

SCRSP/WGA
WPA/9-004
Draft 2
9 September 2005

SURVEILLANCE & CONFLICT RESOLUTION SYSTEMS PANEL
AIRBORNE COLLISION AVOIDANCE SYSTEMS
WORKING GROUP A

(Paris, October 2005)

**Comments on
“Standards for traffic displays
that include ACAS tracks”**

(Prepared by Ken Carpenter)

SUMMARY

Reference 1 proposed that WGA adopt draft standards for displays that include ACAS tracks. This was agreed, and WGA made improvements in the draft standards presented in Reference 1. This paper records comments on the reference, and suggested improvements, for consideration by WGA.

Reference:

- 1 “Standards for traffic displays that include ACAS tracks”, SCRSP/WGA WPA/8-07

1 Introduction

- 1.1 Reference 1 proposed that WGA adopt draft standards for displays that include ACAS tracks. This was agreed, and WGA made improvements in the draft standards presented in Reference 1. This paper records comments on the reference, and suggested improvements, for consideration by WGA.
- 1.2 The paper was circulated to various groups. Comments that can be recorded separately are given in section 2. Otherwise, comments and suggested improvements are marked using Word's revision features on the text approved (for distribution and comment) by WGA, which is attached.

2 Proposed standards

- 2.1 Bob Grove commented that the standard of proof required in M1.2 is too stringent. It is suggested that all the such figures require careful consideration once the proposed standards have stabilised. The second group to comment (see 2.2) suggested changes that would make M1.2 less demanding without changing M1.2 itself, and the changes discussed in 2.3 are also relevant.
- 2.2 The ASAS SG, meeting in Malmo on 14 July, made a number of comments and suggestions. These are recorded in this form. Changes are made in the colour shown ~~there~~ here, and the comments are labelled. ^{A1} The comments are shown in Attachment 2, as well as through the good offices of Microsoft Word.
- 2.3 Comments made during the ASAS SG caused Ken to write Attachment 1. If the changes proposed in Attachment 1 were agreed, they would have the effect shown ~~like this~~ thus. In this case, three new paragraphs are suggested. The third is an addition. The first two replace the preceding paragraphs, which have the same number.
- 2.4 Richard Pugh and Craig Foster reviewed Ken's changes. Except for their major comment, Ken either stole or rejected their ideas, and they are reflected in [his changes](#) as shown in this draft. The major comment was that Ken's text for M1.2, 1.3 and 1.4 is not plain English. They suggested:

M1.2 The probability of determining that an ASAS track and an ACAS track relate to the same aircraft when in fact there are two aircraft shall be less than 1 in 10^7 .

M1.3 The probability of determining that an ASAS track and an ACAS track relate to two aircraft when in fact there is only one aircraft shall be less than 1 in 10^3 .

M1.4 The probability of failing to determine either that an ASAS track and an ACAS track relate to the same aircraft or that the tracks relate to two aircraft shall be less than 1 in 10^2 .

It is not clear that these alternatives words unambiguously convey that the probabilities in question are conditional. The word "condition" (or "conditional") occurs repeatedly in [M1.2, 1.3 and 1.4](#) below. As explained in the Attachment, each probability that is standardised is conditional, the condition being specified in each case and being either that there are in fact two intruders or that there is in fact only one intruder.

- 2.5 Greg Stayton has also commented. Text was added in the Attachment to explain N_0 , N_1 , N_2 , M_0 , M_1 and M_2 . The text for S3 was changed to remove the word "symbol", and make it more general. Finally, Greg (as a manufacturer) stated a definite preference for being told exactly what to do in terms that enabled him to present proof that he has done it. This, for example, he would like to be told the algorithm for associating ASAS and ACAS tracks; I don't think there is anything we can do about that.

Proposed international standards for traffic displays that include ACAS tracks

This material is presented for discussion, to reach consensus before MOPS are finalised and SARPs recommended. It does not represent the final view of SCRSP WGA.

1 Requirement for one track per aircraft

SARPs

S1 Only one track shall be displayed for each distinct aircraft.

S1.1 Where there are data from two (or more) sources that cannot be positively identified as relating to a single aircraft nor positively identified as relating to two (or more) aircraft, flight crew shall be alerted to this fact.

Comments

C1.1 The requirement for only one track is for simplicity. Any concern that this might conceal the presence of a second aircraft should be addressed by S1.1, and M1.1 and M1.2 below. On the other hand, any concerns at the potential difficulty caused by displaying two symbols when the system can't make its mind up are acknowledged, and could justify the development of further Manual material. Operational procedures and training are not under discussion here.

Manual

M1.1 The following requirements (M1.2 – M1.5) should apply when determining whether an ACAS track and an ASAS track relate to a common aircraft. ~~ASAS and ACAS tracks shall be tested to determine whether they relate to common aircraft.~~ ^{A2} KMC3

M1.2 An ASAS track and an ACAS track for aircraft within 6NM and 1200 ft of own aircraft shall be considered to relate to the same aircraft if it can be determined that the probability that they do not do so is less than 1 in ~~10⁷~~ 10⁶. ^{A4}

M1.2 For aircraft within 6NM and 1200 ft of own aircraft, the determination that an ASAS track and an ACAS track relate to the same aircraft shall be such that, given that there are two aircraft, the conditional probability that the two tracks are determined to relate to one aircraft is less than 1 in 10⁶.

Note:- 4.3.3.2^{A5} recommends that all ACAS tracks within 6NM and 1200 ft of own aircraft be displayed when there is a TA.

M1.3 An ASAS track and an ACAS track shall be considered to relate to different aircraft if it can be determined that the probability that they do not do so is less than 1 in 10³.

M1.3 The determination that an ASAS track and an ACAS track relate to different aircraft shall be such that, given that the ASAS track and the ACAS track are for the same aircraft, the conditional probability that the tracks are determined to relate to separate aircraft is less than 1 in 10³.

~~M1.4 Where an ASAS and an ACAS track might or might not relate to the same aircraft, both tracks shall be displayed, together with a clear indication that they potentially relate to the same aircraft.~~ ^{A6}

M1.4 The determination that an ASAS track and an ACAS track relate to the same aircraft or to different aircraft shall be such that the conditional probability that no determination can be made is less than 1 in 10² whether the condition is that there is one aircraft or that there are two aircraft. ^{KMC7}

M1.5 Note: Information that can be used to test the probability that an ASAS and an ACAS track relate to the same aircraft includes the following:

a) for Mode S equipped intruders, the aircraft address;

Note: ^{A8} 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

C1.2 The figure 1 in ~~10⁷-10⁶~~ in M1.2 was chosen on the basis that flight crew should not suffer the concealment of ACAS track, because it is mistakenly diagnosed as the same aircraft as an ASAS track, more frequently than once in 10⁵ flying hours. To complete ~~this~~ calculation, it was assumed that flight crew can see up to ~~100-10~~ ACAS tracks within 6 NM and 1200 ft per hour.

The figure 1 in 10³ in M1.3 was chosen on the basis that showing pilots two tracks for the same aircraft raises issues of credibility and operational acceptability. It is supposed that flight crew could see it happen once ~~a day~~every ten days.

2 Choice of track

SARPs

S1½ Flight crew shall be provided with a means to choose the ACAS display.

S2 Where there is an ASAS track and an ACAS track that have been determined to relate to the same aircraft, the ASAS track shall be displayed provided that it is more accurate than the requirements on ACAS tracks for visual acquisition.

Note:- The Recommendation at 4.3.2.1.3.2 requires that the errors in ACAS bearing measurements should not exceed 10 degrees rms. The requirement on the accuracy of ACAS range measurements stated at 4.3.2.1.3.1 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 S2.

Comment

- C2.1 This is to minimise the risk that the flight crew will manoeuvre on the basis of an ACAS track, contrary to the requirement that ACAS be a measure of last resort independent of separation provision. It also means that the better track will be displayed.
- C2.2 It could be argued (it has been) that the ACAS track should be displayed for an RA. The treatment of RAs is discussed in section 4 below. At present, that discussion is consistent with S2, and it is currently unnecessary to add a redundant clause such as “subject to the provisions of S4” to S2.

3 TAs

SARPs

S3 An ACAS TA shall be indicated on the traffic display in a way that draws attention to the track for the potential threat. ~~by modifying the symbol showing the ASAS track.~~ ^{KMC9}

S3.1 Symbols representing other aircraft within 6NM and 1200 ft of own aircraft shall not be removed from the traffic display when there is a TA.

S3.2 Note: The purpose of the ACAS 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 recommends that all ACAS tracks within 6NM and 1200 ft of own aircraft be displayed when there is a TA.

Comment

- C3.1 S3 is not intended to imply any particular manner of TA display; modification; it does not mean the shape must change (although it might). It is expected that the colour will change to yellow.
- C3.2 It has always been considered important to inform flight crew of other aircraft that they might see and mistake for the potential threat, and this is why S3.1 is stated as a standard. Of course, if the aircraft is

~~outside visual range and the needs of an ASAS application indicate that it should be removed, it is not intended that S3.1 means it should stay;~~ KMC10

Manual

- M3.1 Any ASAS application in progress at the time of a TA should continue.
- M3.2 Note: The treatment of other information currently presented on the traffic display at the time of the TA can 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.

Comment

- C3.3 SCRSP is not certain that there is a continuing need for ACAS TAs. Both version 7 and the advent of ADS-B has 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

SARPs

- S4 An ACAS RA shall be indicated on the traffic display by modifying the symbol showing the ASAS track.
- S4.1 Subject to the absence of other alerts that are determined to have greater priority than an ACAS RA, the traffic display shall be consistent with the need to ensure that the first priority of flight crew is to follow the RA.
- S4.2 Any ASAS application in progress at the time of an RA shall be aborted unless it has been previously determined that it is consistent with the imperative to follow ACAS RAs promptly.

Comment

- C4.1 It has been argued that the occurrence of an RA calls the ASAS track into question. However, it must be remembered that the ACAS 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 their 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 M1.2 sufficiently demanding.

Manual

- M4.1 All information that might distract the flight crew from compliance with the RA shall be removed from the traffic display.

Comment

- C4 The design of ASAS applications needs to consider emergencies and contingencies, which should include ACAS RAs.

Attachment 1

Two tracks, one aircraft?

1 Introduction

The proposed standards for traffic displays that include ACAS tracks include three requirements that have caused some discussion:

- M1.2 An ASAS track and an ACAS track shall be considered to relate to the same aircraft if it can be determined that the probability that they do not do so is less than 1 in 10^7 .
- M1.3 An ASAS track and an ACAS track shall be considered to relate to different aircraft if it can be determined that the probability that they do not do so is less than 1 in 10^3 .
- S1.1 Where there are data from two (or more) sources that cannot be positively identified as relating to a single aircraft nor positively identified as relating to two (or more) aircraft, flight crew shall be alerted to this fact.

As currently written, these tests seem to imply that a real time calculation is made of the probability that two tracks relate to one aircraft. If this probability is greater than $(1.0 - 10^{-7})$, the two tracks are diagnosed as one aircraft. If this probability is less than 10^{-3} , the two tracks are diagnosed as two aircraft. If the probability is anything between these two extremes, S1.1 applies.

The original author must have had a bad day during the 2 minutes it took to draft these standards, because the present author does not believe this is what he meant.

2 Discussion of M1.2 and M1.3

The numbers cited in M1.2 and M1.3 have been criticised. This note does not concern these numbers; they need not be considered realistic to continue reading. Because they are different from each other, there is no need to use symbols to represent them.

Much of the discussion of these standards centres on the undesirability of the grey zone covered by S1.1, and that this (it is argued) must be frequent because the interval between 10^{-3} and $(1.0 - 10^{-7})$ is manifestly large. In fact, even as written, they do not necessarily imply a large number of cases where S1.1 must be invoked. For example, were aircraft address always available and always reliable, comparison of the aircraft addresses would always result in certain (probability of error = 0.0) diagnosis.

A greater problem of principle is that M1.2 and M1.3 imply a design: given two tracks, calculate the probability that they relate to one aircraft; if that probability is greater than $(1.0 - 10^{-7})$, determine that the two tracks are for one aircraft; and if it is less than 10^{-3} , determine that there are two aircraft. There is no reason why an implementation should calculate probabilities, as the example illustrates.

3 Proposed revision

- M1.2* The determination that an ASAS track and an ACAS track relate to the same aircraft shall be such that, given that there are two aircraft, the conditional probability that the two tracks are determined to relate to one aircraft is less than 1 in 10^7 .
- M1.3* The determination that an ASAS track and an ACAS track relate to different aircraft shall be such that, given that the ASAS track and the ACAS track are for the same aircraft, the conditional probability that the tracks are determined to relate to separate aircraft is less than 1 in 10^3 .
- M1.4* The determination that an ASAS track and an ACAS track relate to the same aircraft or to different aircraft shall be such that the conditional probability that no determination can be made is less than 1 in 10^2 whether the condition is that there is one aircraft or that there are two aircraft.
- S1.1 No change.

4 Explanation of M1.2*, M1.3* and M1.4*

Suppose that a large number of ACAS and ACAS track pairs have been assessed. The following table, in which N_0, N_1, N_2, M_0, M_1 and M_2 are integer counts of the number of track pairs with the properties indicated, can be constructed:

	one aircraft diagnosed	no decision	two aircraft diagnosed
there is one aircraft	M_1	M_0	M_2
there are two aircraft	N_1	N_0	N_2

M1.2* requires that

$$\text{probability}(\text{one aircraft diagnosed} \mid \text{two aircraft}) = \frac{N_1}{N_1 + N_0 + N_2} < 10^{-7}$$

M1.3* requires that

$$\text{probability}(\text{two aircraft diagnosed} \mid \text{one aircraft}) = \frac{M_2}{M_1 + M_0 + M_2} < 10^{-3}$$

These can be approximated:

$$N_1 < 10^{-7} \times (N_0 + N_2) \quad \text{and} \quad M_2 < 10^{-3} \times (M_1 + M_0)$$

Similarly, M1.4* can be approximated:

$$N_0 < 10^{-2} \times (N_1 + N_2) \quad \text{and} \quad M_0 < 10^{-2} \times (M_1 + M_2)$$

So that, finally and approximately,

$$M_0 < 10^{-2} \times M_1, \quad M_2 < 10^{-3} \times M_1, \quad N_0 < 10^{-2} \times N_2 \quad \text{and} \quad N_1 < 10^{-7} \times N_2$$

M1.4* is added because, otherwise, M1.2* and M1.3* can be met by never taking a decision. As is the case for the other two numerical limits, the numerical value 1 in 10^2 for the limit on the probability of being unable to reach a decision is not intended seriously.

All three of the numerical limits will need careful examination; indeed, the ASAS SG has already suggested changes. However, the fact that the limit on the probability of failing to reach a decision is larger than the limit on erroneously suggesting that there are two aircraft is meant seriously for two reasons.

- The error of telling the pilot that there are two aircraft when there is only one misleads the pilot. Telling the pilot the system cannot decide is irritating, and clutters the display. Telling a lie is a greater offence than is being confusing or irritating.
- Were it decided that a zone of uncertainty is less tolerable than the error of showing two tracks for one aircraft, it would probably be preferable to eliminate it and use tests that simply decide whether there is one or are two aircraft.

5 Finally, concerning the numbers

The limits used here, 1 in 10^2 , 1 in 10^3 and 1 in 10^7 will certainly need consideration. It is not suggested that any of these three numbers is realistic.

Realistic will mean different things to different people. Many may take the point of view that they can and should do what is possible. For example, if aircraft address is really flaky and position tests do not lead to definitive results, they might argue that the display is none the less of value. However, the events discussed here correspond to hazards and they should be assessed and controlled as such. This is how the limits should be determined. There is the option of deciding that the enterprise cannot be undertaken safely; i.e. if it doesn't work, don't do it.

Attachment 2

Editorial comments embedded in the Word file but additionally copied and pasted here

A1

Thus

A2

The ASAS SG considered this unclear. During his review of the meetings work, Ken formed the opinion that the sentence says nothing that is not implied elsewhere. It is a design detail to say that the method of compliance with S1 is to carry out tests!

KMC3

New wording suggested by Richard Pugh and Craig Foster.

A4

See C1.2

A5

of the ACAS SARPs. Richard and Craig suggested writing these words into the text of the Note. Ken has not done this because the text is proposed text for the ACAS SARPs, and the Secretariat would remove the words. However, between now and then, the words would help those not familiar with the ICAO process and documents.

A6

The ASAS SG considered that S1.1 is sufficient, and that it would be unwise to require both tracks to be shown (although it did not rule that option out).

KMC7

The new M1.4 is not a substitute for the old M1.4. The ASAS SG wished to delete the old M1.4. This left M1.4 unused, so I recycled it.

A8

Redundant. The suggested Note is already part of a Note.

KMC9

The text looks strange when there is no ASAS track for the potential threat. The original purpose was to make clear that the ASAS track should still be shown for intruders that become potential threats. However, S2 already says this.

KMC10

Made redundant by the ASAS SG change in S3.1