This is a change in this version, in response to popular demand. It could well make it more difficult to build a system that meets the requirements.
 - iv) It is proposed that the track displayed is the ASAS track, whether it is the better track or not. There is a proviso that the ASAS track is to be good enough to aid visual acquisition of the TCAS target. No exception for a TA or an RA is suggested. (In other words, silence makes quite a strong statement.)
 - v) TAs must be indicated on the display, as (but it still does not say “in the same way as”) they are currently on the TCAS display. Whether any data should be removed from the display is explicitly stated to be an open issue, likely to be determined from the context.
 - vi) Similarly, RAs must be indicated on the display, but here it stipulates in the same way as they are currently indicated on the TCAS display. The priority of following the RA is stated.

4 Conclusion

- 4.1 SC147 is asked to review the proposed material, to make comments and to pass its comments to the ASP.

Proposed standards for traffic displays that include TCAS tracks

1 Requirement for one track per aircraft

1.1 Only one track shall be displayed for each distinct aircraft.

Comment

The requirement for only one track is for simplicity. It presupposes that it is possible to examine two tracks and decide that they relate to a single aircraft or, conversely, that they relate to two aircraft. In general, absolute confidence will not be possible. The error of diagnosing a single aircraft when there are two is addressed in 1.2.1, while that of diagnosing two aircraft when there is only one is addressed in 1.2.2. Finally, the possibility that a decision with the required confidence is not possible is discussed in 1.2.3.

1.2 The following requirements (1.2.1 – 1.2.4) apply when determining whether a TCAS track and an ASAS track relate to a common aircraft.

1.2.1 When there are two aircraft both within 6NM and 1200ft of own aircraft, one with a TCAS track and the other with an ASAS track, the conditional probability of erroneously determining that the two tracks relate to one aircraft shall be less than *TBD*.

Comment [H1]: Why limit this requirement to 6 Nm and 1200ft?

Note:- 4.3.3.2 [of the ACAS SARPs] recommends that all TCAS tracks within 6NM and 1200ft of own aircraft be displayed when there is a TA.

1.2.2 When there is an ASAS track and a TCAS track for the same aircraft, the conditional probability of erroneously determining that the two tracks relate to different aircraft shall be less than *TBD*.

1.2.3 For each TCAS track, it shall be determined unambiguously whether it is for the same aircraft as an available ASAS track. For each ASAS track, it shall be determined unambiguously whether it is for the same aircraft as an available TCAS track.

Comment [H2]: This requirement looks similar to 1.2.1 except that it doesn't allow for a probability of failure.

1.2.4 Note: Information that can be used to test the probability that an ASAS and a TCAS track relate to the same aircraft includes the following:

- a) for Mode S equipped intruders, the aircraft address;
Unfortunately, aircraft addresses are duplicated and can change in flight.
- b) the 3D positions of the candidate intruders and potentially their 3D velocities;
- c) the time evolution of the two tracks.

Comments

On 1.2.1

The threshold, *TBD*, should be chosen on the basis that flight crew should not suffer the concealment of TCAS track because it is mistakenly diagnosed as the same aircraft as an ASAS track, too frequently. The tolerable frequency for this error should be determined by considering its potential consequences, which in this case include collision with the aircraft that was tracked by TCAS due to the track not being displayed. If the ASAS tracks are being used for separation provision, we are considering a common failure mode between separation provision and collision avoidance that has been created by using a single display for the two functions. Collision avoidance is expected to operate independently of separation provision and to provide additional protection beyond that provided by separation provision. This failure mode has to be negligible in that context, and this sets a more stringent standard than that normally applied to catastrophic consequence. A counter-argument could be that TCAS is not expected to track every transponder equipped intruder successfully, and that failure to display a TCAS track because it has been mistakenly associated with the ASAS track for another aircraft is merely another source of failure. The problem with this counter-argument is that it compares a common mode failure with simple failures in the collision avoidance function, and the two are not comparable.

Comment [H3]: I would remind the author that the pressure altitude source and the reply delay is used for both separation and collision avoidance today. To suggest that TCAS and SSR are completely independent is misleading.

Comment [H4]: I think this paragraph over emphasizes the part the plan view plays in the TCAS interface to the pilot. The key display interface a pilot should be following during a RA is the Vertical Speed cue. Even if ASSAP processing mistakenly merges a TCAS and ASAP target for display, it should have no effect on the Vertical Guidance from TCAS. If the incorrectly merged target is so close in Range, Bearing, Altitude, Velocity that the system thinks it is the same, the pilot will be directed to look at the correct position in the sky. If they can visually distinguish the threat from adjacent traffic, that is not a safety issue. It may be a system trust issue or customer satisfaction issue.

On 1.2.2:

The threshold, *TBD*, should be chosen on the basis that showing pilots two tracks for the same aircraft raises issues of credibility and operational acceptability. Thus, the value *TBD* in 1.2.2 is likely to be very much less stringent than that of *TBD* in 1.2.1.

On 1.2.3

This is a change from the previous version, in which it was proposed that the frequency of being unable to decide be limited and that flight crew be advised that firm association of two tracks is not possible. The change was made in response to comments from the OWG, which could be summarised as: "Pilots are not prepared to tolerate a display that says it cannot make up its mind. They would prefer to have the two tracks displayed as though they are two aircraft, without warning that they might correspond to the same aircraft." Making this change reduces the prospects of being able to design a system that meets the requirements, and presupposes that it is worse to tell flight crew that the system cannot make up its mind than it is to tell the flight crew that there is one aircraft when in fact there are two, or *vice versa*.

2 Choice of track

2.1 Flight crew shall be provided with a means to choose the TCAS display (thus suppressing all ASAS tracks and information).

2.1½ Where there is an ASAS track for which there is no corresponding TCAS track, there shall be an indication that it is not possible to generate a TCAS TA or RA against that aircraft.

2.2 Where there is an ASAS track and a TCAS track that have been determined to relate to the same aircraft, the ASAS track shall be displayed provided that it meets ~~it is more accurate than~~ the requirements on TCAS tracks for visual acquisition. When the ASAS track does not meet the requirements on TCAS tracks for visual acquisition, the displayed track shall be based on the TCAS position data.

Note:- The Recommendation at 4.3.2.1.3.2 [of the ACAS SARPs] requires that the errors in TCAS bearing measurements should not exceed 10 degrees rms. The requirement on the accuracy of TCAS range measurements stated at 4.3.2.1.3.1 [of the ACAS SARPs] is to support the use of the range measurements in the collision avoidance logic; it is not to support visual acquisition so is not relevant to 2.2.

Comment

This is to minimise the risk that the flight crew will manoeuvre on the basis of a TCAS track, contrary to the requirement that TCAS be a measure of last resort; independent of separation provision. It might well also mean that the better track will be displayed, but this is neither the requirement nor its source. The requirement is to display the ASAS track even when it is inferior, provided it is good enough. (For example, the ASAS track might be based on TIS-B.)

It is argued by some that the TCAS track should be displayed for an RA. The treatment of RAs is discussed in section 4 below. At present, that discussion is consistent with 2.2, and it is currently unnecessary to add a clause such as "subject to the provisions of section 4" to 2.2.

3 TAs

3.1 When there is a TCAS TA, the potential threat shall be indicated and distinguished clearly from the other intruders shown on the traffic display.

Comment

3.1 is not meant to imply any particular manner of TA display; it would be satisfied by a simple change in colour (to yellow?) There have been repeated comments that the present TCAS symbology should be used when there is an RA, but I do not recall such comments for TAs. Do we want to require present TCAS symbology for TAs when the tracks in question are not TCAS tracks? I would suggest that this is a question that we can safely leave to the SC186 CDTI group.

Comment [H5]: I'm not convinced yet that this is a requirement. In the current TCAS system, an aircraft that is not a TCAS track simply isn't displayed at all. Displaying traffic that would otherwise be invisible is clearly better than the current system. Whether or not the pilot needs to know they are protected by a collision avoidance function begs the question of operational changes. Will a pilot need to do something different if she knows a target on the display is not tracked by TCAS. If so, then it is a requirement. If not, then it isn't. As a novice pilot familiar with this equipment, I find it hard to imagine why I would ever need to know this.

Comment [H6]: There is a proposal within ASSAP for best track selection. I encourage Ken to review it and provide feedback. His insight would provide a valuable benefit.

- 3.2 Recommendation:- Symbols representing other aircraft within 6NM and 1200ft of own aircraft should not be removed from the traffic display when there is a TA.

Note 1: The purpose of the TCAS TA traffic display is to aid visual acquisition. Flight crew need a full picture, so far as is consistent with simplicity, so that they do not mistake a benign intruder for the potential threat. 4.3.3.2 [of the ACAS SARPs] recommends that all TCAS tracks within 6NM and 1200ft of own aircraft be displayed when there is a TA.

- 3.3 Note 2:- In general, the occurrence of a TCAS TA is not good reason to abort an ASAS application. Whether the ASAS application should continue or not needs to be determined as part of the analysis and specification of the ASAS application, but the default presumption would be that the ASAS application continues.

Note 3:- The treatment of other information currently presented on the traffic display at the time of the TA needs to be determined according to the needs of any ASAS application in progress at the time and the need for simplicity. Heading information in particular can be a valuable aid to visual acquisition, but it could also increase the risk that flight crew will be enticed by the TA to manoeuvre inappropriately.

Comments

Dan Morgan commented that there should be a requirement for an application to consider and define how information provided by the application is handled during a TA and an RA. I have not proposed this because I believe such a statement would be an ASAS requirement or (worse) a requirement on the methods to be used when developing ASAS requirements. This paper is intended to be limited to TCAS requirements; requirements for ASAS are for SC186 to determine.

Some members of SCRSP have informally questioned the continuing need for TCAS TAs. Both version 7 (particularly horizontal miss distance filtering) and the advent of ADS-B have changed the circumstances since TCAS was first introduced, and the design compromises made when TCAS was first built might no longer be appropriate. Where there is an on-board ASAS, that might well provide a similar function but in a way that is better suited to the operations envisaged. SCRSP has always taken the view that it is the RAs that provide the collision avoidance function.

4 RAs

- 4.1 When there is a TCAS RA, the occurrence of the RA shall be shown on the traffic display. The threat shall be indicated and distinguished clearly from the other intruders shown on the traffic display.

4.1.1 The standard TCAS symbology shall be used to indicate the threat on the traffic display.

- 4.2 Subject to the absence of other alerts that are determined to have greater priority than a TCAS RA, the traffic display shall be consistent with the need to ensure that the first priority of flight crew is to follow the RA.

4.2.1 All information that might distract the flight crew from complying with the RA shall be removed from the traffic display.

- 4.3 Note:- The design of ASAS applications needs to consider emergencies and contingencies, which should include TCAS RAs. The default presumption would be that the ASAS application must be aborted.

Comments

These standards make no mention of whether the track to be displayed when there is a TCAS RA is to be the TCAS track. However, (at present) 2.2 above answers that question. The proposal made here is that it would be inappropriate to draw attention to the traffic display when there is an RA by making more than the minimal changes. This would imply that the source for the tracks should not change on an RA, and thus that the tracks displayed would normally be ASAS tracks. This should be sufficient for the sole TCAS purpose of the traffic displays, which is to aid visual acquisition.

It has been argued that the occurrence of an RA calls the related ASAS track into question. However, it must be remembered that the TCAS track and the ASAS track should be in very similar positions, because they have been determined to relate to the same aircraft with a high degree of confidence. (See section 1.) That leaves the possibility that there is an error in the correlation. Well, it does, but this is far from the most

plausible reason for there being an RA, and this should probably be taken as reason for making sure that the software is sound and the level of confidence defined in 1.2.1 is sufficiently demanding.