Performance Specifications of ACAS Monitoring System for the collection of ACAS RA downlink information

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Abstract

Work Area 1 of this work package deals with the integration of downlinked information on ACAS RAs in procedures and controller working environment. Display of ACAS RA downlinked information to the controller is expected to provide timely and dependable information about the events of RAs occurring on board aircraft. This document provides, from a user's perspective, the high level specifications for the technical system providing the downlinked information. It has been developed in close cooperation with WP15.4.3.

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Executive summary

Display of ACAS RA downlinked information to the controller is expected to often precede pilot RA reports or even to be the only source of such information, thereby providing more timely and dependable information about the events of RAs occurring on board aircraft. This document provides, from a user's perspective, the high level specifications for the technical system providing the downlinked information. It follows the structure of ISO 9126 and has been developed in close cooperation with WP15.4.3.

1 Introduction

1.1 Purpose of the document

One solution that project 04.08.03 (Ground-Airborne Safety Net Compatibility) aims at is to ensure that airborne safety nets and ground-based safety nets remain compatible in the changing ATM environment and to provide guidance to other SESAR projects. To achieve this goal this work package investigates how ACAS RA downlinked information to the controller can be used to provide timely and dependable information about the events of RAs occurring on board aircraft.

This document defines minimum performance of the ACAS Resolution Advisory (RA) information collecting system in order to satisfy efficient operational use. This document has been developed after consultation with 15.4.3 to capture their needs.

This document has been developed taking the following definitions into account:

> Performance Specification: Written requirement that describes the functional performance criteria required for a particular equipment, material, or product. In contrast, a design specification describes design characteristics and manufacturing methodology [1].
>
> Performance Specification: A specification expressed in terms of an expected outcome or acceptable performance standard. Often used in design-build criteria to articulate the Owner requirements [2]

This document has been developed in close cooperation with WP15.4.3. As it specifies no display requirements, but functional data acquisition requirements only, no coordination with 10.4.3 was seeked. This document is a preliminary specification document needed for the validation in step 2. Enhancements and updates to the requirements on the ACAS monitoring system may become necessary for V3 validation when producing an operational requirements document (expected mid 2012).

1.2 Intended readership

Primarily, this document is intended for all project participants. Besides this, it will be of interest to project 15.04.03, which develops the corresponding data delivery system.

1.3 Background

The main goal of project 4.8.3 is to ensure that airborne safety nets and ground-based safety nets remain compatible in the changing ATM environment. To achieve this, the project will, Inter alia, evaluate concepts of using alerts coming from an SNET of one side in systems of the other side in a stepwise and coordinated manner with relevant SESAR projects. For example, controllers who are not aware of the presence of an RA onboard an aircraft in proximity with another may provide avoiding instructions or clearances that conflict with the resolution advisory or delay its execution, thus degrading safety.

With the current deployment of SSR Mode S stations and other systems allowing to receive RA information transmitted by ACAS systems, the occurrence of an ACAS RA onboard an aircraft can be automatically detected on the ground. This capability will also be granted for ADS-B in the near future (DO260-B). However, such time-critical information may be affected by latency and its use by controllers requires clarification.

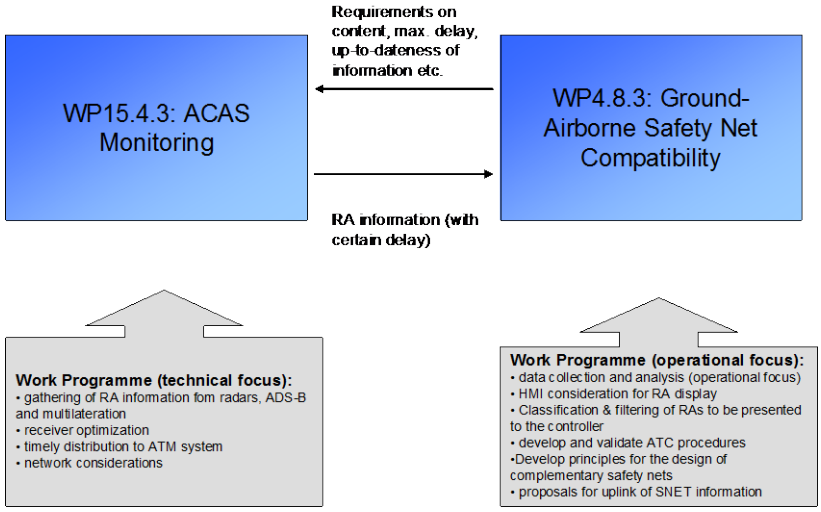

Figure 1-1: Relationship between WP4.8.3 (operational) and WP15.4.3 (technical)

Basically, work package 15.4.3 is dealing with the technical aspects of receiving and collecting ACAS RA information on the ground and sending them to the controller CWP, whereas work package 4.8.3 (Ground-Airborne SNET compatibility) is dealing with the operational aspects of integrating this information into the operational procedures (i.e. how much to present, when, how,…). The interrelation between these two work packages is bilateral, as the technical information flows from WP15.4.3 to 4.8.3, but operational requirements flow vice versa. This document is providing the performance specification for using downlinked RA information in an operational environment.

1.4 Previous Studies and Work

The technical feasibility and operational usefulness of display of ACAS RA downlinked information to the controller has been investigated by many organisations since the introduction of ACAS. EUROCONTROL and DFS co-organised an RA Downlink workshop in Berlin on 27th October 2009. The workshop documentation [6] provides a good overview of the work on which the current document builds. The RA Downlink workshop calls for urgent resolution of remaining issues such as procedures and controller responsibilities and possible safety implications. The specification of the ACAS monitoring system is one necessary step into this direction.

1.4.1 RA Downlink Experiments

A first RA Downlink Experiment was conducted in 2003 at the EUROCONTROL Experimental Centre. A preceding interactive real-time RA Downlink Experiment was conducted between October 2005 and January 2006 at the EUROCONTROL Experimental Centre.

The majority of the participants in the first experiments saw clear operational benefits in the provision of RA information to the controller. The second experiment showed that RA Downlink increased the controllers' understanding of the RA situation. However, this benefit potentially occurred at the expense of attending to other (lower priority) aircraft in the sector.

1.4.2 RA downlink technical study

The RA Downlink Technical Study [1] concluded that RA Downlink is technically feasible. Within the Mode-S coverage area, Mode-S RA reports were identified as the best solution. These Mode-S RA reports are already specified in ICAO Annex 10 [5]. Outside the Mode-S coverage area, the 1090

Extended Squitter can potentially be used for RA Downlink. At its time, the study concluded that it was too expensive to set up a dedicated infrastructure for RA Downlink.

1.4.3 RA Downlink Latency Study

Any potential benefit of RA Downlink will depend on the delay with which the message is delivered. In order to investigate the impact of delays, an RA Downlink Latency Study was conducted [7]. The study considered both technologies established as suitable, that is Mode-S and 1090 Extended Squitter.

According to this study, an en-route controller, on average, would be aware of an RA 30 second after the RA has been presented to the pilot. With Mode-S RA reports, the controller would be aware about the RAs in 95% of the cases within 9 seconds of their occurrence.

At its time, the study concluded that the downlink of RA information was sufficiently timely to allow for a significant increase in the controller's awareness of the RA encounter.

However, the current requirement is that a RA is shown to the controller within 4 seconds (see REQ_4.8.3_08), which can't be met with RA Downlink only.

1.4.4 BFU Recommendation

On June 1, 2002, two aircraft collided in the vicinity of Überlingen (Lake Constance). The accident was investigated by the German BFU (Bundesstelle für Flugunfalluntersuchung). Within the final report, a number of recommendations were given to avoid the point of systemic weakness. One reads as follows:

> BFU Safety Recommendation 08/2004:
>
> To enhance the performance of ACAS ICAO should initiate the development of downlinking RAs to ATC, using such techniques as SSR Mode S and ADS-B

1.4.5 Conclusion

Display of ACAS RA downlinked information to the controller has shown to be technically feasible, operationally beneficial and may be desirable from a safety point of view, provided the open issues regarding legal aspects, generic safety case and operational procedures in [6] are solved.

1.5 Acronyms and Terminology

Term	Definition
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependent Surveillance - Broadcast
ATC	Air Traffic Control
ATM	Air Traffic Management
BFU	Bundesstelle für Flugunfalluntersuchung

Term	Definition
E-ATMS	European Air Traffic Management System
IFR	Instrument Flight Rules
RA	Resolution Advisory
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
TCAS	Traffic Alert and Collision Avoidance System
VFR	Visual Flight Rules

2 Functional Performance Requirement

2.1 General

Within WP4.8.3, work is currently going on to define ATC operations including the display of ACAS RA downlinked information to the controller [10]. In that context, operational requirements have been set up: From these, appropriate functional performance requirements have been derived which are documented hereafter.

The main issue is that neither candidate alone can meet the requirements set up by [10], as explained in Appendix A. Thus, a combination of RA downlink, RA broadcast and RA coordination message is to be used by the ACAS Monitoring System. This is a prerequisite if an online indication at the CWP is to be used.

2.2 ACAS Monitoring System for online use

The ACAS monitoring system is intended to deliver comprehensive information on ACAS RA events in a timely manner to display them in an appropriate way to the controller (called “online use”).

The following performance specifications according to the structure of ISO 9126 [9] have been set up.

No.	Type	Requirement
REQ_4.8.3_SPR_RADL_01	Functionality (Interopera-bility)	The ACAS monitoring system shall provide RA information in the format Asterix CAT 4 using appropriate data items. *Note: the corresponding data items still have to be developed; proposals are expected from WP15.4.3*
REQ_4.8.3_SPR_RADL_02	Functionality (Interopera-bility)	The ACAS monitoring system shall be capable of providing RA downlink information, RA coordination messages as well as RA broadcast information.
REQ_4.8.3_SPR_RADL_03	Functionality (Interopera-bility)	It shall be capable to link the ACAS monitoring system to ATM Simulators and to ATM systems through UDP/IP
REQ_4.8.3_SPR_RADL_04	Functionality (Interopera-bility)	The ACAS monitoring system shall be suitable for use for the anticipated traffic numbers in core Europe until at least 2030 [11], [12]
REQ_4.8.3_SPR_RADL_05	Functionality (Interopera-bility)	The ACAS monitoring system shall be able to monitor aircraft equipped with TCAS II versions 6.04A, 7.0 and 7.1.
REQ_4.8.3_SPR_RADL_06	Functionality (Security)	The ACAS monitoring system shall provide security solutions which prevent read and write access to data
REQ_4.8.3_SPR_RADL_07	Usability	The ACAS monitoring system shall merge complementary information and suppress redundant information when analyzing the received data. This shall include information received for the same aircraft as RA downlink, RA coordination and RA broadcast message as well as for information which has already been sent. In an ACAS-ACAS encounter, RA information from both aircraft shall be provided (if available).
REQ_4.8.3_SPR_RADL_08	Usability	The monitoring system shall provide an RA message to the ATM system within 2 seconds from the annunciation of the RA in the cockpit in 95% of the cases. *Note: The overall “event-to-display” shall be less than 4 seconds. The various transmission times are illustrated with Figure 2-1)*
REQ_4.8.3_SPR_RADL_09	Usability	The monitoring system shall provide an RA termination message to the ATM system within 4 seconds from annunciation of “Clear of Conflict” in

No.	Type	Requirement
		the cockpit in 95% of the cases.
REQ_4.8.3_SPR_RADL_10	Usability	The ACAS monitoring system shall provide coverage above FL100 and in major TMAs within the defined airspace (e.g. ANSP, FAB etc.)
REQ_4.8.3_SPR_RADL_11	Usability	The ACAS monitoring system shall filter out technical error cases (e.g. empty data fields, missing intruder data, undefined data in data fields received, …)
REQ_4.8.3_SPR_RADL_12	Usability	The ACAS monitoring system shall provide the following raw RA information when an RA event occurs and when the RA changes Aircraft 1 (aircraft sending RA information) per message received: - Aircraft identification (call sign or registration) - aircraft address (24 bit Mode S address) - type of the RA (ARA field as specified in [5]) - source of event (RA DL, Broadcast or Coordination message) - time stamp (resolution 1 s)
REQ_4.8.3_SPR_RADL_13	Usabillity	The ACAS monitoring system shall additionally provide the following information when an RA event occurs as soon as it becomes available: In case of a threat indicated as Mode S equipped (TTI=1) in received messages: - Aircraft 2 address (24 bit Mode S address) In case of a threat indicated as not Mode S equipped (TTI=2) in received messages: - Aircraft 2 altitude, range and bearing - Aircraft 2 Mode A code (when possible) *Note: Aircraft 2 is the threat*
REQ_4.8.3_SPR_RADL_14	Usability	The ACAS monitoring system shall time stamp received RA messages using GPS with a resolution of 1s
REQ_4.8.3_SPR_RADL_15	Functionality	The ACAS monitoring system shall provide periodic status information via an appropriate Asterix CAT4 data item (message rate 1 per 5 seconds or better) *Note: the corresponding data item still has to be developed; proposals are expected from WP15.4.3*

The following Figure 2-1 may serve to illustrate the different delay figures mentioned above.

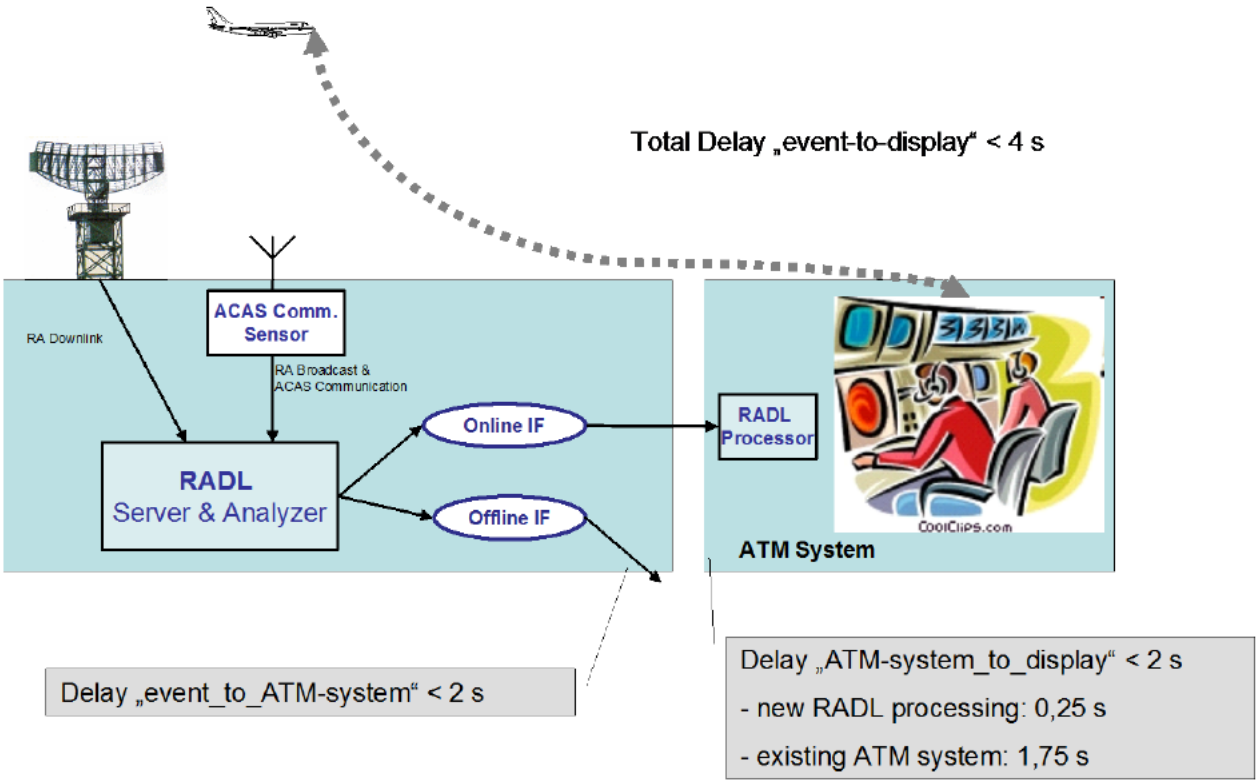

Figure 2-1: From ACAS RA to Controller Display

2.3 ACAS Monitoring System for offline use

The ACAS monitoring system is intended to deliver information on ACAS RA events to analyse them (called “offline use”). All pertinent RA Downlink data shall be made available for off-line analysis. Off-line analysis may need access to other data sources as well (surveillance data and voice recordings) for complete analysis.

The following performance specifications have been set up.

No.	Type	Requirement
REQ_4.8.3_SPR_RADL_16	Usability	The ACAS monitoring system shall provide the following summary RA information per event: - Date - Time (UTC) with a resolution of 1s - Aircraft 1 identification (call sign or registration) - Aircraft 1 address (24 bit Mode S address) - type of the RA (ARA field as specified in [5]) - Geographical location of event (LAT/LON in WGS84) In case of a threat indicated as Mode S equipped (TTI=1) in received messages: - Aircraft 2 address (24 bit Mode S address) In case of a threat indicated as not Mode S equipped (TTI=2) in received messages: - Aircraft 2 altitude, range and bearing - Aircraft 2 Mode A code (when possible) *Note: Aircraft 1 is the transmitter of the RA information, Aircraft 2 is the threat*

3 References

[1] http://www.businessdictionary.com/definition/performance-specification.html

[2] http://www.colorado.edu/engineering/civil/db/DBS/glossary.cgi?word=Performance+Specification

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[5] **Standards and Recommended Practices and Guidance Material for Airborne Collision Avoidance Systems** Convention on International Civil Aviation, Annex 10, Volume IV, 3rd Edition, ICAO, July 2002.

[6] RA Downlink workshop documentation: http://www.eurocontrol.int/safety-nets/public/standard_page/berlin_workshop_09.html

[7] **Study of Latency of RA Downlink,** EUROCONTROL, Edition 1.3, 15/05/2007

[8] **FARADS (Feasibility of ACAS RA Downlink Study),** Technical Study of RA Downlink Methods – Supplement, EUROCONTROL, Edition 1.0, 12 October 2009

[9] ISO/IEC Standard on Software Engineering (ISO 9126): http://www.sqa.net/iso9126.html

[10] **ATC operations including the display of ACAS RA downlinked information to the controller - initial version**. Initial Draft 0.0.1, EUROCONTROL

[11] **1030/1090 Scenario Description Deliverable**, Draft 00.00.01, SESAR WP15.01.06

[12] **Long - Term Forecast: IFR Flight Movements 2008 – 2030**, Edition Number: v1.0, Edition Date: 19/11/08, EUROCONTROL

[13] **Analyse von ACAS-Ausweichanweisungen am Boden,** TE im Fokus 1/2010 (German research magazine publication), 28.05.2010, DFS

Appendix A

A.1Analysis of ACAS RA information on the Ground

A.1.1 Sources

In the case of an RA, various communication processes are activated. The details depend on the level of the ACAS on board the involved aircraft. For the identification of ACAS events on the ground various sources are available:

- RA Downlink - In any case, the information of the active RA is stored in the BDS-register 30(16) of the Mode S transponder as "Active Resolution Advisory". If the aircraft is routinely interrogated by a Mode S radar, the transponder will indicate in ist reply that this register contains information. The radar system can now read out the data of that register in a further interrogation. This process is referred to as RA downlink and takes place on the SSR reply channel (1090 MHz).
- RA-broadcast - The above mentioned information stored in the BDS register is transmitted via a further communication process, the RA-broadcast. The RA broadcast is transmitted on the SSR interrogation frequency 1030MHz and can be received by surrounding ACAS systems, but not by Mode S radars. The information content of the RA broadcast partly coincides with the RA downlink, it includes the RA data from the aforementioned BDS-Register 30 (16) but own Mode A and Mode C instead of the threat related information.
- RA Coordination messages - If both aircraft are ACAS-equipped, the RAs will be coordinated between the two aircraft. The first aircraft to which an RA is given transmits a so-called "RA coordination message" to the intruder that will be responded with a "coordination reply". If both aircraft select simultaneously the same RA, the aircraft with the higher address inverts its RA.

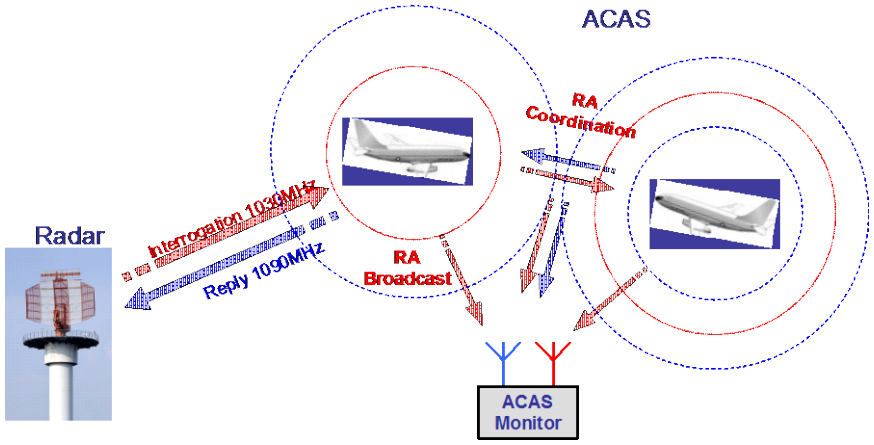

Figure 3-1: Radar and ACAS Signals

A.1.2 Timing

In case of an RA initiation in an aircraft, the information on the corresponding RA is available by different means and in different information extend.

- RA Downlink: The Mode S transponder transmits the information on request of a Mode S radar as the so called RA downlink. Due to the rotating antenna system, the delay between the initiation of the RA and the availability on ground cannot be determined. In the worst case the delay is equivalent to the rotation time of the antenna. For the German Mode S infrastructure [13], a worst case update time of less than 8 seconds for 87% and a average update time of less than 5s for 95% of the RA events was determined. Taking into account the detection of RA events outside the German airspace, covered by the radar infrastructure

but perhaps with a degraded probability of detection, the portion for the detection within the German airspace might be even higher. After the termination of the RA, the RA information remains for additional 18s in the Mode S transponder and will be sent to the ground sensor with the termination bit activated. The time span between the RA initiation on board and the first interrogation cannot be identified as well as the time span between the last interrogation and the end of the RA (indicated as yellow periods in Figure 3-2).

- The RA communication between the involved aircraft is triggered once per second. The ACAS which has issued the RA sends the coordination message to the intruder up to 12 times each cycle until the reception of the coordination reply. The ACAS Monitor neither can determine the cycle nor the number of the message or reply. Therefore the time of the RA initiation cannot be calculated by the information received on the RA communication channel.
- The RA broadcast is transmitted immediately by the TCAS transmitter when the RA is displayed on board. Due to a limited PD the successive detection of the first or all RA broadcasts is not possible, hence the timestamp of the RA initiation on Board is still unknown.

The following figure describes by different colors these schedules and their corresponding sources.

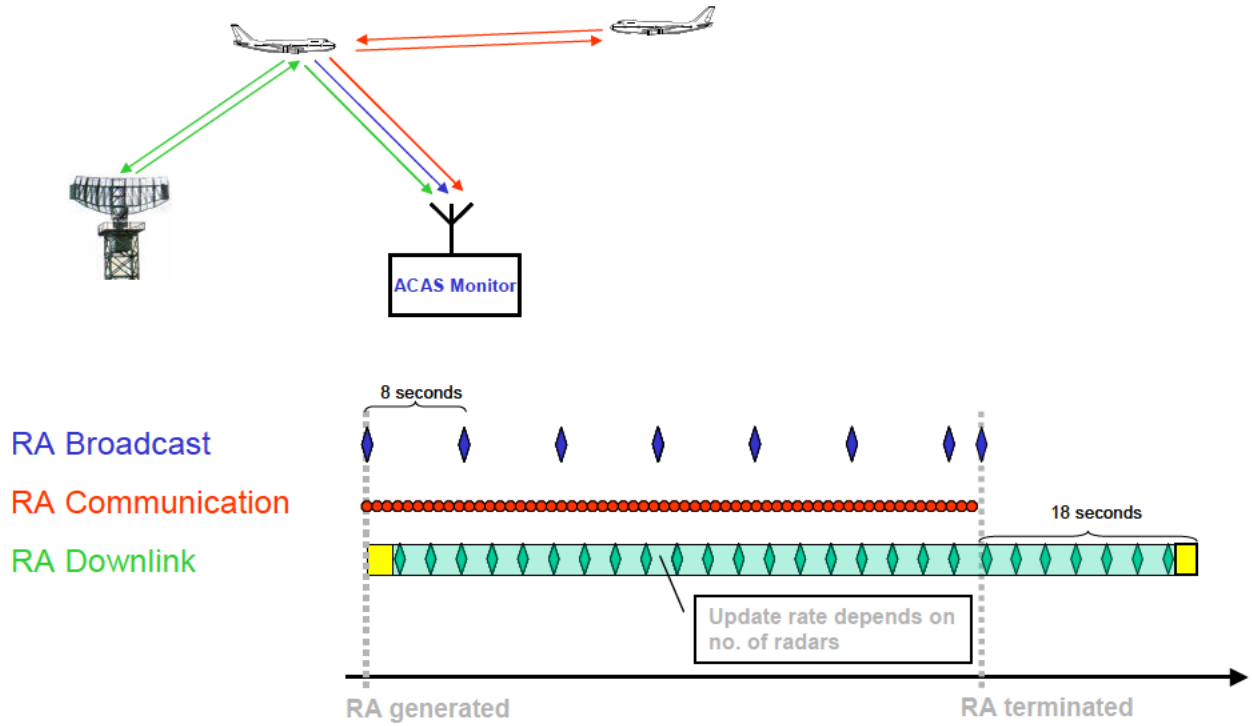

Figure 3-2: Source and sequence of different ACAS RA information

With the combination of RA downlink and RA broadcast information it is possible to derive the timestamp of the RA initiation with a high rate and accuracy.

With the figures given above, it can be assumed that the first RA downlink will be received with a delay less than 8 seconds to the initiation of the RA. With at least one successful reception of a RA broadcast, the calculation of the timestamp is straight forward.

$$T_{RA} = T_{RAB} - n \cdot 8s$$

$$n = \left\lceil \frac{T_{RAB} - T_{RAD}}{8s} \right\rceil$$

with T_{RAB} = time of receipt of RA broadcast, T_{RAD} = time of first receipt of RA downlink

-**END OF DOCUMENT -**