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FARADS - Technical Study of RA Downlink Methods - Supplement

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Abstract

A study of all technical means for the downlink of ACAS RA information was initially conducted in 2004. This report updates the finding of the original study to incorporate emerging technology developments such as ACAS Monitor and Wide Area Multilateration (WAM).

Keywords

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CONTENTS

EXECUTIVE SUMMARY

In May 2007, EUROCONTROL published a report assessing the technical suitability of several technical means for communicating ACAS RA information to an ATC centre on the ground.

Since that report was published, two new candidate means have been developed and this supplement has been produced to extend the assessment to them. The new candidates are:

- ACAS-Monitor, a system developed in Germany specifically to detect ACAS events. It was originally developed as a tool for off-line analysis and this study considers its application as a real-time alerting system.
- Wide Area Multilateration (WAM), a general surveillance technique that is being deployed in several European countries.

The candidates were compared against a number of evaluation criteria that are described in the main report.

One of the criteria was that 95% of RA events must be detected, and that both aircraft in every encounter should be identified. This is a requirement that should be reviewed and confirmed with operational staff because it has a significant impact on the conclusions. Specifically, the minimum proportion of detected ACAS events must be confirmed, and whether both aircraft need to be identified in every encounter.

Neither candidate met all the given requirements, although ACAS-Monitor met more of them. The main issue is that neither candidate can meet the quality of service requirement – to detect 95% of RA events, and identify both aircraft involved because of the number of RA events between TCAS-equipped and non TCAS-equipped aircraft. The reason is that if the encounter is between TCAS-equipped and non TCAS-equipped aircraft, then the intruder aircraft (the non TCAS-equipped one) is not identified in the RA broadcast message which is used by both candidates to detect the RA event. Hence both aircraft *cannot* be detected. This type of encounter happens often enough that a 95% detection rate of both aircraft cannot be assured.

A new ADS-B RA message (currently under definition) is potentially valuable here because it contains the identity of the target and intruder aircraft. As long as the TCAS-equipped aircraft is also equipped with ADS-B, then both aircraft will be identified. An aircraft broadcasting the ADS-B RA message would also be broadcasting other ADS-B messages that contain useful information such as the target aircraft position and altitude. However, equipping with the ADS-B message will not be possible until the relevant standards have been finalised and will then incur some airborne costs which could not be justified by the need to report RA events alone. Hence this approach also has some qualifications against the evaluation criteria.

Both candidates would require wide-area deployment. In the case of WAM, this would be to support surveillance.

Some other issues identified were:

- The WAM system has the potential to extract the Mode S RA report, which contains information on the target and intruder aircraft. However, the WAM system has to first learn of the RA event (for example by detecting another message) before it can request this message from the target aircraft. This significantly reduces the benefit of this message.
- ACAS-Monitor can receive the RA Broadcast message. With this message, only the Mode A code of the target is known. In a future Mode S-only environment, unique Mode A codes may not be assigned, which would make this field useless.
- It is unclear if any messages transmitted from top-mounted antennas can be reliably received on the ground. It is recommended that this is investigated.

Two recommendations are made:

- The operational requirement for detection of events and both aircraft in each event should be reviewed and confirmed.
- Reception from top-mounted antennas is further investigated. This remains an area of uncertain performance.

1. INTRODUCTION

1.1 General

In May 2007, EUROCONTROL published a report [ref 1] assessing the technical suitability of several technical means for communicating ACAS RA information to an ATC centre on the ground.

Since that report was published, two new technologies have been developed. EUROCONTROL has therefore produced this supplement to repeat the assessment for the new candidates. It has been prepared by Helios Technology Ltd on behalf of the EUROCONTROL FARADS project.

The new candidates are:

- ACAS-Monitor, a system developed in Germany specifically to detect ACAS events.
- Wide Area Multilateration (WAM), a general surveillance technique that is being deployed in several European countries.

The assessment approach is to compare both candidates against a number of evaluation criteria. It is recommended that the reader familiarise themselves with the methodology and evaluation criteria in the main report. In general, this supplement does not repeat information from it.

2. CANDIDATE TECHNOLOGIES

2.1 Introduction

This section describes the new candidate datalink technologies of ACAS-Monitor and Wide Area Multilateration (WAM).

In both cases, ADS-B RA messages are considered as an option that would enhance the core technology.

2.2 ACAS-Monitor

ACAS-Monitor is a system that has been developed in Germany by the Technische Universität Braunschweig (TUB) with support from the Deutsche Flugsicherung GmbH (DFS).

ACAS-Monitor initially monitored [ref 2] reports in the Langen area. It conducted continuous recording from June 2007. Up to May 2008 it monitored 302 events in 221 days. The system was due to be expanded [ref 3] to cover three new ground stations in Southern Germany, interconnected with TU-Braunschweig to cover also Frankfurt and Munich".

ACAS-Monitor ground stations receive and process all ACAS and Mode S messages broadcast on 1030 and 1090 MHz.

Results from ACAS-Monitor are as follows [ref 3]:

- 376 ACAS events were detected in one year in Northern Germany, about one event per 4000 flight hours.
- In 235 events, only one aircraft is known. No air-air communication was monitored and the unknown participant is either out of range or not TCAS equipped.
- In addition, 158 further events were due to "intentional closing manoeuvres" and are not subject to any review or investigation.

ACAS-Monitor was initially developed as an off-line system for post-processing RA events. A real-time application would be required to report RA events to controllers as they occur. It is understood that a development of ACAS-Monitor into a real-time alerting system is already being considered.

2.3 Wide Area Multilateration (WAM)

WAM systems receive aircraft transponder transmissions at a number of ground stations. The time of arrival of the transmission at each ground station is compared and the position of the aircraft is calculated. A description of WAM can be found in the Eurocontrol Skyways [ref 4] magazine.

Multilateration is widely deployed at airports to monitor aircraft on the airport surface. These systems are not intended for wide area coverage. In Europe, few WAM systems presently exist but more are planned. The most significant operational WAM systems in Europe cover most of Czech airspace and the approach to Innsbruck airport.

A WAM system monitors all 1090MHz transmissions but not usually 1030 MHz transmissions. WAM systems usually also include a (1030MHz) transmitter function that can interrogate the aircraft as required.

2.4 Messages monitored by the candidate technologies

RA events can be detected from the ground in several ways:

- The RA Broadcast message. This message is transmitted on 1030 MHz by TCAS-equipped aircraft. It is transmitted when the RA is generated and repeated approximately every 8s or when the RA changes.
- ACAS co-ordination messages. These are the messages sent between two TCAS-equipped aircraft to co-ordinate the RA. They are transmitted on 1030 and 1090MHz.
- ADS-B RA messages. This message is currently under definition in EUROCAE WG 51 so it is a future option. The message definition is being added to the 1090MHz Extended Squitter MOPS version and only a draft MOPS is available [ref 5]. The message is described in Annex C.
- Mode S RA report. This message is intended for extraction by a Mode S radar. The radar is made aware that the message is available by a flag setting in the normal Mode S surveillance replies. When the ground station becomes aware the report is waiting, it extracts it using another interrogation. This report is extracted using a 1030MHz interrogation, which a WAM system would be capable of but the ACAS-Monitor system would not. Some issues regarding the Mode S RA report are discussed below.

These messages are monitored by the technical candidates as follows:

Messages monitored	Frequency	ACAS-Monitor	WAM
RA Broadcasts	1030 MHZ	X	
ACAS coordination messages	1030 MHz uplink	X	
	1090MHz downlink	X	X
ADS-B RA message [1]	1090MHz	X	X
Mode S RA report [2]	1090MHz		X
Notes: 1 – ADS-B message are currently under definition for a future version of MOPS. 2 – Discussed below.			

Table 1: Messages monitored by candidate systems

The WAM system will only become aware that a Mode S RA report is waiting when it sees a standard Mode S surveillance reply (a DF4 or 5 message) – it could then extract the RA Report with a 1030MHz interrogation.

The Mode S surveillance replies are generated by Mode S radar (not the WAM system). If there are no Mode S radars in the vicinity, then the WAM system would never see a Mode S Surveillance Reply.

Hence the value of this depends on the circumstances:

- In a Mode S Radar environment, the WAM system would become aware of the available Mode S RA report. It could extract it, which would be valuable if the Mode S radar does not.
- In a non-Mode S environment, the WAM system may become aware of an RA event by observing ACAS co-ordination downlink messages. In this case, there should be a waiting Mode S RA report and it can try to extract it. However, most of the information would already be available to the ground station in the ACAS co-ordination downlink message.

In the second case the WAM system could extract the Mode S RA report, eg, every second. It would then be able to track the RA continuously.

Once the WAM system has received the Mode S RA report, it can determine the 24bit address of the intruder aircraft (if it is Mode S equipped). It can then attempt to extract a Mode S RA report from that aircraft also.

3. ANALYSIS OF TECHNOLOGY AGAINST CRITERIA

In this section, each candidate technology is compared with the criteria.

3.1 Technical

3.1.1 Data content in messages

The following table shows the data content in each message and therefore available to each monitoring system:

Information	Mode S RA report	RA Broadcast	ACAS Coordination uplink	ACAS Coordination down-link	ADS-B RA message	ACAS-Monitor	WAM
24 bit address of aircraft	Yes (1)		Yes (1)	Yes (1)	Yes	Yes	Yes
Mode A identity code (ID)	If DL 21	Yes				Yes	If DL 21
Altitude Code (AC)	If DL 20	Yes		Yes		Yes	Yes
Address-Parity (AP)	Yes	Yes	Yes	Yes		Yes	Yes
Active Resolution Advisory (ARA)	Yes	Yes		Yes	Yes	Yes	Yes
Resolution advisory complement (RAC)	Yes	Yes		Yes	Yes	Yes	Yes
RA Terminated (RAT)	Yes	Yes		Yes	Yes	Yes	Yes
Multiple threat encounter (MTE)	Yes	Yes		Yes	Yes	Yes	Yes
Threat type indicator (TTI)	Yes				Yes	Yes	Yes
Threat identity data (TID)	Yes				Yes	Yes	Yes
Flight Status (FS)	Yes			Yes		Yes	Yes
Multiple Threat Bit			Yes			Yes	
Cancel vertical RAC			Yes			Yes	
Vertical RAC			Yes			Yes	
ACAS Capability or Max Airspeed				Yes		Yes	Yes
Parity (Pi)					Yes	Yes	Yes
Notes 1) Present but some ground processing is required to decode it.							

Table 2: Available RA data

3.1.1.1 Fields relating to the RA

It can be seen that much of the same information is available from both candidates. The ARA, RAC, RAT and MTE fields specifying the details of the RA are all present.

3.1.1.2 Fields identifying the target

There are some important differences in other information available from the messages. The target aircraft is identified in a variety of different ways. In the Mode S RA report and ADS-B RA message, the target aircraft is identified via the aircraft's 24-bit address. The aircraft's Mode A code is also available as part of the Mode S RA report if requested.

ACAS Coordination messages do not contain a 24-bit address in plain sight nor a Mode A code. Instead the 24-bit address is contained in the address-parity field, i.e. overlaid with parity information used for error checking the message. With a suitable monitoring network, the 24 bit address can be decoded and this is indeed done by the ACAS-Monitor system. It is expected that a WAM system would do the same.

Identification of the target aircraft is an essential element of the RA Downlink concept. Only Mode S RA reports and ADS-B RA messages provide a reliable and complete identification via the 24-bit address in plain sight.

One issue discussed in the main report is that the aircraft's Mode A code is the sole means of identification in an RA Broadcast message. In the future, some States may stop using unique Mode A codes when they have Mode S fully implemented. In this case RA Broadcast would be an unsuitable technology for RA Downlink. Nevertheless, this problem should not affect the candidate technologies since they can gather identification from the Mode S RA report and ACAS Coordination Downlink messages.

3.1.1.3 Fields identifying the intruder

Mode S RA reports and ADS-B RA messages identify the intruder aircraft (or most recent intruder in multi-aircraft encounters). This information is contained in the TTI and TID fields of the downlink messages. Both candidates can receive this information.

3.1.2 Quality of service

As in the main report, the quality of service issues considered are the number of erroneous reports and availability of information from different types of encounter. Latency is considered later in Section 3.3.1.

The number of erroneous reports to the ground should not differ significantly between the technologies. All technologies have a degree of error identification and correction included in their message formats which minimise the possibility of inaccurate reporting to the ground. Furthermore, the same data is usually available from several different messages so it can be cross-checked. The ground processing (eg consistency checks) will also identify and remove other errors.

The required availability of information is that 95% of RA events should be detected, and both involved aircraft should be identified.

The availability of information from different types of encounter varies between messages. As observed in the main report, there are a number of issues when just monitoring ACAS co-ordination messages:

1) They are only generated between ACAS II equipped aircraft (about 80% of aircraft flying IFR in ECAC [ref 1]) and operating in RA mode. No coordination messages are transmitted against Mode A/C equipped aircraft. Therefore the proportion of ACAS encounters (assuming a single intruder) in which ACAS coordination messages are transmitted is only about 64%.

2) They are transmitted from the aircraft's top or bottom antenna as discussed previously. Therefore reliable detection by a ground network may not be possible.

The Mode S RA report and the ADS-B RA message would identify both aircraft involved in an ACAS event (even if only one of those aircraft were ACAS-equipped).

Table 3 shows the data available when a TCAS-equipped aircraft encounters a non TCAS-equipped aircraft.

Information	Mode S RA report	RA Broadcast	ACAS Coordination uplink	ACAS Coordination down-link	ADS-B RA message
24 bit address of aircraft	Yes		Not transmitted	Not transmitted	Yes
Mode A identity code (ID)	If DL 21	Yes			
Altitude Code (AC)	If DL 20	Yes			
Address-Parity (AP)	Yes	Yes			
Active Resolution Advisory (ARA)	Yes	Yes			Yes
Resolution advisory complement (RAC)	Yes	Yes			Yes
RA Terminated (RAT)	Yes	Yes			Yes
Multiple threat encounter (MTE)	Yes	Yes			Yes
Threat type indicator (TTI)	Yes				Yes
Threat identity data (TID)	Yes				Yes
Flight Status (FS)	Yes				
Multiple Threat Bit					
Cancel vertical RAC					
Vertical RAC					
ACAS Capability or Max Airspeed					
Parity (Pi)					Yes

Table 3: Available RA Data in a TCAS / non-TCAS encounter

3.2 Business

3.2.1 Airborne costs

The ACAS-Monitor system works today by receiving the messages from existing TCAS-equipped aircraft. Therefore no airborne costs are required for this candidate.

Both candidates would receive the ADS-B RA message when it becomes available and implemented on aircraft.

A planned "Implementing Rule for Surveillance Performance and Interoperability Requirements", currently draft [ref 6], is expected to mandate the carriage of ADS-B equipment on new aircraft from 2012 and for existing aircraft by 2015. The mandate is expected to apply aircraft with a maximum certificated take-off mass exceeding 5700 kg or having a maximum cruising true airspeed capability greater than 250 knots.

However, the ADS-B RA message is presently only defined in draft in the new version of the MOPS. The mandate is expected to refer to the existing (not new) version of the MOPS and it must be assumed that aircraft complying with the standard will not necessarily transmit the required message.

As new aircraft are deployed, they are likely to have more modern equipment and will comply with the new MOPS. Over time, therefore, the proportion of aircraft transmitting ADS-B RA messages will increase.

The cost of deploying the new MOPS standard to the existing fleet is not known because the standard is not finalised. It is likely that existing transponders could be “software upgraded” to meet the new version of MOPS and therefore this change could be limited to a €5000 per transponder [ref 1].

3.2.2 Ground costs

ACAS-Monitor implementation would require a ground network of passive 1030/1090MHz receivers. The main report estimated that 167 ground receivers would be required for all ECAC States at a cost of €15m. There is no reason to assume a significant change to this cost.

A WAM network will require more ground stations to ensure that each aircraft is visible to 4 ground receivers. (This is the minimum visibility for a WAM network to allow for continued operation when 1 ground receiver fails.) The use of multiple ground receivers is required so that WAM can provide surveillance coverage – it is not a requirement to support RA Downlink monitoring.

At a first estimate, WAM implementation costs would therefore be 4-times those of ACAS-Monitor, ie €60m. However, the multiple coverage of the WAM network is required for ATC surveillance purposes – not for RA monitoring. So it is not reasonable to assign this cost to the RA monitoring system. In fact, ACAS RA monitoring should be seen as a ‘free benefit’ of WAM systems where they are installed.

Some additional processing would be required to allow the WAM network to process and extract RA data. This is not expected to be a significant cost.

3.3 Operational

3.3.1 Latency

Latency is the delay between the RA occurring onboard the aircraft and the RA notification being successfully delivered to the ATC centre.

The delivery times for 95% of messages are calculated in expected and worst case scenarios. As in the main report, two types of delay are considered:

- The delay in sending information from the aircraft to the ground. This depends on the repetition rate of the data, the probability of reception at each ground station and the number of ground stations that attempt to receive it.
- Ground-delays, which are a 5s communications delay from receiver to ATC centre and a 1s centre processing time. Note these figure have changed from the original report when they were 1s and 3s respectively. The first figure is now based on ref 8, using the 95% “forwarded data items" value for approach and the second on Eurocontrol expert judgement.)

Tables 5 and 6 give the main datalink assumptions for the latency calculations. Some explanation of the assumptions is given below:

- ACAS coordination messages are sent when an RA occurs and thereafter if the RA event changes. We have assumed this could happen every 10s, although it could be longer than this.
- ADS-B RA messages may be transmitted at an average interval of 0.8s or 2.5s (depending on what other messages the transponder is transmitting). Expected performance uses 0.8s and worst case uses 2.5s.
- An ACAS-Monitor study [ref 3] has provided the probability of reception for the different message types shown.
- The probability of reception at a 1090MHz receiver is estimated at 50% in ref 1 and 40% in ref 3. In both cases, the probability of reception is assumed at 50% in the nominal case, and 40% for the worst-case scenario.
- The probability of reception at a 1030 MHz receiver is estimated at 100% in ref 3. A probability of 90% is used for the worst case scenario to match the 10% reduction assumed for the 1090 MHz receiver worst-case scenario.
- The WAM system is assumed to have 4 overlapping ground stations for each aircraft in the expected case. In the worst case, it has assumed one has failed and only 3 are present.
- It is assumed that the WAM system can attempt to extract the Mode S RA Report once per second, once it identifies that an RA has occurred.

	Repetition rate	**Pr(reception) per ground station**	**Number of ground stations**
ACAS-Monitor			
ACAS co-ordination uplink	1s	100%	1
ACAS co-ordination downlink	1s	50%	1
RA Broadcast	8s	100%	1
ADS-B RA message	0.8s	50%	1
WAM			
ACAS co-ordination downlink	1s	50%	4
Mode S RA report *	1s when available	50%	4
ADS-B RA message	0.8s	50%	4
* Note that extraction of the Mode S RA report cannot occur until the ground system has detected the RA event through another means, such as monitoring ACAS co-ordination messages.			

Table 4: Assumptions for expected performance

	Repetition rate	**Pr(reception) per ground station**	**Number of ground stations**
ACAS-Monitor			
ACAS co-ordination uplink	1s	90%	1
ACAS co-ordination downlink	1s	40%	1
RA Broadcast	8s	90%	1
ADS-B RA message	2.5s	40%	1
WAM			
ACAS co-ordination downlink	1s	40%	3
Mode S RA report *	1s when available	40%	3
ADS-B RA message	2.5s	40%	3
* Note that extraction of the Mode S RA report cannot occur until the ground system has detected the RA event through another means, such as monitoring ACAS co-ordination messages.			

Table 5: Assumptions for worst case performance

The calculations are made using the same logic as the main report (Annex E). The results, rounded to the nearest second, are shown in the table below.

	ACAS-Monitor		**WAM**	
	Expected latency (s)	**Worse case latency (s)**	**Expected latency (s)**	**Worse case latency (s)**
ACAS co-ordination uplink	6	7	n/a	n/a
ACAS co-ordination downlink	10	11	7	7
RA Broadcast	6	14	n/a	n/a
Mode S RA report	n/a	n/a	8	8
ADS-B RA message	10	21	8	11

Table 6: Estimated latencies

The following notes provide some explanation of the figures:

- The ground delays (ground communications and centre processing) are always 6s. So no individual figure can be less than this.
- ACAS co-ordination uplink messages are sent on 1030MHz (which has a high probability of reception) and once a second. So they are likely to be received quickly and reliably.
- ACAS co-ordination downlink message are sent on 1090MHz (which has a lower probability of reception) and also once a second. Because of the lower probability of reception, several messages may need to be received before once can be correctly decoded giving this a slight worse performance than ACAS co-ordination uplink messages.
- RA broadcast messages are sent every 8s, so if the first message is not received there is an 8s delay to the next opportunity. This explains the large gap between expected and worst-case scenarios.
- ADS-B RA is transmitted every second, but in the worst case has a fairly low probability of reception (40%). Therefore the message must be re-sent a significant number of times before it achieves the 95% probability of reception, and this explains the large gap between expected and worst-case performance for ACAS-Monitor.

It can be seen from the table that some of the messages for the worst case scenario for both candidates do not meet the 10s latency requirement.

3.4 Summary of evaluation

The above analysis can be summarised specifying how each technology ranks against each criteria. This is shown in the table below.

	ACAS-Monitor	WAM	ACAS-Monitor + ADS-B RA	WAM + ADS-B RA
High Priority				
Latency (95%)	[A]	[A]		
Airside cost			[B]	[B]
Ground cost	[C]	[C]	[C]	[C]
Quality of service/ completeness	1	2		
Identification of target	[D]	3		
Medium Priority				
Identification of intruder	[E]	4		
Changes to SARPS / MOPS			[F]	[F]
Deployment timescales (Air)			[G]	[G]
Deployment timescales (ground)				

Table 7: Summary of Candidate Technologies against Criteria

Indicates a failure to meet a criteria	X
Indicates a criteria can only be met with qualification Z	[Z]
Indicates a criterion has been met.	

Qualifications:

[A] Neither candidate meets the latency requirement for some messages in the worst case scenario.

[B] Both candidates would benefit more from the availability of the ADS-B RA message. This will require an upgrade to existing ADS-B transponders.

[C] None of the candidates are implemented ECAC-wide today and would need to be deployed as such.

[D] When relying on RA Broadcast, only the Mode A code of the target is known. In a total Mode S environment, unique Mode A codes may not be assigned.

[E] Intruder identity would only be available to ACAS-Monitor where both aircraft are TCAS equipped and can be monitored by the ground system.

[F] Changes to MOPS are required and are already underway.

[G] ADS-B MOPS must be completed and deployed.

Notes

1) The ACAS-Monitor system cannot detect 95% of RAs without ADS-B RA messages because, without it, both aircraft can only be identified where they are both TCAS-equipped.

2) A WAM system will not detect 95% of RAs without ADS-B RA messages.

3) The target is only identified from ACAS co-ordination downlink messages or Mode S RA reports – neither of which may be available.

4) Intruder identity is available in the Mode S RA report, but this message will not always be available to the WAM system.

4. SUMMARY AND CONCLUSIONS

4.1 Summary

The suitability of each candidate technology for RA downlink is discussed below.

In this assessment, the candidate technologies are monitoring several downlink techniques. Of these, the (future) ADS-B RA message is potentially the most useful because it contains the identity of the target and intruder aircraft. Only the Mode S RA report also has these data items, but it would need to be extracted by a ground interrogation. An aircraft broadcasting the ADS-B RA message would also be broadcasting other ADS-B messages that contain useful information such as the target aircraft position and altitude.

ACAS-Monitor

At present, ACAS-Monitor fails to meet the quality of service requirement – to detect 95% of RA events, and identify both aircraft involved. It would also not meet the 10s latency requirement in the worst-case scenario.

Although it monitors ACAS co-ordination messages and the RA Broadcast, the ACAS co-ordination messages are only sent in encounters where both aircraft are TCAS-equipped (about 64% as estimated in the main report). The RA Broadcast does not identify the intruder aircraft, so in an encounter between a TCAS-equipped and non TCAS-equipped aircraft, the latter will not be identified.

If the ADS-B RA message were widely deployed then this limitation would be overcome since it includes information on both the target and intruder aircraft.

Another technical issue is that when relying on the RA Broadcast, only the Mode A code of the target is known. In a future Mode S-only environment, unique Mode A codes may not be assigned, which would make this field useless.

Most of the worst-case latencies are above the required 10s. However, ACAS-Monitor was initially designed for off-line analysis. If deployed for real-time reporting performance, it is expected that changes could be made to reduce the latency (eg installing a dual-coverage ground network).

It is unclear if ACAS-Monitor can reliably detect ACAS co-ordination messages when they are transmitted from top-mounted antennas. It is recommended that this is investigated.

WAM

The WAM system would not presently meet the given requirements for an RA monitor. This is because it would not achieve a 95% detection rate of both aircraft. In several encounter types, it may not even be able to identify the target or intruder aircraft. It would also not meet the 10s latency requirement in the worst-case scenario.

For example, WAM will only receive the ACAS co-ordination downlink messages on 1090MHz (not uplink messages which are transmitted on 1030MHz). If the aircraft is transmitting the co-ordination downlink messages from the top-mounted antenna then they may not be received on the ground. In this case, the WAM system might completely miss the encounter.

However, if ADS-B RA messages are widely deployed then WAM would meet the given requirements.

WAM offers an interesting technical possibility – to extract the Mode S RA report in the same way that a Mode S radar would. The weakness of this concept is that it would only become aware that a RA Report is waiting to be extracted if it sees a Mode S surveillance message – and that would only happen in a Mode S radar environment anyway.

4.2 Conclusions

Both systems have some shortfalls against the given requirements, but ACAS-Monitor meets more of them.

One of the most significant requirements is the need to detect 95% of RA events, and to identify both aircraft involved for these events. It appears that neither candidate can meet this without the ADS-B RA message being widely deployed. For example, the ACAS-Monitor system reports statistics for one year of “376 ACAS events… In 235 events only one aircraft is known”.

This requirement should be reviewed and confirmed because it has such a significant impact on the evaluation. The questions to be asked are:

- What proportion of ACAS events must be detected to be acceptable?
- Do both aircraft need to be identified in every encounter?

4.3 Recommendations

It is recommended that:

- The operational requirement for detection of events and both aircraft in each event should be reviewed and confirmed.
- Reception from top-mounted antennas is further investigated. This remains an area of uncertain performance.

A REFERENCES

1 “FARADS - Technical Study of RA Downlink Methods”, Edition 1.4, 14 May 2007, EUROCONTROL.

2 “The DFS ACAS-Monitor Project”, Safety Nets Workshop, Brussels, 27 May 2008, DFS.

3 “ACAS-Monitoring of 1000 000 flight hours in the North German Airspace”, J Gottstein and P Form, TU-Braunschweig.

4 http://www.eurocontrol.int/epr/gallery/content/public/docs/skyway_autumn_2005/p32.pdf

5 “Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B)”, Working Paper 1090-WP25-06 - DRAFT of DO-260A++ - Version 1, RTCA.

6 “Laying down requirements for the Performance and Interoperability of Surveillance for the Single European Sky”, Draft COMMISSION REGULATION (EC), Draft SPI IR Framework – V1.0, 4 November 2008.

7 ICAO SARPS Annex 10, Vol IV, §4.3.8.4.2.2.1.

8 “ATM Surveillance System Standard Requirements”, Working Draft, v0.27, 01 July 2009, EUROCONTROL.

B Acronyms

ADS-B	Automatic Dependent Surveillance – Broadcast
DFS	Deutsche Flugsicherung GmbH
MOPS	Minimum Operation Performance Specification
TUB	Technische Universität Braunschweig
RA	Resolution Advisory
WAM	Wide Area Multilateration

Message fields from ACAS and Mode S messages

ID	Mode A identity code
AC	Altitude Code
AP	Address-Parity
ARA	Active Resolution Advisory
RAC	Resolution advisory complement
RAT	RA Terminated
MTE	Multiple threat encounter
TTI	Threat type indicator
TID	Threat type identity
FS	Flight Status

C Description of the Draft ADS-B RA message

C.1 Introduction

This section gives describes the current draft ADS-B RA message and protocol described in the latest version of the 1090MHz Extended Squitter ADS-B MOPS [ref 5]. This specification is subject to change.

It is of interest, but outside the scope of this report, that the MOPS also include other data relevant to ACAS. For example, it includes a flag to indicate if TCAS is present and operational on the aircraft.

C.2 ADS-B RA message

The latest draft of ADS-B MOPS includes a specification for a message to broadcast ACAS RA information. It is “event-driven” meaning that it is only transmitted while a ACAS RA is active (and for a short time after).

The contents of the ADS-B RA message are the same as that specified in ICAO SARPS Annex 10, Vol IV, §4.3.8.4.2.2.1., Register 3016, [ref 7], which was considered in the original version of this report. It is therefore reasonable to assume that this message content is fairly stable.

ACAS RA information is contained in several messages:

- The message is 2.2.3.2.7.8.2 1090ES TCAS Resolution Advisory (RA) Broadcast Message (Subtype=2).
- In the MOPS, message Type 28 Subtype 2 provides additional information regarding the ACAS RA.

The message includes the following fields:

- 24 bit address of aircraft,
- Active Resolution Advisory (ARA),
- Resolution advisory complement (RAC),
- RA Terminated (RAT),
- Multiple threat encounter (MTE),
- Threat type indicator (TTI),
- Threat type identity (TID).

The transmission of this message shall begin within 0.5 seconds after the transponder notification of the initiation of a RA and be terminated 10 seconds after the RA termination.

The message is transmitted at an average rate of 0.8 or 2.5s – depending on whether the “Emergency/priority status” message is being transmitted at the same time. It has priority of several other messages, including all “event driven” messages.

C.3 ACAS RA active flag

An indication of whether a RA is active is also given in the Aircraft Operational Status Messages (TYPE=31, Subtype=0 or 1). These messages include a one-bit subfield to indicate if an RA is presently active on the aircraft.

The flag is contained in “ME” bit 27 (Message bit 59) of the OM subfield in Aircraft Operational Status Messages (TYPE=31, Subtype=0 or 1).

This bit is set to “1” when a RA is active.

When an RA is active, this message is broadcast at an average rate of 0.8s until 24s after the RA terminates.