

Overview of ACAS II

(incorporating version 7.1)

Version 3.2 - 24 July 2014

Note: This presentation material has been designed to support the training of people involved in the use of the Airborne Collision Avoidance System (ACAS). However, it is not, per se, designed for the complete training of controllers or pilots. The principal and essential technical and operational features of ACAS are introduced. For a deeper knowledge, the reader is advised to refer to documentation listed in the Resources section.

The information contained in this presentation and EUROCONTROL ACAS II Bulletins is considered to be accurate at the time of publishing and is subject to change.

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History of changes		
Version 2.0	1 February 2011	Released version
Version 2.1	17 February 2011	Corrected broken hyperlinks on slide 25
Version 3.0	12 January 2012	Incorporation of version 7.1, added pitch cue display of RAs, minor updates and editorial changes
Version 3.1	27 February 2013	Correction and additions on slides: 10, 15, 33, 47, 48, 51, 52, 97, 98
Version 3.2	24 July 2014	Updated hyperlinks. Slide 29.

How to use this presentation?

- Use page up/page down keys to move from one slide to the other
- Jump directly to another section using the tabs at the top of the screen
- Check www.eurocontrol.int/acas to see if there is an updated version of this presentation available
- Please submit any comments/questions regarding this presentation material to: acas@eurocontrol.int

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[Example: IVSI combined with traffic display](#)

What is ACAS?

- **ACAS: Airborne Collision Avoidance System**
- ACAS detects and tracks other **altitude reporting** aircraft
- ACAS improves safety acting as a "last resort" safety net against mid-air or near mid-air collisions
- ACAS equipage requires a Mode S transponder
- ACAS is standardised by ICAO (Annex 10)

What is TCAS?

- **TCAS: Traffic Alert and Collision Avoidance System**
- TCAS is the only commercially available implementation of the ICAO standard for ACAS II
- TCAS II Minimum Operational Performance Specification (MOPS) have been published by RTCA (DO-185B) and EUROCAE (ED-143).

TCAS versions

- **TCAS II version 6.04a** – old version of TCAS II
 - never mandated in Europe
 - still used by some military aircraft or foreign aircraft (which do not fall within the current European mandate)
- **TCAS II version 7.0** currently mandated in Europe
 - to be gradually phased out and replaced by version 7.1
- **TCAS II version 7.1** mandated in Europe
 - for all new aircraft after 1 March 2012
 - for all aircraft after 1 December 2015
- **TCAS II version 7.1** mandated by ICAO (Annex 10):
 - for all new installations after 1 January 2014
 - for all units after 1 January 2017

Note: TCAS versions are backwards compatible

ACAS II / TCAS II principles

- Designed for **collision avoidance only**
- **Independent** of ground-based systems, the auto-pilot and of NAV systems
- ACAS parameters as far as possible chosen to be compatible with separation standards – but ACAS:
 - Does not warn of loss of separation
 - Sometimes generates unnecessary (nuisance) alerts

Types of alerts

Two types of alerts are generated by ACAS/TCAS:

TA - Traffic Advisory (or Traffic Alert)

- Alert warning the pilot of the presence of another aircraft that may become a threat

RA - Resolution Advisory

- Alert providing information to pilots on how to modify or regulate their vertical speed to avoid a potential mid-air collision
- Sense (direction) of RAs is coordinated between ACAS equipped aircraft

Types of ACAS

- **ACAS I** issues Traffic Advisories (**TAs**)
- **ACAS II** issues Resolution Advisories (**RAs**), in addition to **TAs**, in the vertical plane only
- **ACAS III** issues Resolution Advisories (**RAs**), in addition to **TAs**, in both the vertical and in the horizontal plane
- Only **ACAS II** standards have been defined and approved
- ACAS III is unlikely to be ever developed
- Instead, a future collision avoidance system (**ACAS X**) is currently under development
 - ACAS X will not provide horizontal manoeuvres
 - ACAS X to be commercially available in early 2020s.

ACAS II functions

- Surveillance of adjacent transponders (nominal range = 14 NM)
- Must be able to process at least 30 aircraft
- Display of information on Instantaneous Vertical Speed Indicators (IVSI) or on EFIS (ND + PFD)
- Co-ordination between two TCAS units (through the Mode S data-link)
- Processing cycle = **1 second**

Equipage requirement

Europe:

The carriage of ACAS II is mandatory for all civil fixed-wing turbine-engined aircraft having a maximum take-off mass **exceeding 5700 kg** or a maximum approved passenger seating configuration of more than **19**

Mandated versions in Europe:

Version 7.0 after 1 January 2005

Version 7.1 after 1 March 2012 for new aircraft

Version 7.1 after 1 December 2015 all aircraft (currently equipped with version 7.0)

Note: Some military and business aviation aircraft have been equipped on a voluntary basis.

Outside Europe:

Equipage mandates vary by region

Minimum Equipment List (MEL)

For Aircraft Operator's Certificate (AOC) holders:

- Flying with an inoperative ACAS II is permitted provided it is done in accordance with the applicable Minimum Equipment List (MEL) provisions
- Fault must be rectified within 10 days (3 days for flights in German airspace) or less if so prescribed by the MEL

Safety improvement

- ACAS II improves safety by reducing the risk of mid-air collision by a factor of about 4
- But...
 - ACAS is not a safety critical system for airspace management
 - Airspace management and procedures must be safe in absence of ACAS (ACAS introduces additional protection)

Limitations

- TCAS II will automatically fail if the input from the aircraft's barometric altimeter, radio altimeter or transponder is lost
- No RAs or TAs against any threats with a closure speed of over 1200 knots or vertical rates over 10,000 ft/min.
- RAs can be generated before ATC separation minima are violated and even when ATC separation minima will not be violated.

History of implementation 1956-1999

1956

First conceptual design, following a mid-air collision over the Grand Canyon (USA)

1981

US FAA pursue the development of TCAS, following a 1978 mid-air collision over California

1986

Another mid-air collision over California, followed by a phased TCAS II mandate in USA

1991

TCAS II version 6.02 mandated in the USA

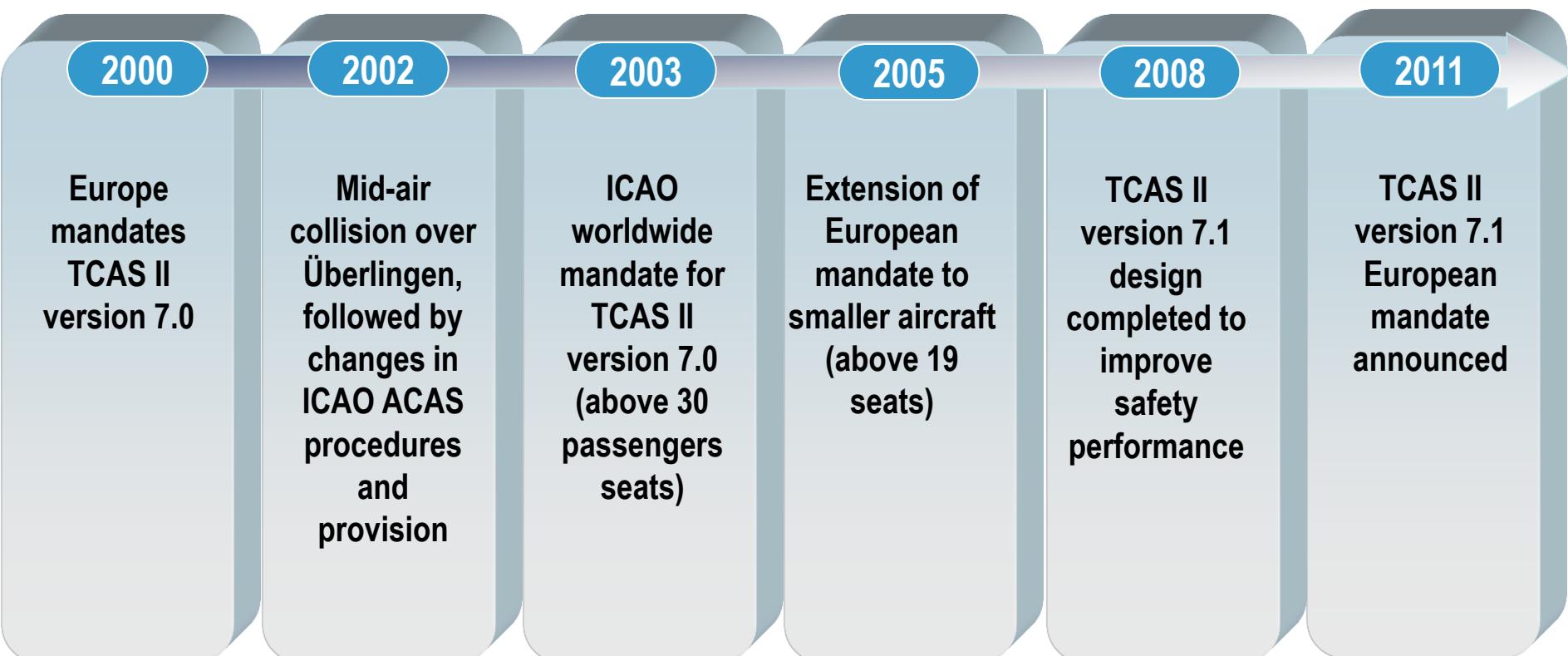
1996

Mid-air collision near New Delhi results in TCAS II mandate in India

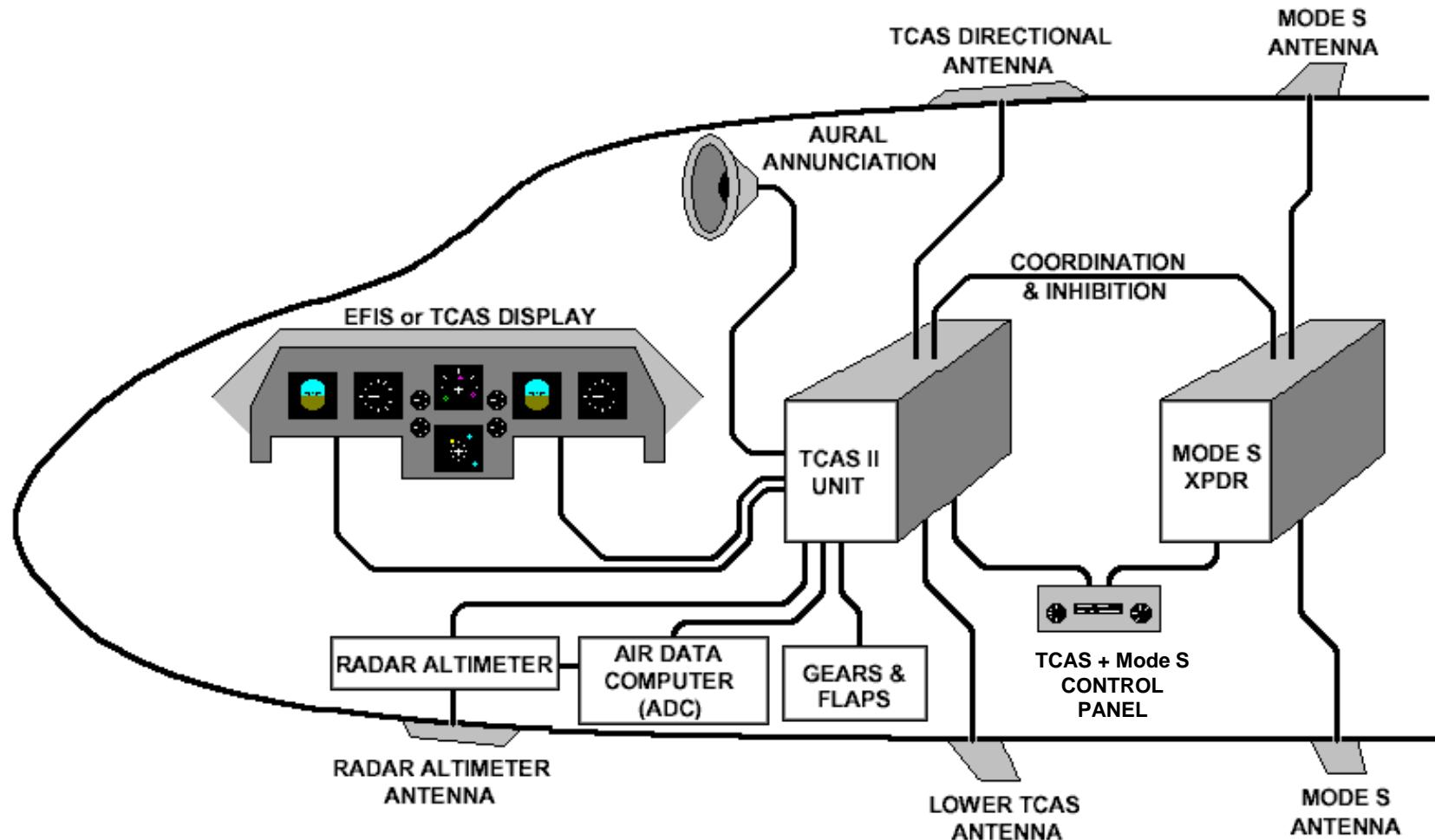
1997

TCAS II version 7.0 design finalized

History of implementation 2000-2011

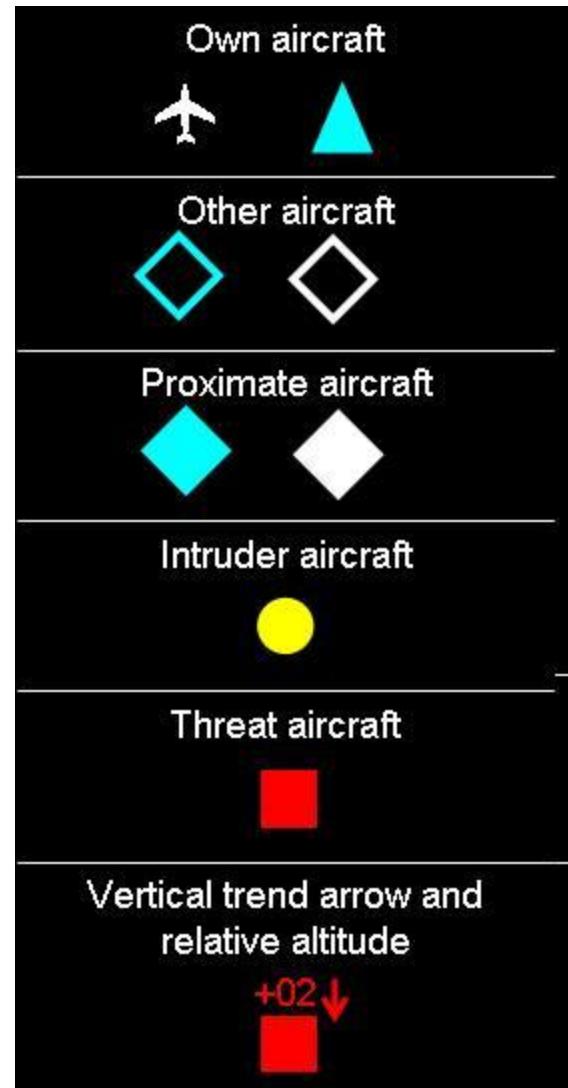


Equipment schematic diagram



TCAS traffic display

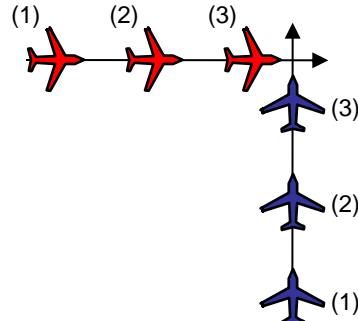
- Designed to aid visual acquisition of intruders
- Surrounding traffic displayed:
 - No past positions (track history), no speed vector, no track identity information
 - Not possible for the pilot to determine trajectory of other aircraft
 - Proximate traffic = within 6 NM and 1200 feet
 - Vertical trend arrow displayed if the vertical speed of other aircraft is more than 500 ft/min
 - Relative altitude shown in hundreds of feet above the symbol for traffic above and below the symbol for traffic below.



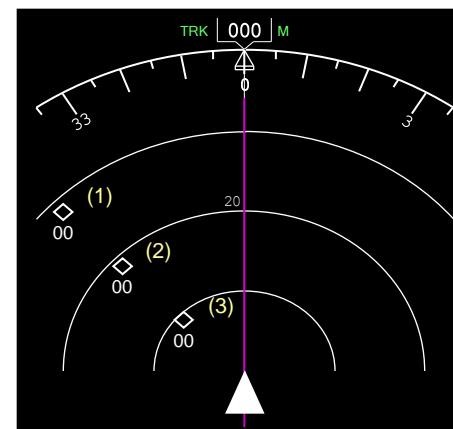
Details of TCAS displays vary according to manufacturer

TCAS traffic display – moving reference

- TCAS traffic display accuracy is limited
- The reference for the TCAS traffic display is own aircraft position
 - Major cause of TCAS traffic display misinterpretation
- For example, when two aircraft are converging at 90° the crossing track appears to be converging at a 45° angle on the TCAS traffic display



Aircraft trajectories converge at 90°



Closure appears to be at 45°

TCAS traffic display example: Dedicated display



TCAS traffic display example: EFIS

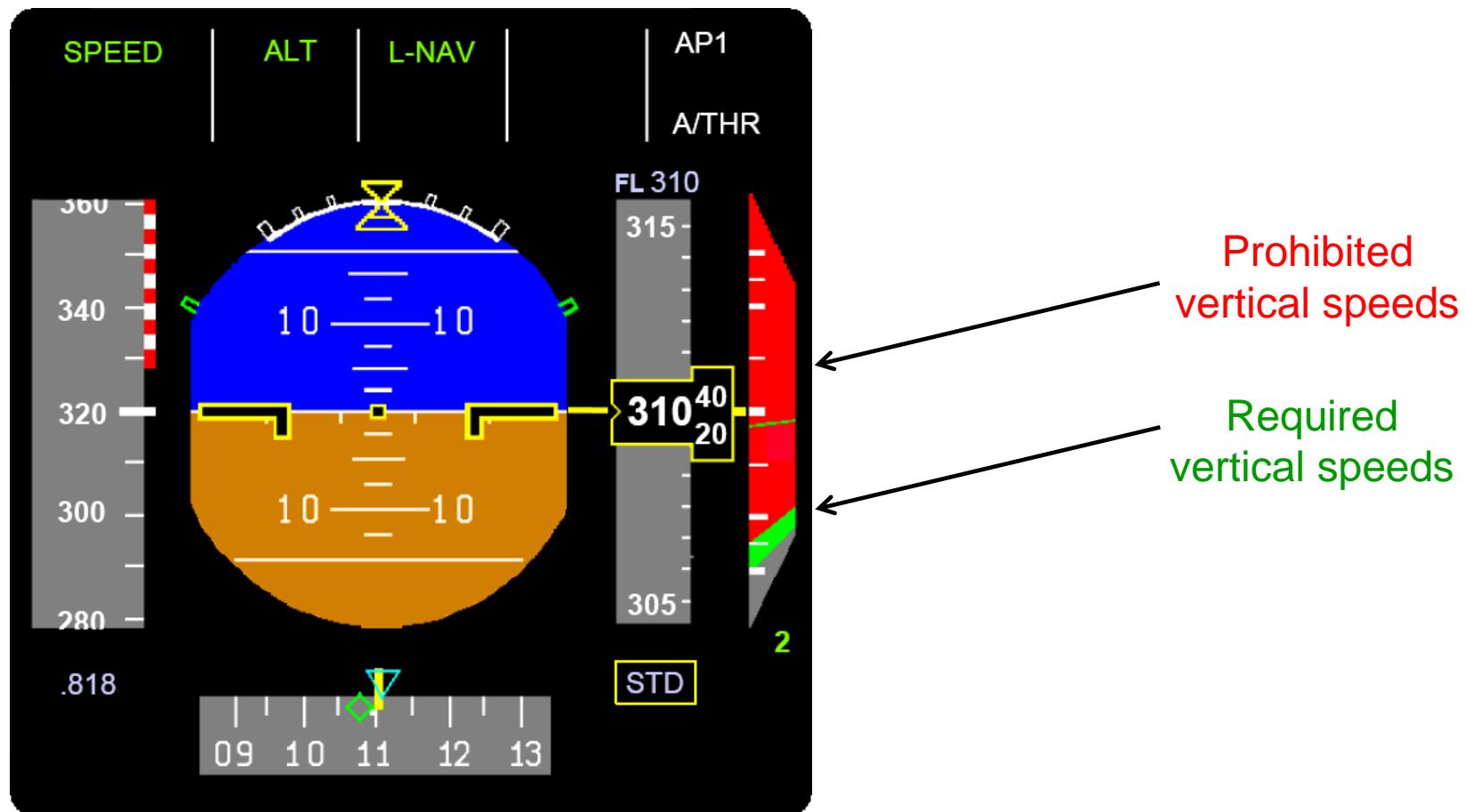


TCAS RA display

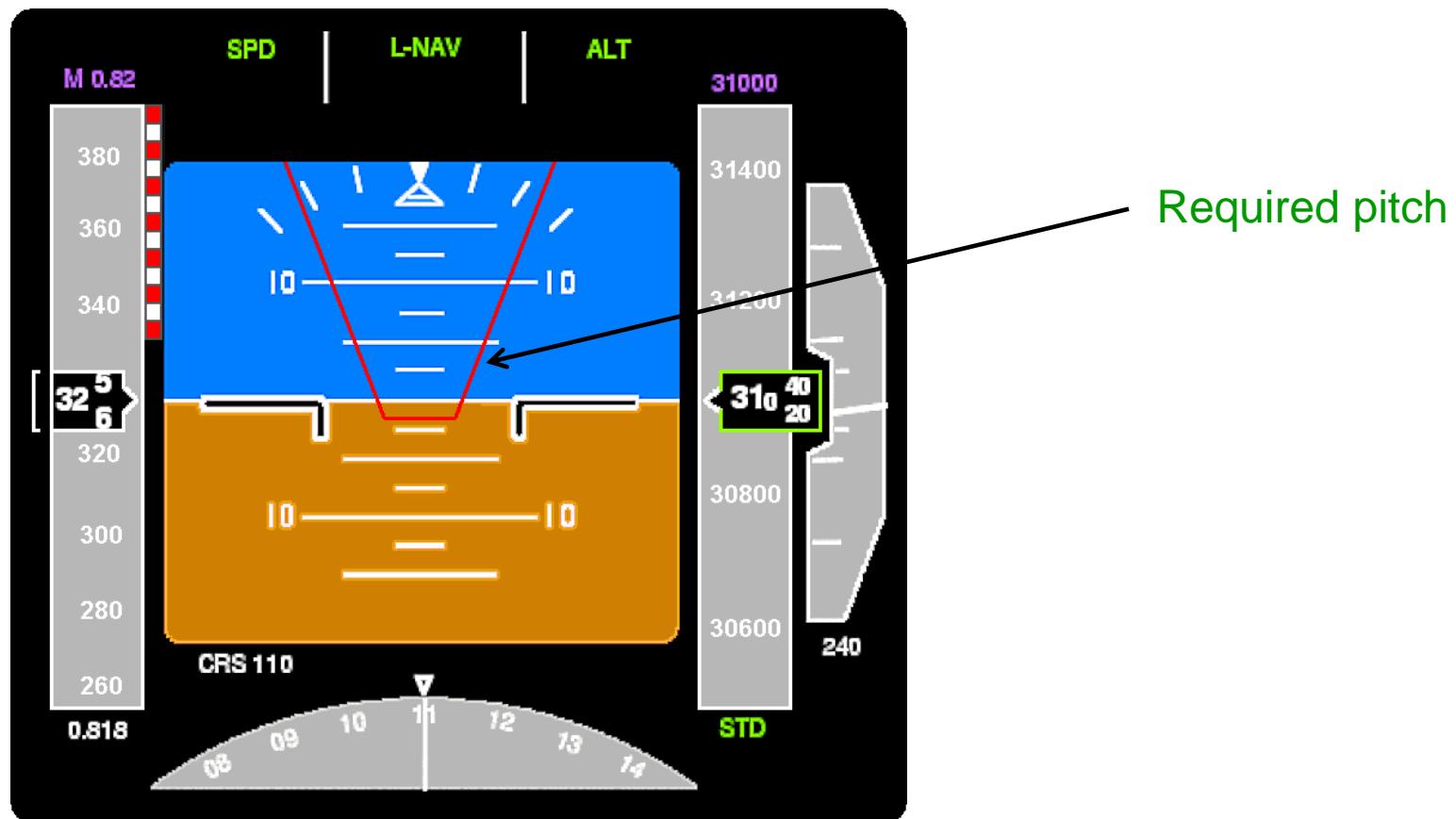
- Indication to pilot of prohibited and required vertical manoeuvres
- Either:
 - vertical rates - red (prohibited) and green (required) areas on IVSI or on vertical speed tape accompanying PFD
 - pitch cue - indicating required attitude on PFD
- Aural annunciation (alert) of RA through a loud speaker

Details of TCAS displays vary according to manufacturer

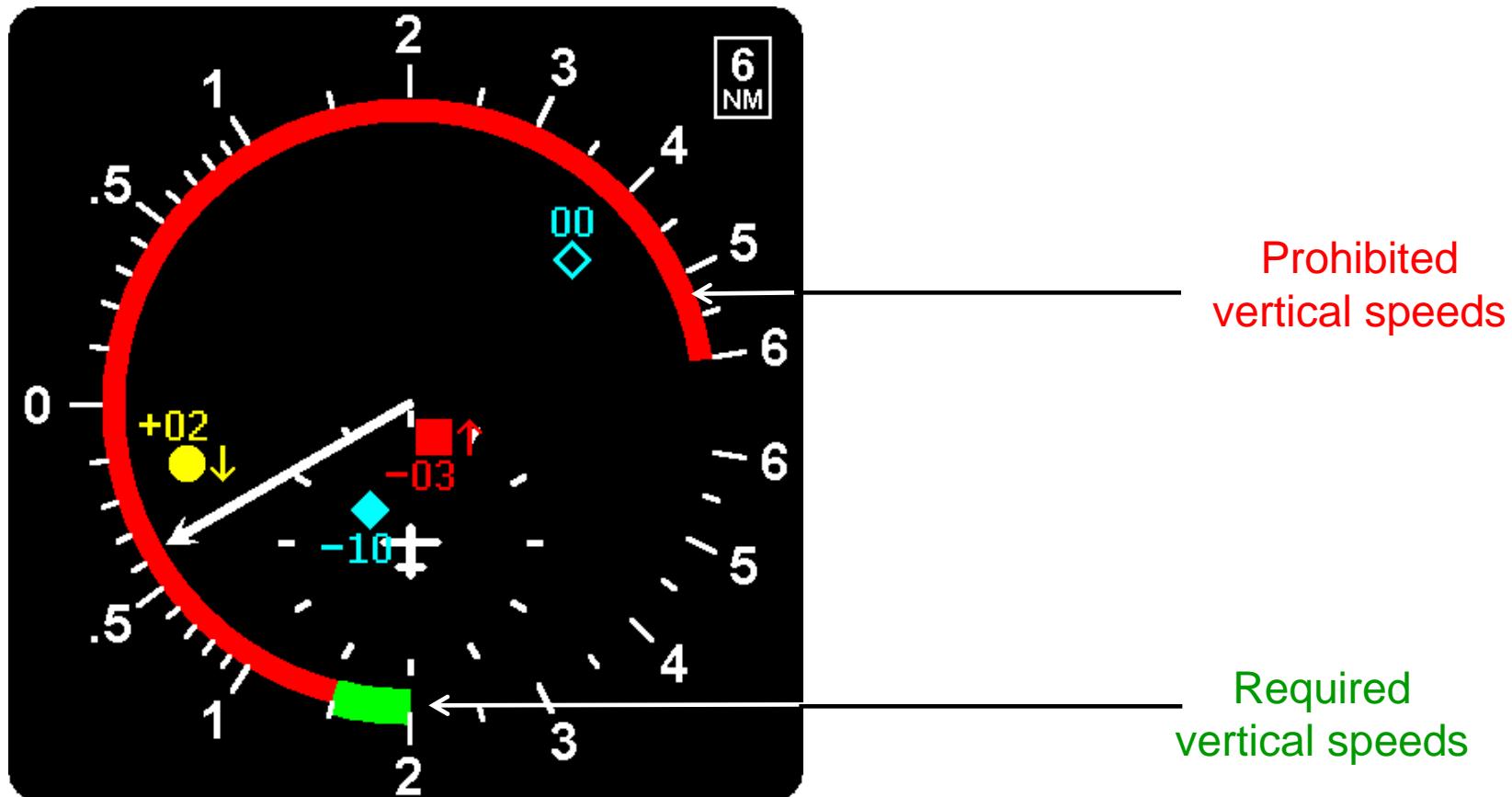
TCAS RA display example: PFD & vertical speed tape



TCAS RA display example: PFD & pitch cue



RA display example: IVSI combined with traffic display



ACAS Operations

Levels of protections

[RA generation inhibitions](#)

[TCAS protected volumes](#)

[RA aural alerts version 7.0](#)

[RA aural alerts version 7.1](#)

[TCAS II version 7.1 changes](#)

[Traffic Advisory \(TA\)](#)

[TA – pilot actions](#)

[Resolution Advisory \(RA\)](#)

[RA – pilot actions \(1/2\)](#)

[RA – pilot actions \(2/2\)](#)

Resolution advisories:

[Adjust Vertical Speed RA \(version 7.0 only\)](#)

[Level Off RA - initial RA \(version 7.1 only\)](#)

[Level Off - weakening RA \(version 7.1 only\)](#)

[Monitor Vertical Speed RA](#)

[Maintain Vertical Speed RA](#)

[Crossing Maintain Vertical Speed RA](#)

[Climb RA](#)

[Increase Climb RA](#)

[Crossing Climb RA](#)

[Reversal Climb RA](#)

[Descend RA](#)

[Increase Descent RA](#)

[Crossing Descent RA](#)

[Reversal Descent RA](#)

[Multi-threat RA](#)

[RA Termination](#)

TCAS II operations on the ground

[Operating mode – STBY](#)

[Operating mode – XPNDR](#)

[Operating mode – ALT OFF](#)

[Operating mode – TA Only](#)

[Operating mode – TA/RA or AUTOMATIC](#)

Levels of protections

Threat aircraft equipment	Own aircraft (TCAS II)
No transponder	Not detected
Mode A transponder only	Not detected
Mode A/C transponder with no altitude reports	TA, intruder shown on TCAS traffic display without altitude
Mode C or Mode S transponder	TA and RA
TCAS I	TA and RA
TCAS II	TA and coordinated RA

RA generation inhibitions

- RAs are inhibited close to the ground based on radio altimeter reported heights

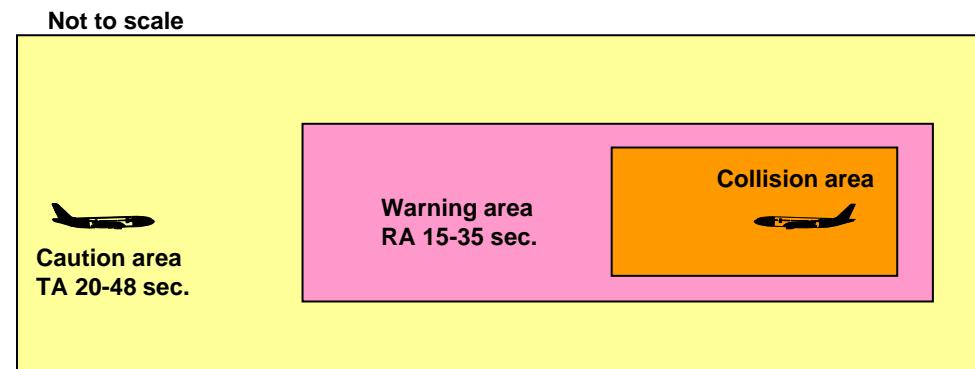
Alert type	Alert inhibited below
Increase descent RA	1550 ft (± 100 ft) AGL
Descend RA	1100 ft (± 100 ft) AGL
All RAs	1000 ft (± 100 ft) AGL
All TCAS aural alerts	500 ft (± 100 ft) AGL

Note: +100 ft values will apply to descending aircraft, -100 ft values will apply to climbing aircraft

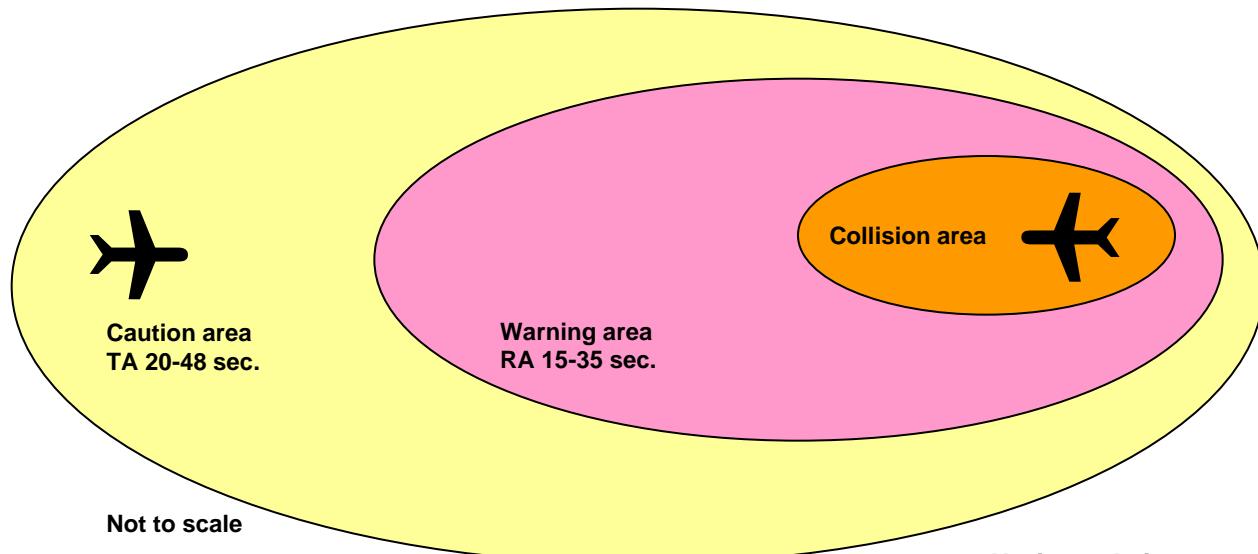
- In case of stall, windshear, and ground proximity warnings
 - RA aural annunciations (alerts) will be inhibited
 - TCAS II will automatically be placed into the TA-only mode

TCAS protected volumes

Theoretical “protected volume” around each TCAS equipped aircraft



Vertical view



Horizontal view

RA aural alerts TCAS II version 7.0

Upward sense			Downward sense		
RA	Required vertical rate (ft/min)	Aural	RA	Required vertical rate (ft/min)	Aural
Climb	1500	Climb, climb	Descend	– 1500	Descend, descend
Crossing Climb	1500	Climb, crossing climb; Climb, crossing climb	Crossing Descent	– 1500	Descend, crossing descend; Descend, crossing descend
Maintain Climb	1500 to 4400	Maintain vertical speed, maintain	Maintain Descent	– 1500 to – 4400	Maintain vertical speed, maintain
Maintain Crossing Climb	1500 to 4400	Maintain vertical speed, crossing maintain	Maintain Crossing Descent	– 1500 to – 4400	Maintain vertical speed, crossing maintain
Reduce Descent ¹	0 – 500 – 1000 – 2000	Adjust vertical speed, adjust	Reduce Climb ¹	0 500 1000 2000	Adjust vertical speed, adjust
Reversal Climb ²	1500	Climb, climb NOW; Climb, climb NOW	Reversal Descent ²	– 1500	Descend, descend NOW; Descend, descend NOW
Increase Climb ²	2500	Increase climb, increase climb	Increase Descent ²	– 2500	Increase descent, increase descent
Preventive RA	No change	Monitor vertical speed	Preventive RA	No change	Monitor vertical speed
RA Removed	—	Clear of conflict	RA Removed	—	Clear of conflict

¹ Replaced by “Level off, level off” in version 7.1

² Not possible as an initial RA

RA aural alerts TCAS II version 7.1

Upward sense			Downward sense		
RA	Required vertical rate (ft/min)	Aural	RA	Required vertical rate (ft/min)	Aural
Climb	1500	Climb, climb	Descend	– 1500	Descend, descend
Crossing Climb	1500	Climb, crossing climb; Climb, crossing climb	Crossing Descent	– 1500	Descend, crossing descend; Descend, crossing descend
Maintain Climb	1500 to 4400	Maintain vertical speed, maintain	Maintain Descent	– 1500 to – 4400	Maintain vertical speed, maintain
Maintain Crossing Climb	1500 to 4400	Maintain vertical speed, crossing maintain	Maintain Crossing Descent	– 1500 to – 4400	Maintain vertical speed, crossing maintain
Level Off ¹	0	Level off, level off	Level Off ¹	0	Level off, level off
Reversal Climb ²	1500	Climb, climb NOW; Climb, climb NOW	Reversal Descent ²	– 1500	Descend, descend NOW; Descend, descend NOW
Increase Climb ²	2500	Increase climb, increase climb	Increase Descent ²	– 2500	Increase descent, increase descent
Preventive RA	No change	Monitor vertical speed	Preventive RA	No change	Monitor vertical speed
RA Removed	—	Clear of conflict	RA Removed	—	Clear of conflict

¹ New RA in version 7.1, replacing “Adjust vertical speed, adjust” from version 7.0

² Not possible as an initial RA

TCAS II version 7.1 changes

- Safety issues identified in TCAS II version 7.0:
 - Unintentional opposite pilot response to “Adjust vertical speed, adjust” RAs
 - Flaws in the reversal logic
- TCAS II version 7.1 addresses these issues
 - “Adjust vertical speed, adjust” replaced with “Level off, level off” RA
 - Reversal logic improved (transparent to pilots)

More information:



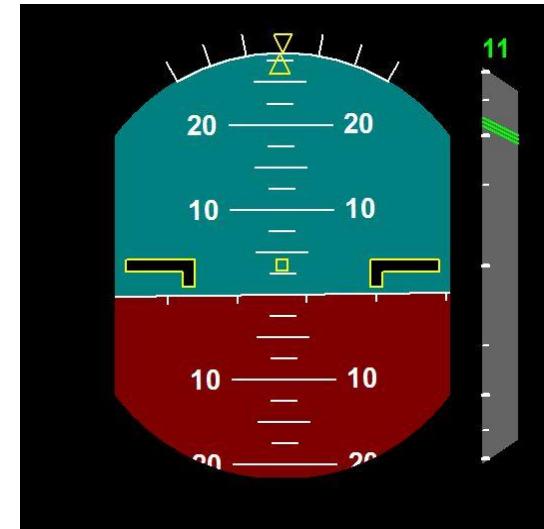
[TCAS II version 7.1 for pilots
\(presentation\)](#)



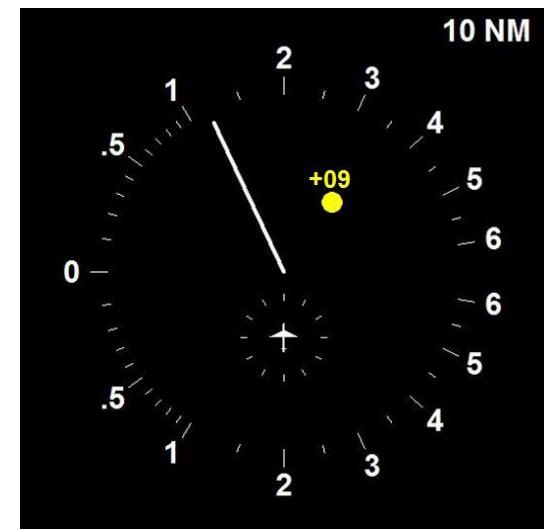
[TCAS II version 7.1 for air traffic controllers \(presentation\)](#)

Traffic Advisory (TA)

- **Objective:** to aid visual acquisition of an intruder; prepares the crew for a possible RA
- **Thresholds:**
 - 20 - 48 sec. before Closest Point of Approach
 - 10 - 13 sec. before RA
- Symbol on traffic display: amber circle



Traffic, traffic



Note: Generic IVSI and pitch cue instruments are shown.

TA – pilot actions

- Prepare for a possible RA
- **No manoeuvres** shall be made in response to a TA
- TAs are **not** required to be reported to ATC

Resolution Advisory (RA)

- **Objective:** to achieve a safe vertical distance from a threat aircraft (between 300 and 700 ft)
- **Threshold:** 15 - 35 sec.
- Aural annunciations (alert): depends on the RA issued
- Symbol on traffic display: red square 
- Takes into account **all altitude reporting threats – updated every second**

RA – pilot actions (1/2)

Pilot actions:

- Respond to **first RA** within **5 seconds**
- Respond to **subsequent RAs** within **2.5 seconds**
- Required acceleration: 0.25g, or 0.35g for increase rate RAs and reversal of sense RAs
- Do **not** manoeuvre contrary to the RA
- During an RA it is essential that pilots follow RA indications

RA – pilot actions (2/2)

- Report to ATC RAs causing a deviation from the current clearance as soon as workload permits:
[callsign] TCAS RA (pronounced Tee-Cas-Ar-Ay)
- After “Clear of Conflict” return to the last clearance and notify ATC or seek alternative ATC instructions:
[callsign] CLEAR OF CONFLICT (assigned clearance)
RESUMED or
[callsign] CLEAR OF CONFLICT, RETURNING TO (assigned clearance)

The following slides show TCAS alerts and describe the required pilot actions

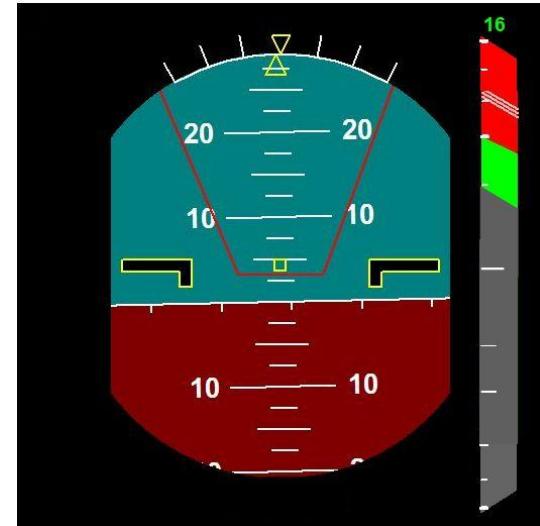
Note: Generic IVSI and pitch cue instruments are shown.

Adjust Vertical Speed RA

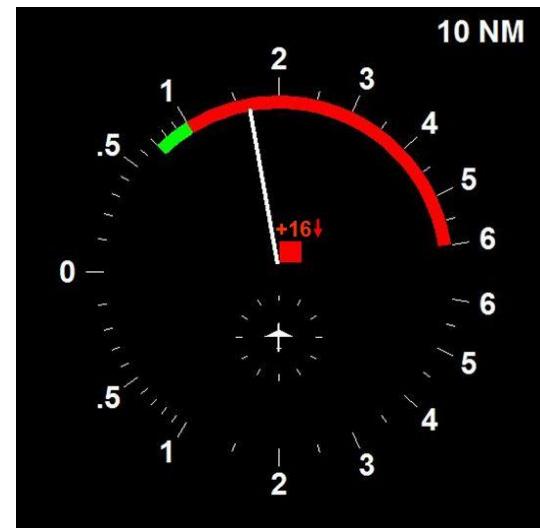
Version 7.0 only

- Adjust Vertical Speed RA **always requires a reduction of vertical speed** (as indicated on the RA display).
 - In this example: reduce the rate of climb to 1000 ft/min. or less
- Possible rates posted are:
 - 2000 ft/min.
 - 1000 ft/min.
 - 500 ft/min.
 - 0 ft/min. (i.e. “level off”)

This RA has been replaced by “Level off, level off” RA in version 7.1



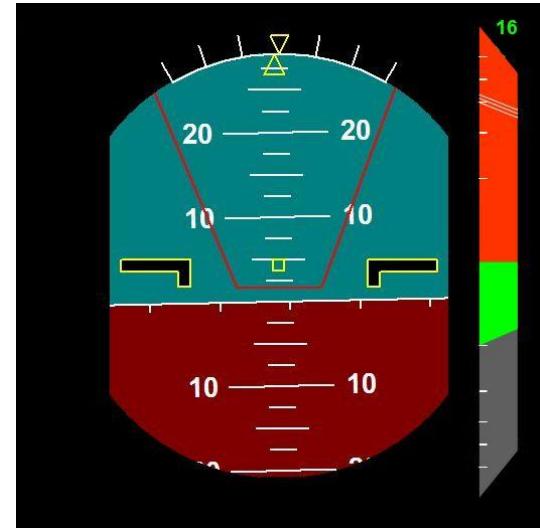
Adjust vertical speed,
adjust



Level Off RA (initial RA)

Version 7.1 only

- **Reduce the vertical rate to 0 ft/min** (i.e. level off)
- The level off must be achieved **promptly**, not at the standard next flight level (e.g. FL200, FL210, etc.)



Level off,
level off



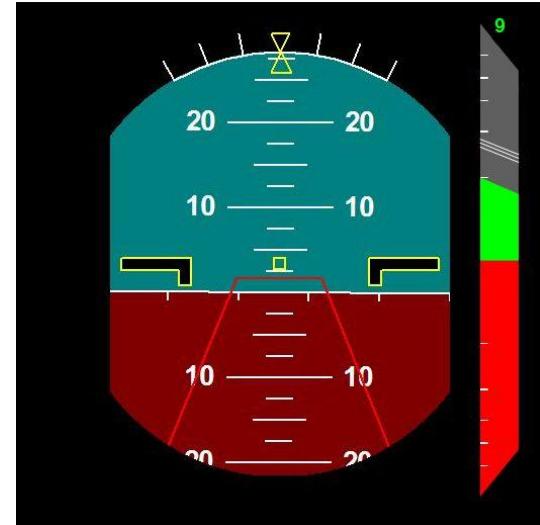
New RA introduced in version 7.1 replacing
“Adjust vertical speed, adjust” RA

Level Off (weakening RA)

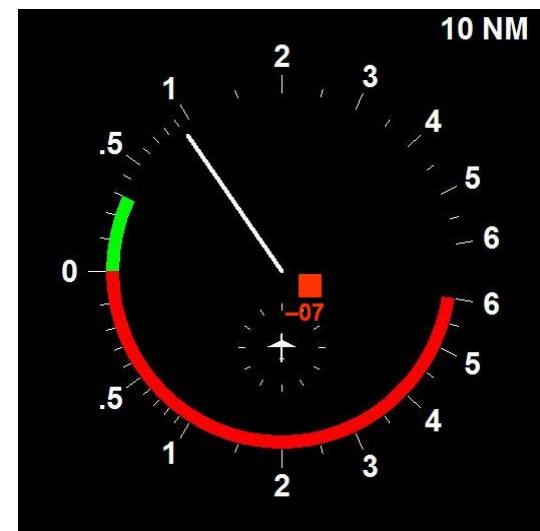
Version 7.1 only

- Weakening RA (usually subsequent to Climb or Descend RA)
- Reduce the vertical rate to 0 ft/min (i.e. level off)
- The level off must be achieved promptly, not at the standard next flight level

New RA introduced in version 7.1 replacing “Adjust vertical speed, adjust” RA

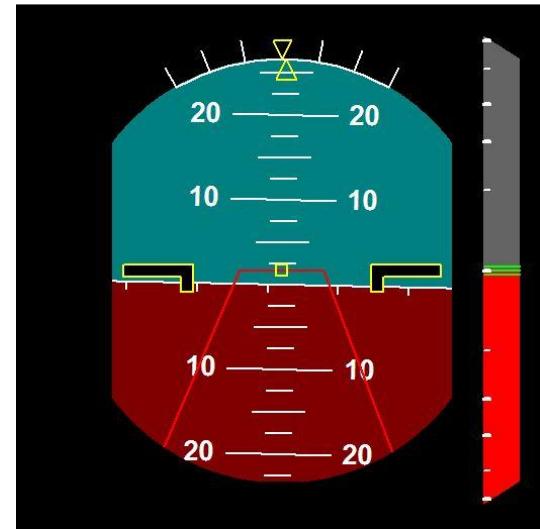


Level off,
level off

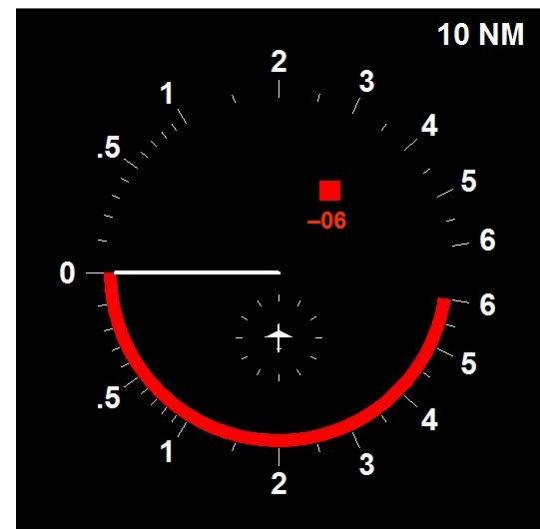


Monitor Vertical Speed RA

- No change in vertical speed is required
- Continue the current vertical speed (in this example continue the level flight but not to descend)

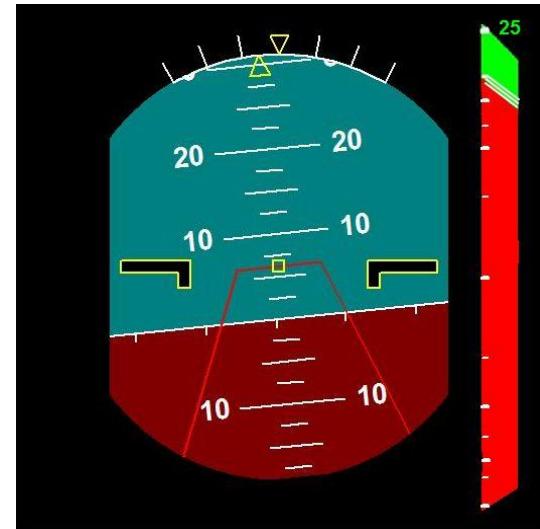


Monitor
vertical speed

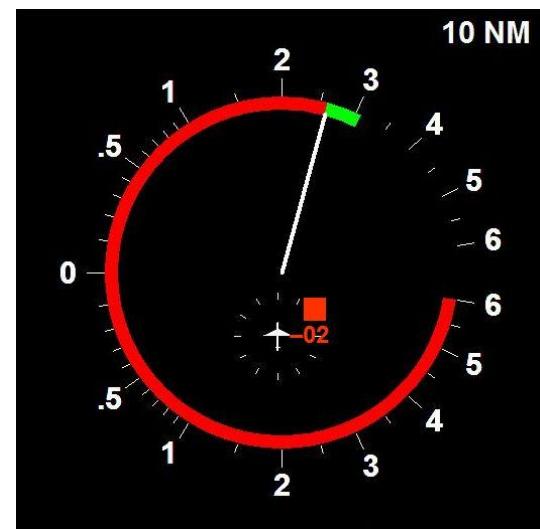


Maintain Vertical Speed RA

- Continue the current vertical speed (do not reduce)
- This RA only occurs when already climbing/descending at more than 1500 ft/min.
- Note: May be confusing when climbing but starting to descend (or vice versa): When the pilot looks at the display the current vertical speed could already be in the red

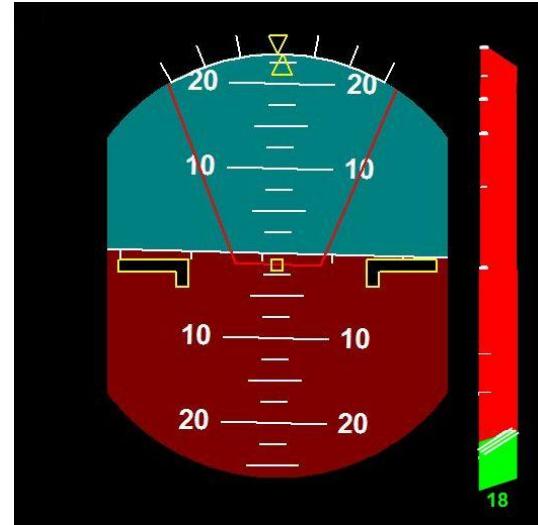


Maintain
vertical speed



Crossing Maintain Vertical Speed RA

- Continue the current vertical speed (do not reduce)
- The altitude of the threat aircraft will be crossed during the RA
- This RA only occurs when already climbing/descending at more than 1500 ft/min.
- Also, the note on the previous slide

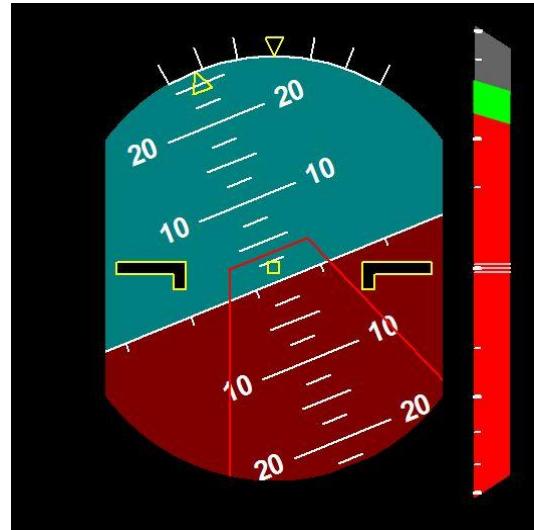


 Maintain vertical speed,
crossing maintain

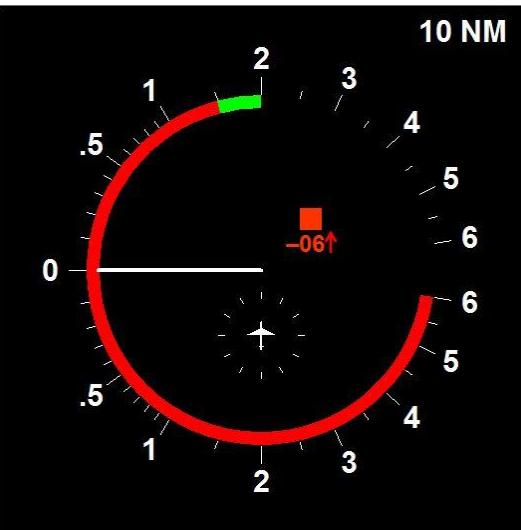


Climb RA

- Start climbing to achieve the vertical speed of 1500-2000 ft/min.

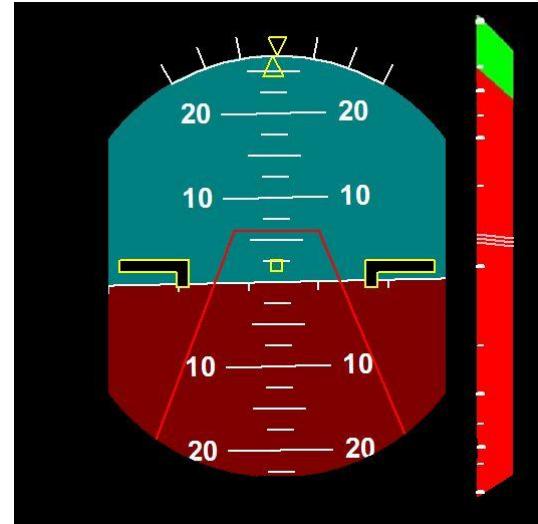


Climb,
climb



Increase Climb RA

- Increase the climb rate to achieve 2500-3000 ft/min.

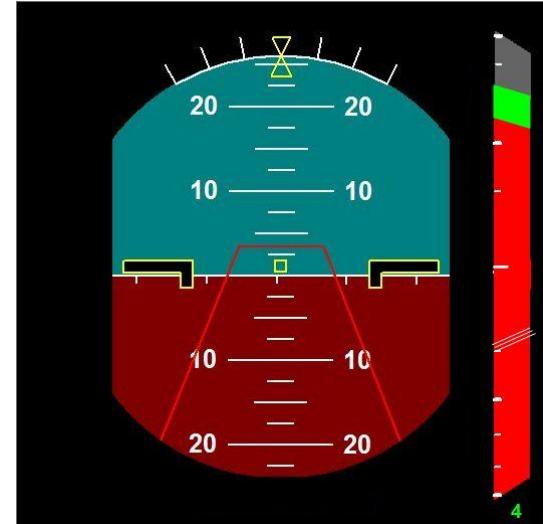


Increase climb,
increase climb



Crossing Climb RA

- Start climbing to achieve the vertical speed of 1500-2000 ft/min.
- The altitude of the threat aircraft will be crossed during the RA

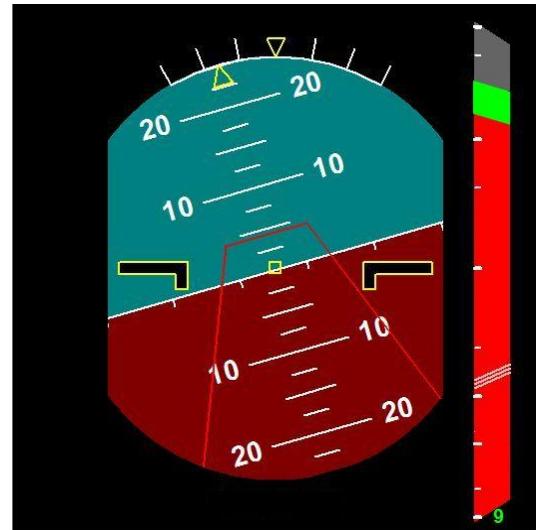


Climb, crossing climb;
climb, crossing climb

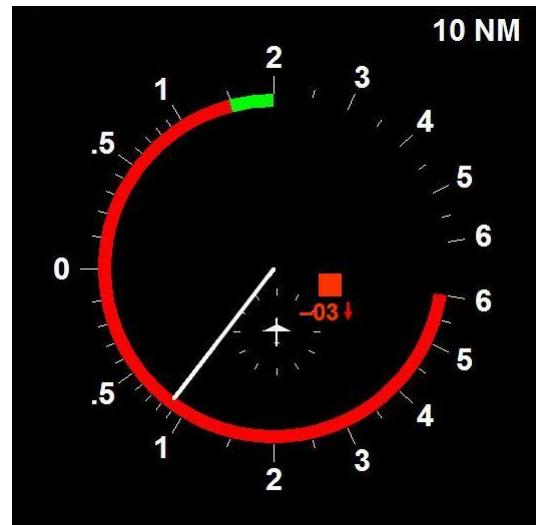


Reversal Climb RA

- Change of RA from descend to climb
- Start climbing to achieve the vertical speed of 1500-2000 ft/min.

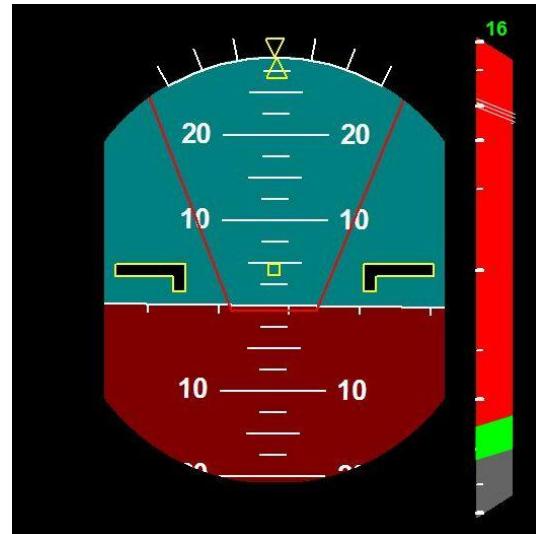


Speaker icon: Climb, climb NOW;
climb, climb NOW



Descend RA

- Start descending to achieve the vertical speed of 1500-2000 ft/min.

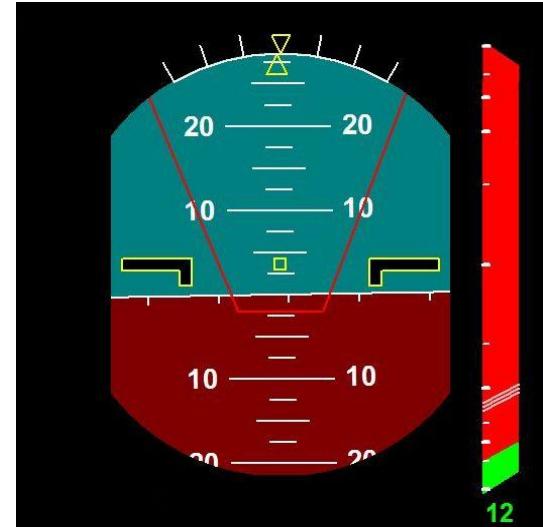


Descend,
descend

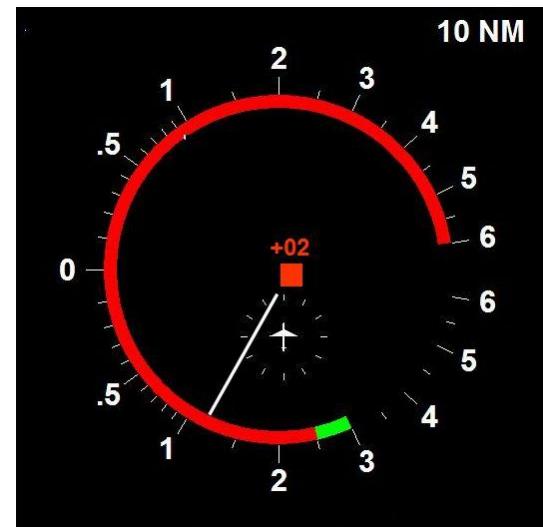


Increase Descent RA

- Increase the descent rate to 2500-3000 ft/min.

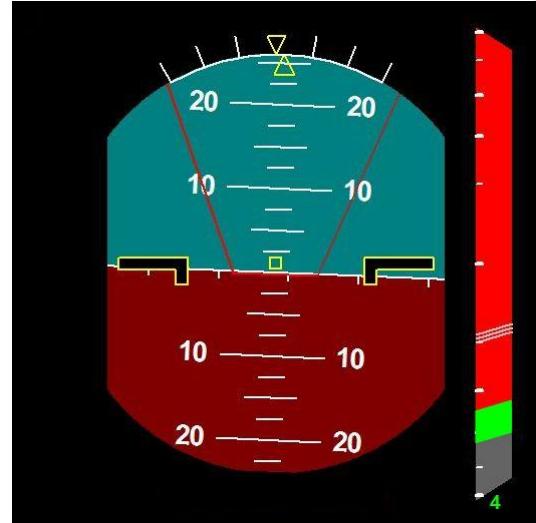


🔊 Increase descent,
increase descent



Crossing Descent RA

- Start descending to achieve the vertical speed of 1500-2000 ft/min.
- The altitude of the threat aircraft will be crossed during the RA



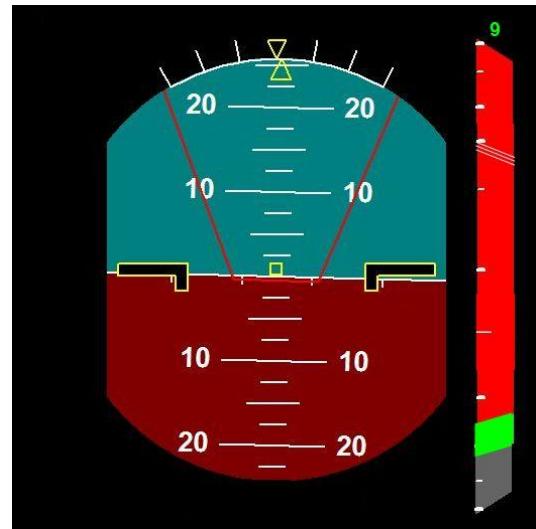
Speaker icon: Descend, crossing descend;
descend, crossing descend;





Reversal Descent RA

- Change of RA from climb to descent
- Start descending to achieve the vertical speed of 1500-2000 ft/min.



Descend, descend NOW;
descend, descend NOW



Multi-threat RA

- When there is a threat above and below a combination of advisories can be issued at the same time
- This examples shows, a combination of advisories to prevent descent and climb toward the intruders below and above
- Aural annunciation will vary depending on the manoeuvre required and TCAS version
- In this example:

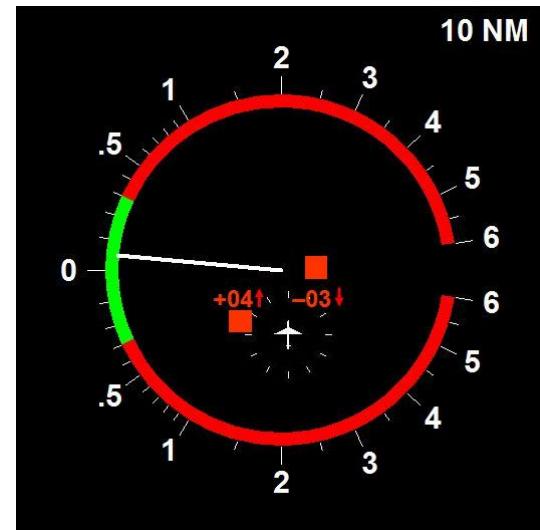
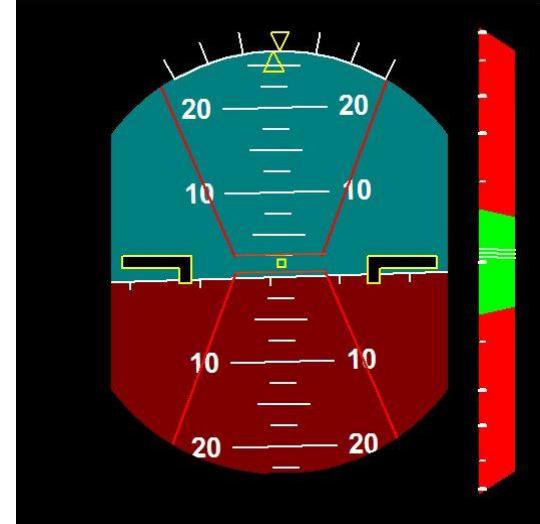
Version 7.1



Level off, level off

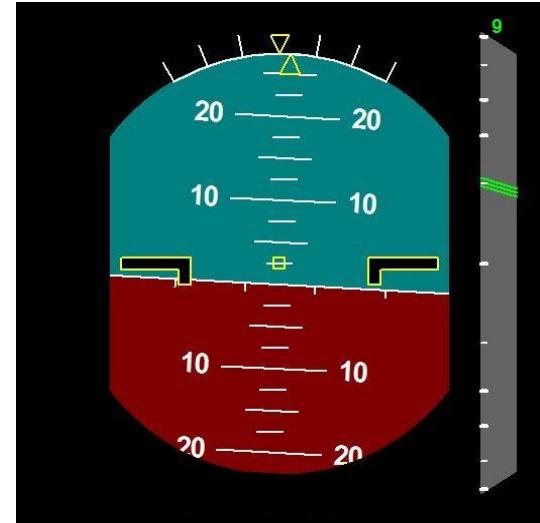
Version 7.0

Adjust vertical speed, adjust

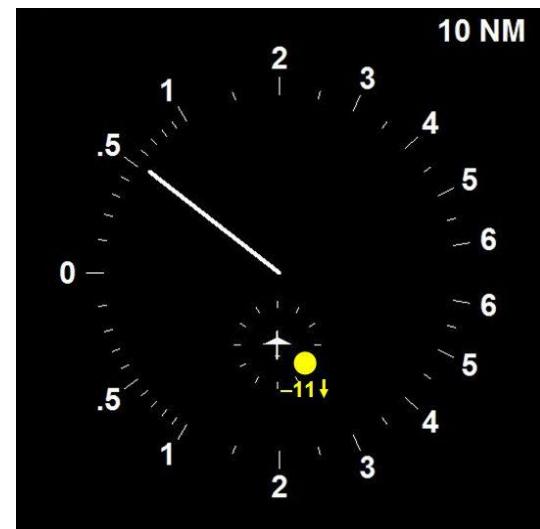


RA Termination

- Return to previous clearance
- Required/prohibited vertical speeds are removed from the display
- Report resuming previous clearance to ATC:
[callsign] CLEAR OF CONFLICT (assigned clearance) RESUMED
 or
**[callsign] CLEAR OF CONFLICT,
 RETURNING TO (assigned clearance)**
- Or follow new ATC clearance



Clear
of conflict



TCAS II operations on the ground

- TCAS II operation on the airport surface provides no safety benefit, except when approaching/on the active runway
 - Turn TCAS on for a short period of time before crossing/entering an active runway to double-check for the presence of any aircraft on short finals
- Routine operation of TCAS II on the ground can degrade:
 - Performance of ATC radars
 - Surveillance performed by airborne TCAS II units

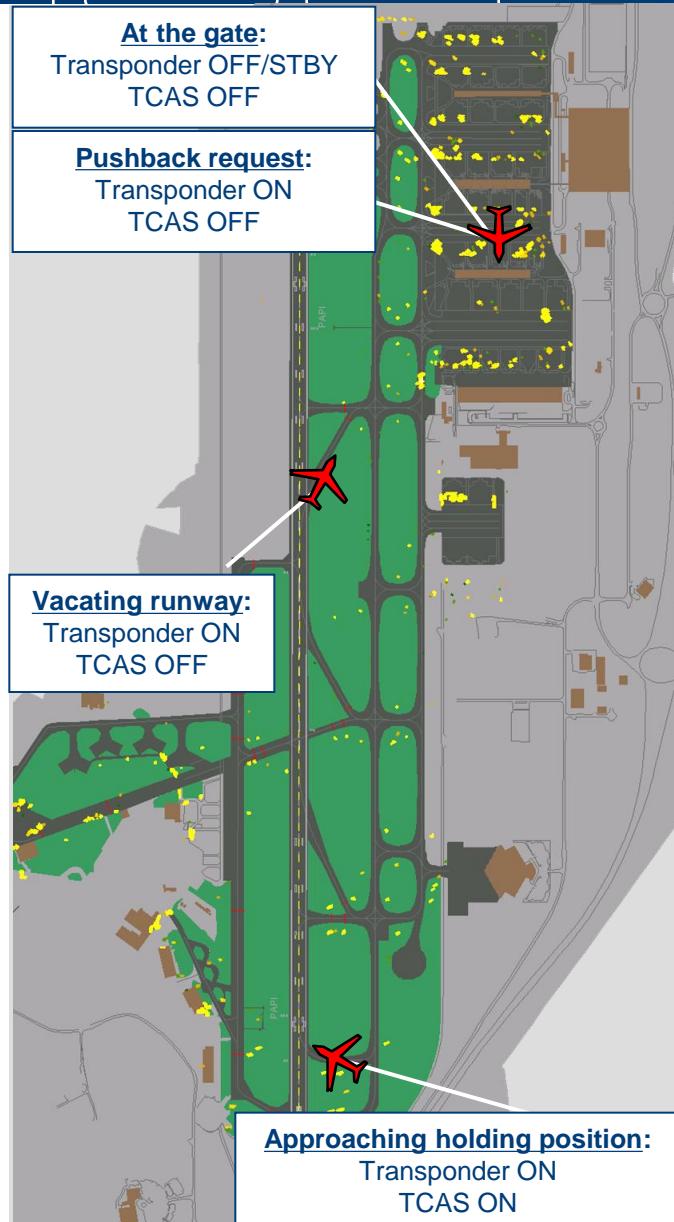


Illustration shows the required equipment status depending on aircraft position

Operating mode – STBY



Transponder	TCAS	RAs generated by	
		Own aircraft	Intruder
Off	Off	No	No
Own aircraft invisible to both ATC radars/surveillance and other TCAS equipped aircraft.			
To be used at the gate.			

Operating mode – XPNDR



Transponder	TCAS	RAs generated by	
		Own aircraft	Intruder
On	Off	No	Yes
Own aircraft visible to ATC radars/surveillance and other TCAS equipped aircraft. Uncoordinated RAs can be generated by intruders.			
Departure: Select XPNDR during push-back Arrival: Select XPNDR once the runway has been vacated			

Operating mode – ALT OFF



Transponder	TCAS	RAs generated by	
		Own aircraft	Intruder
On, no altitude reporting	Off	No	No
Own aircraft visible to ATC radars/surveillance without altitude and other TCAS equipped aircraft but no RAs can be generated.			
Should be selected if requested by ATC (if altitude reports are incorrect) and in other circumstances as per Operations Manual			

Operating mode – TA Only



Transponder	TCAS	RAs generated by	
		Own aircraft	Intruder
On	On (TA-only)	No	Yes
Own TCAS can generate TAs only. Other TCAS aircraft can generate (uncoordinated) RAs.			
Use limited to the situations described in the Operations Manual, such as engine failure, emergency descent and other specific conditions			

Operating mode – TA/RA or AUTOMATIC



Transponder	TCAS	RAs generated by	
		Own aircraft	Intruder
On	On	Yes	Yes
Own aircraft can generate RAs. RAs with other TCAS aircraft are coordinated.			
Standard mode of operation			

Encounters

Sequence of alerts

- 1 – Proximate traffic detected
- 2 – TA
- 3 – First RA: Climb
- 4 – RA weakens
- 5 – Clear of Conflict

Real-life examples of encounters

- Manoeuvres in opposite direction to the displayed RA
- Misinterpretation of Adjust Vertical Speed RA
- Correct response to Adjust Vertical Speed RA
- Weakening Adjust Vertical Speed RA not followed
- Climb RA at the maximum certified flight level
- RAs against VFRs
- Manoeuvring based on traffic display

Sequence of alerts

- The following slides will:
 - Show a possible sequence of alerts in a conflict with an aircraft below
 - Show the RA displayed on IVSI and pitch cue display
 - Describe the required pilot actions

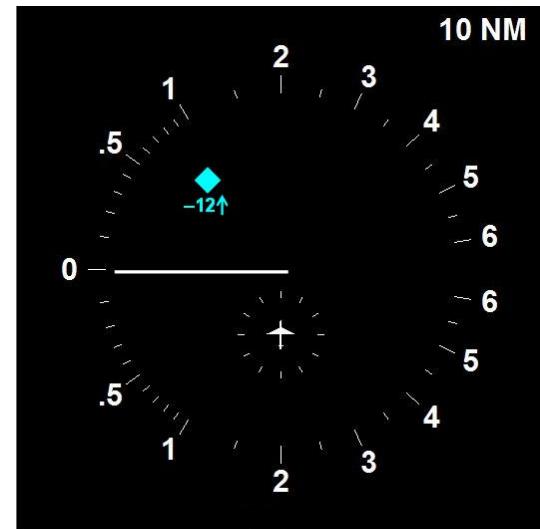
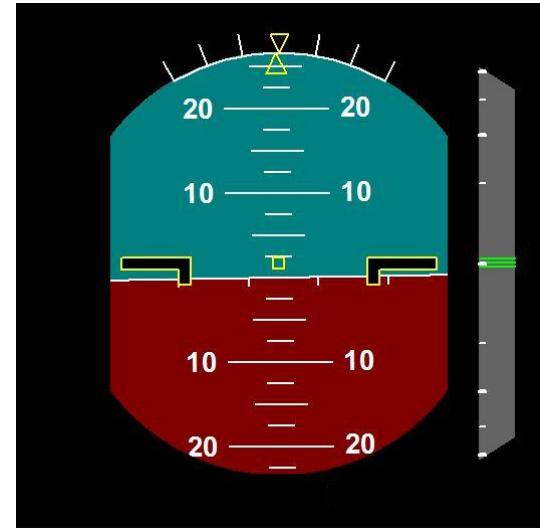
Note: Generic IVSI and pitch cue displays are shown.

Sequence of alerts:

1 – Proximate traffic detected

Required actions:

- None
- Situational awareness aid only

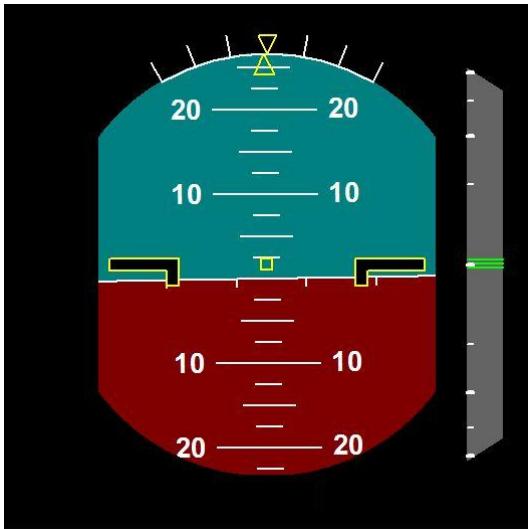


Sequence of alerts:

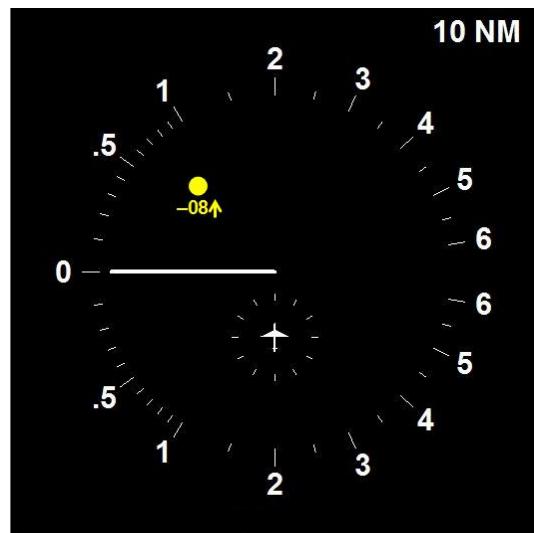
2 – TA

Required actions:

- Do not manoeuvre
- Try to acquire the other aircraft visually
- Prepare for a possible RA



Traffic, traffic

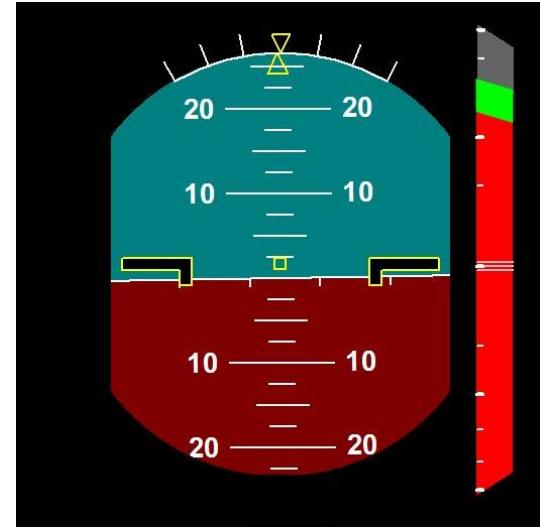


Sequence of alerts:

3 – First RA: Climb

Required actions:

- Establish climb rate of 1500-2000 ft/min.
- Report RA to ATC:
[callsign] TCAS RA
(pronounced Tee-Cas-Ar-Ay)
- Follow the RA even if there is a conflict between the RA and an ATC instruction to manoeuvre



Climb,
climb



Sequence of alerts:

4 – RA weakens

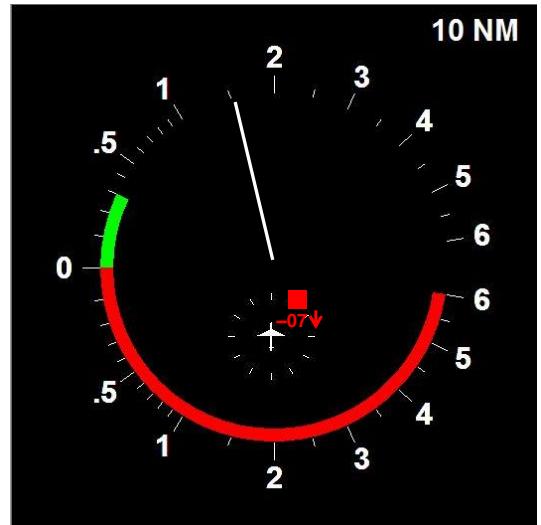
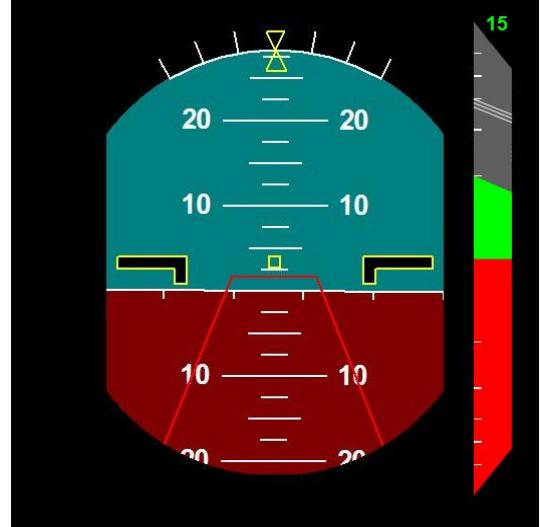
Required actions:

- Reduce vertical speed to 0 ft/min.

Version 7.0

 Version 7.1

Adjust vertical speed, adjust
 Level off, level off

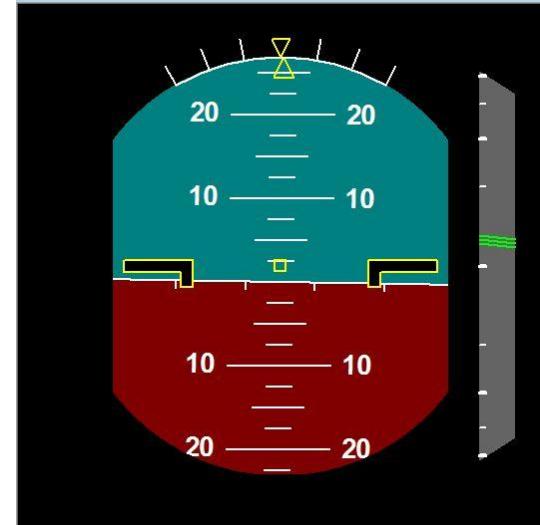


Sequence of alerts:

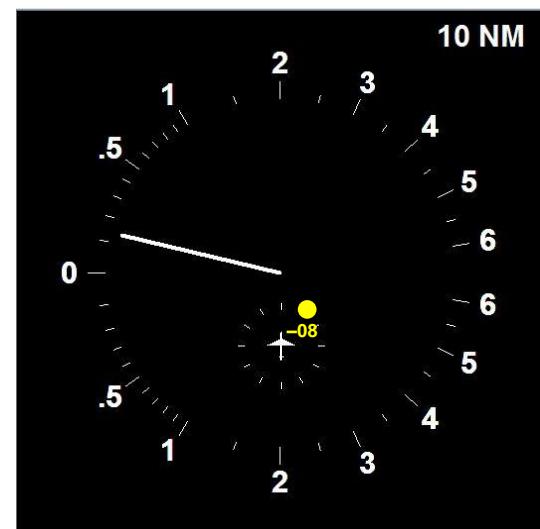
5 – Clear of Conflict

Required actions:

- Return to previous clearance
- Report resuming previous clearance to ATC:
[callsign] CLEAR OF CONFLICT (assigned clearance) RESUMED
- or
- [callsign] CLEAR OF CONFLICT, RETURNING TO (assigned clearance)**
- or
- Follow new ATC clearance



Clear of conflict



Real-life examples of encounters

- The following slides are based on real-life examples of encounters published in ACAS II Bulletins. These examples will:
 - Describe pilot actions
 - Discuss what kind of mistakes were made and how correct actions improved or could have improved the situation.

[Manoeuvres in opposite direction to the displayed RA](#)

[Misinterpretation of Adjust Vertical Speed RA](#)

[Correct response to Adjust Vertical Speed RA](#)

[Weakening Adjust Vertical Speed RA not followed](#)

[Climb RA at the maximum certified flight level](#)

[RAs against VFRs](#)

[Manoeuvring based on traffic display](#)

More examples of real-life encounters can be found in [EUROCONTROL ACAS II Bulletins](#).

Manoeuvres in opposite direction to the displayed RA

Due to ATC error, a B737 is cleared to climb to FL320 against an A330 that has been cleared to descend to FL310 on a conflicting track.

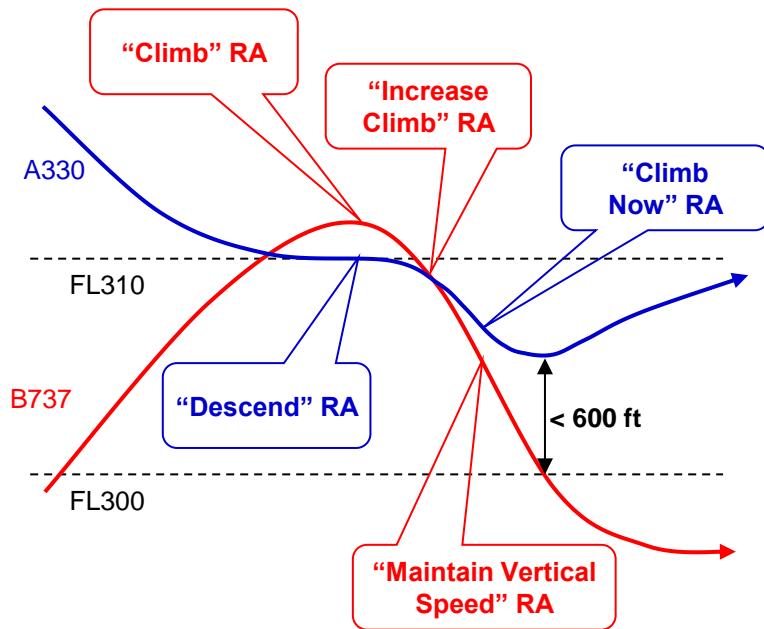
The controller issues late instructions, to the B737 to descend immediately to FL290 and to the A330 to climb immediately to FL320.

Simultaneously, both aircraft receive coordinated RAs: the A330 has a “Descend” RA and the B737 a “Climb” RA.

The A330 flight crew immediately informs the controller and initiates a descent whereas the B737 flight crew decides to ignore their “Climb” RA *“since [they] have intruding aircraft visual”*. Instead, they continue a steep descent while initiating an evasive turn.

The manoeuvre of the B737 in the opposite direction to the “Climb” RA forces both TCAS units to reverse the RA senses. As a result, the minimum distance is 0.9 NM at less than 600 ft according to radar data.

Simulations indicate that if the B737 flight crew had followed the “Climb” RA, the vertical distance would have been greater than 800 ft, and there would have been no reversal RAs nor subsequent altitude crossing.



Source: [ACAS Bulletin II no. 5](#)

Misinterpretation of Adjust Vertical Speed RA

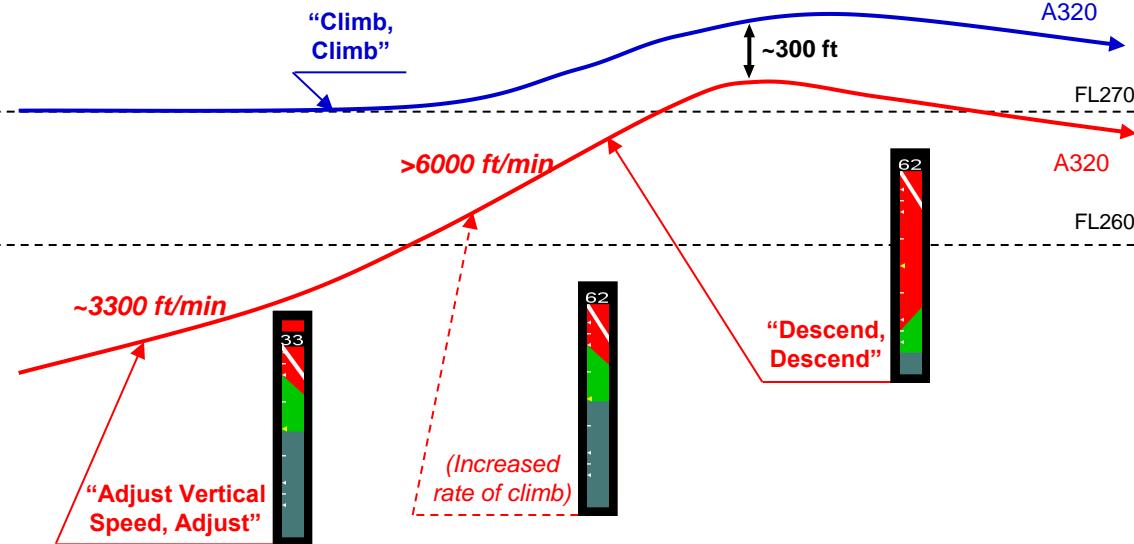
An A320 is level at FL270, heading south. Another A320 is cleared to climb to FL260, heading north. Its rate of climb is about 3300 ft/min. When passing through FL253, its TCAS triggers an initial “Adjust Vertical Speed” RA requiring a reduction in the rate of climb to 1000 ft/min.

However, the flight crew misinterprets the RA and reacts opposite to it: the rate of climb is increased to more than 6000 ft/min. instead of being reduced.

The closure rate increases between the two aircraft and the RA is strengthened to a “Descend” RA. The flight crew follows this second RA but the manoeuvre takes time to be effective.

As a result of the wrong reaction to the “Adjust Vertical Speed” RA, the climbing A320 busts its flight level by 1200 ft and the level A320 receives a “Climb” RA, which the flight crew follows. **The vertical distance is 300 ft with 0.8 NM.**

If the flight crew had correctly reduced the rate of climb as required by TCAS, simulations show that not only would the climbing A320 have been able to level off correctly, but that the A320 1000 feet above would not have received an RA.



Source: [ACAS Bulletin II no. 3](#)

Correct response to Adjust Vertical Speed RA

An A340 is descending from FL140 to FL120 with vertical speed of 1400 ft/min.

An A319 is climbing to FL110 with a high vertical speed (about 4000 ft/min.).

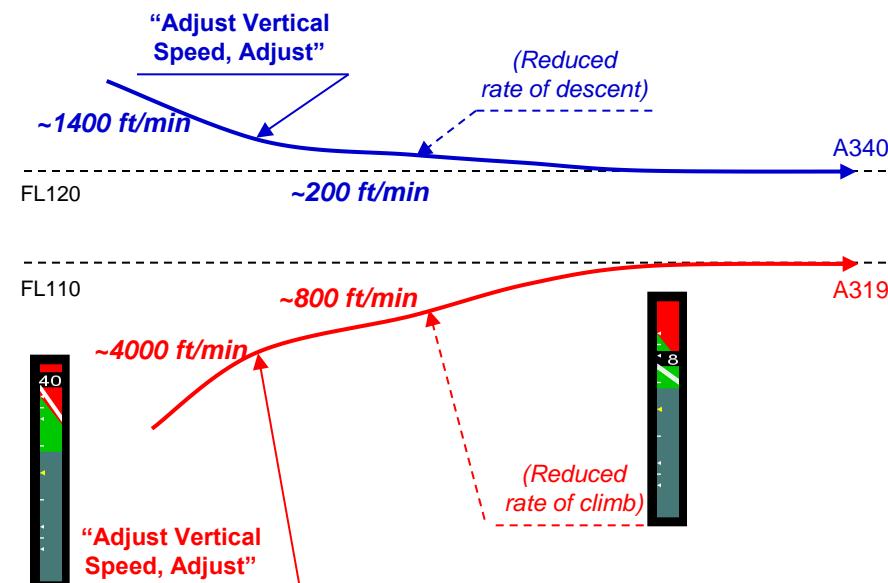
The aircraft are converging and expected to pass 0.1 NM apart but their cleared levels are 1000 ft apart.

The simultaneous horizontal and high rate of vertical convergence causes TCAS II to trigger "Adjust Vertical Speed" RAs before the aircraft have levelled off at their cleared flight levels:

- the A340 is required to reduce its rate of descent to 1000 ft/min.;
- the A319 is required to reduce its rate of climb to 2000 ft/min.

Both flight crews follow these RAs correctly, reducing their vertical speed below the maximum value required by TCAS II.

As a result, both aircraft continue to climb and descend with reduced vertical speeds. Then they level off at their cleared flight level; there is no disruption to ATC.



Source: [ACAS Bulletin II no. 3](#)

Weakening Adjust Vertical Speed RA not followed

A Fokker 100, cleared to descend to FL110, levels off at the cleared flight level.

A C182, on an opposite route, is cleared to climb to FL100. However, it busts its flight level by 700 ft before starting to descend back to FL100.

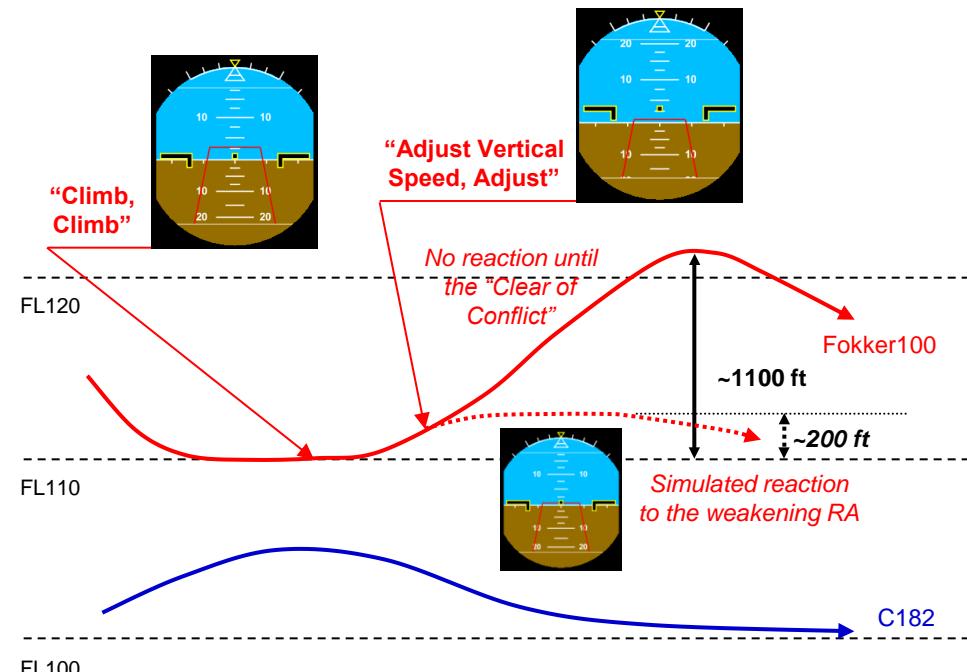
Due to the horizontal convergence and the small vertical distance between the aircraft, the Fokker 100 receives a “Climb” RA, which the flight crew follows.

10 seconds after the “Climb” RA, a weakening “Adjust Vertical Speed” RA is generated since a safe vertical distance has been achieved and the aircraft are diverging vertically.

However, the flight crew continues to climb and only stops climbing once the “Clear of Conflict” is issued.

This excessive deviation was unnecessary and resulted in a deviation of 1100 ft. Although not the case here, it could have generated a subsequent conflict.

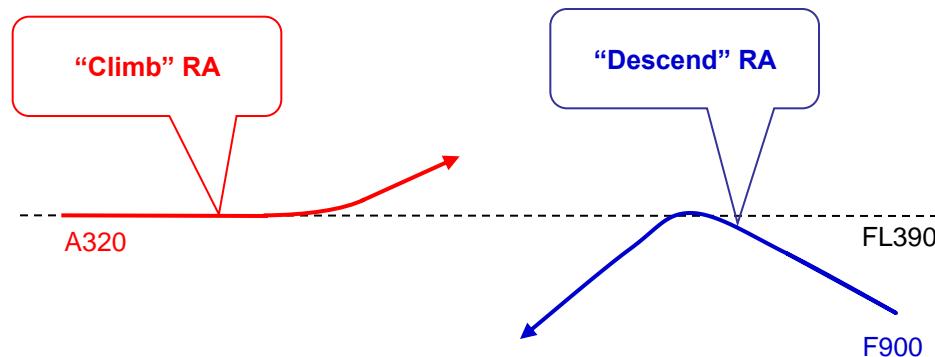
Simulations indicate that if the Fokker 100 flight crew had followed the weakening RA, the deviation would have been approximately 200 ft.



Source: [ACAS Bulletin II no. 3](#)

Climb RA at the maximum certified flight level

An A320 is cruising at FL390. A converging Falcon 900 is climbing to FL400 with a rate of climb requirement that will ensure separation from the A320. However, the F900 pilot unexpectedly informs the controller that the rate of climb cannot be maintained (due to an increase in air temperature).



Consequently, to resolve what has become a conflict, the controller issues appropriate instructions telling both aircraft to turn left 30 degrees. A few seconds later, despite complying with the turn instructions, both aircraft receive coordinated RAs: a "Climb" RA for the A320 and a "Descend" RA for the F900.

Although the A320 was at its maximum certified flight level and in the turn, the pilot follows the RA and starts to climb, achieving a 800 ft/min. climb rate. The F900 pilot responds to the RA as well and starts to descend. As a result of these manoeuvres, the aircraft pass at 1370 ft and 1.1 NM.

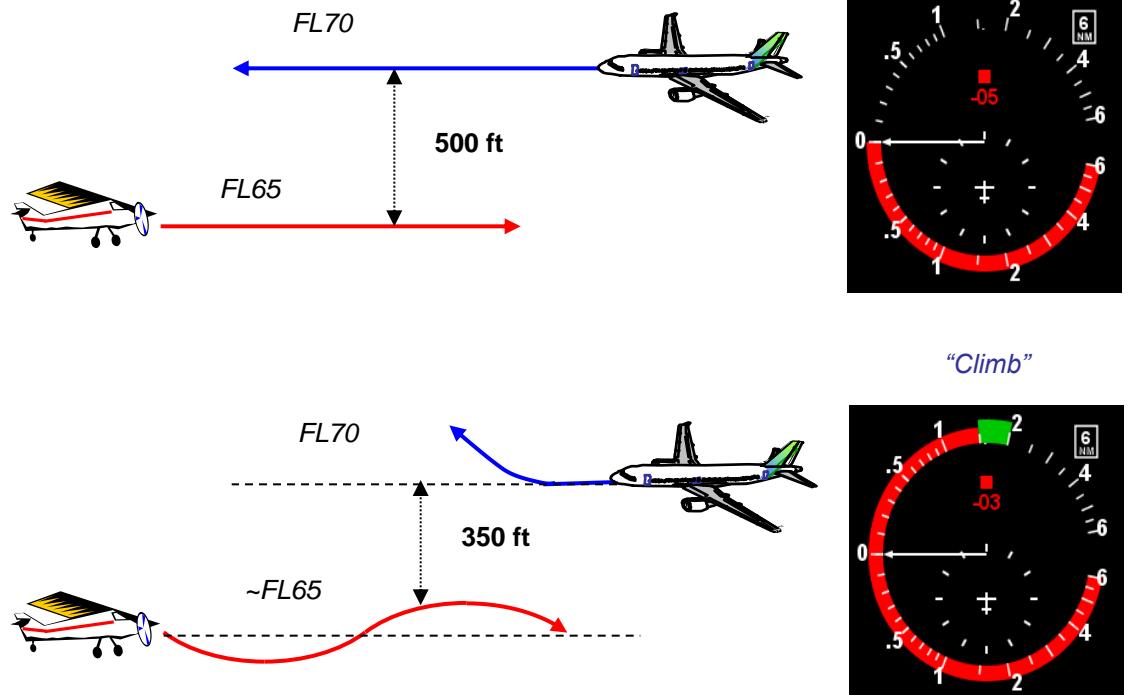
Source: [ACAS Bulletin II no. 8](#)

RAs against aircraft flying VFR

In the normal operating altitudes of VFR traffic, RAs will be caused if VFR traffic operates in the close proximity to IFR traffic with 500 ft separation.

Below 10,000 ft, in Class D or Class E airspace, encounters between IFR and VFR traffic frequently occur when both aircraft are level and separated by 500 ft. In these encounters, TCAS will generate a "Monitor Vertical Speed" RA, which does not require a vertical deviation.

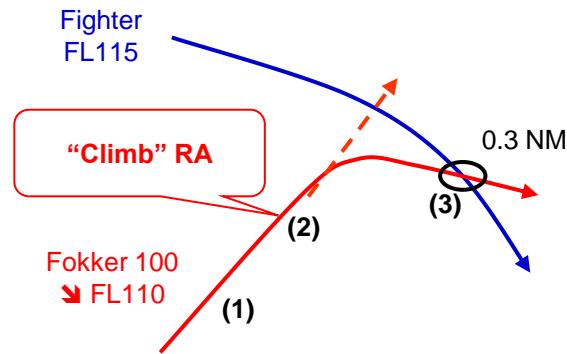
Operational experience shows that VFRs sometimes do not maintain their level flight perfectly. If there is a significant vertical deviation, "Climb" or "Descend" RAs will be generated on-board the TCAS-equipped aircraft.



Source: [ACAS Bulletin II no. 4](#)

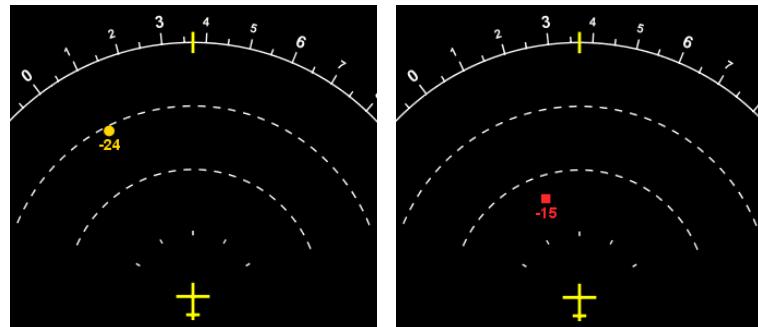
Manoeuvring based on traffic display

A Fokker 100 is descending to FL110. Its TCAS triggers a “Traffic Advisory” and then a “Climb” RA when passing FL130, against a fighter at FL115. The pilot correctly follows the RA and starts to climb.



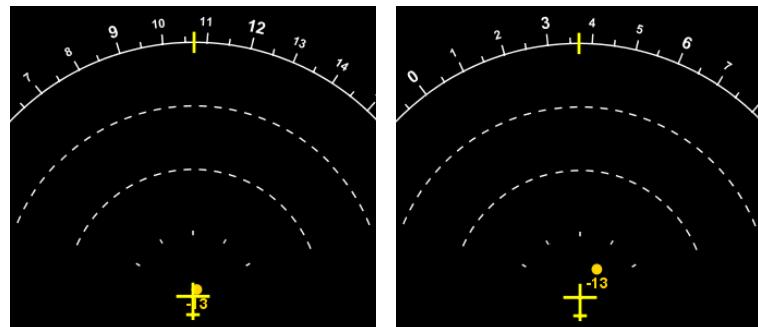
However, the pilot also initiates a 70-degree right turn based on the TCAS traffic display which shows the intruder on the left. The climb provides a safe vertical separation (more than 1000 ft) whereas **the right turn actually reduces the horizontal separation** from 1 NM to 0.3 NM.

Due to the relative motion of the symbol and the lack of speed vector on the TCAS traffic display, the flight crew incorrectly interpreted that the intruder was converging towards the own aircraft from the left on a bearing of 30 degrees. However, the ground track angle was about 90 degrees as shown on the figure above.



(1) “Traffic, Traffic”

(2) “Climb, Climb”



(3) “Clear of Conflict”

Projected fighter position
if no turn executed

Source: [ACAS Bulletin II no. 7](#)

FAQs (Frequently Asked Questions)

What is the difference between TCAS and ACAS?

How does ACAS II work if one aircraft is using the standard altimeter setting and the other QNH?

What is ACAS I (TCAS I)?

What is the frequency of RAs?

Is it required to follow an RA if the conflict aircraft is in sight?

Can aircraft equipped only with Mode A transponders be detected by TCAS II?

Can an RA be generated against an aircraft that is not TCAS II equipped?

Should RAs be ignored during closely spaced parallel approaches?

More FAQs available on the EUROCONTROL website: www.eurocontrol.int/acas

What is the difference between TCAS and ACAS?

TCAS (Traffic Alert and Collision Avoidance System) is a specific implementation of the ACAS (Airborne Collision Avoidance System) concept. TCAS II version 7.0 is currently the only available equipment that is fully compliant with the ACAS II Standards and Recommended Practices (SARPs).

ACAS II provides "Resolution Advisories" (RAs) in the vertical sense (direction) advising the pilot how to regulate or adjust his vertical speed so as to avoid a collision.

TCAS II Minimum Operational Performance Specification (MOPS) have been published by RTCA (DO-185B) and EUROCAE (ED-143).

How does ACAS II work if one aircraft is using the standard altimeter setting and the other QNH?

TCAS II always utilises pressure altitude information which relates to the standard pressure (altimeter setting 1013.25 hPa).

TCAS II operations are not affected if aircraft are flying Flight Levels on the standard pressure setting, altitude on QNH, or height on QFE as all always the same pressure source (i.e. standard) is used. The pressure selection by the flight crew does not affect the TCAS II system at all.

Additionally, below 1750 feet, ACAS also uses radio altimeter data.

What is ACAS I (TCAS I)?

ACAS I provides Traffic Advisories (TAs) but does not provide collision avoidance manoeuvre indications (RAs are not issued). Currently the only implementation of the ACAS I concept is TCAS I. ICAO Standards and Recommended Practices (SARPs) for ACAS I are published in ICAO Annex 10, volume IV and are limited to interoperability and interference issues with ACAS II. TCAS I Minimum Operational Performance Specification (MOPS) have been published by RTCA (DO-197A).

ACAS I is not mandated in Europe and there are no operational rules regarding the use of ACAS I. The main purpose of ACAS I is to aid pilots in acquiring threats visually; the collision avoidance manoeuvre direction is left to pilot's discretion. ACAS I operations cannot be coordinated with ACAS II.

What is the frequency of RAs?

It is estimated, through various monitoring programmes and data obtained from operators, that an RA occurs approximately every 1000 flight hours on short and medium haul aircraft. The number increases to 3000 hours for long haul aircraft.

The results of monitoring of core European airspace (conducted within the EUROCONTROL PASS project) showed that in 80% of encounters only one aircraft involved in the encounter received an RA. This was because the threat aircraft was not TCAS II equipped, or the geometry of the conflict was such that the RA was not generated on the TCAS-equipped threat aircraft, or the threat's TCAS was in TA-only mode. An RA encounter was observed every 2160 flight hours.

The most common observed RA was the Adjust Vertical Speed which amounted for 67% of all RAs, followed by the Climb (13%) and Descend (9%).

Is it required to follow an RA if the conflict aircraft is in sight?

Provisions of ICAO PANS-OPS (Doc. 8168) are very clear - in the event of a Resolution Advisory (RA), the pilot must respond immediately by following the RA unless doing so would jeopardize the safety of the aircraft.

That provision applies in all airspace classes and all meteorological conditions (i.e. VMC and IMC). If there is a conflict between the posted RA and an air traffic control (ATC) instruction, the RA must be followed and the ATC instruction ignored. The pilot must never manoeuvre in the opposite direction to an RA.

RAs will be triggered if TCAS calculates that there is a risk of collision between aircraft. The evaluation whether the RA was 'nuisance' can be done reliably in hindsight only. In real-time the pilot has little chance to assess whether the traffic acquired visually is in fact the one against which the RA has been generated.

Can aircraft equipped only with Mode A transponders be detected by TCAS II?

Aircraft equipped with Mode A transponders only are not tracked nor detected by ACAS II because ACAS II does not use Mode A interrogations. However, if the aircraft is equipped with Mode A/C transponder but does not provide altitude information (Mode C) this aircraft will be tracked as a non-altitude reporting target using range and bearing information and it will be shown on TCAS II traffic display. Neither a data tag nor a trend arrow will be shown for traffic symbol of an intruder that is not reporting altitude. TAs will be generated against non-altitude reporting aircraft when the range test for TA generation is satisfied. Non-altitude reporting aircraft are deemed to be at the same altitude as own aircraft.

Can an RA be generated against an aircraft that is not TCAS II equipped?

An RA can be generated against all aircraft equipped with an altitude reporting transponder (Mode S or Mode A/C). The intruder does not need to be fitted with TCAS II. However, RAs are coordinated only between TCAS II equipped aircraft.

Experience shows that in the majority of cases only one aircraft will receive an RA (regardless of whether the intruder is TCAS II aircraft or not).

Should RAs be ignored during closely spaced parallel approaches?

TCAS II should be operated in the TA/RA mode at all times. An aircraft operating in the TA-only mode is denied the benefit of collision avoidance. When TCAS TA/RA mode is selected, then the crew should follow an RA generated. Not to do so would not only deny own aircraft the safety benefit provided by the RA, but would also compromise the effectiveness of a coordinated RA generated on the other aircraft.

Even when closely-spaced parallel approaches procedures are correctly applied 'nuisance' RAs may occasionally occur. However, the safety benefit provided by ACAS takes precedence over an occasional 'nuisance' RA. Additionally, there is always a possibility that another aircraft will penetrate the approach airspace causing a real threat.

ICAO Provisions

[ICAO Doc. 8168 \(PANS-OPS\)](#)

[ICAO Doc. 4444 \(PANS-ATM\)](#)

[ICAO Doc. 9863 \(ACAS II Manual\)](#)

[Further sources of ICAO ACAS related provisions](#)

Doc. 8168 (1/4)

Airborne collision avoidance system (ACAS) indications shall be used by pilots in the avoidance of potential collisions, the enhancement of situational awareness, and the active search for, and visual acquisition of, conflicting traffic.

Doc. 8168, part VIII, para. 3.1.1

Pilots should use appropriate procedures by which an aeroplane climbing or descending to an assigned altitude or flight level, especially with an autopilot engaged, may do so at a rate less than 8 m/s (or 1 500 ft/min) throughout the last 300 m (or 1 000 ft) of climb or descent to the assigned altitude or flight level when the pilot is made aware of another aircraft at or approaching an adjacent altitude or flight level, unless otherwise instructed by ATC. These procedures are intended to avoid unnecessary airborne collision avoidance system (ACAS II) resolution advisories in aircraft at or approaching adjacent altitudes or flight levels. For commercial operations, these procedures should be specified by the operator.

Doc. 8168, part VIII, para. 3.3

Doc. 8168 (2/4)

Nothing in the procedures specified in 3.2 hereunder shall prevent pilots-in-command from exercising their best judgement and full authority in the choice of the best course of action to resolve a traffic conflict or avert a potential collision.

Note 1.— The ability of ACAS to fulfil its role of assisting pilots in the avoidance of potential collisions is dependent on the correct and timely response by pilots to ACAS indications. Operational experience has shown that the correct response by pilots is dependent on the effectiveness of initial and recurrent training in ACAS procedures.

Note 2.— ACAS II Training Guidelines for Pilots are provided in Attachment A to Part VIII.

Doc. 8168, part VIII, para. 3.1.2

Doc. 8168 (3/4)

The indications generated by ACAS shall be used by pilots in conformity with the following safety considerations:

a) pilots shall not manoeuvre their aircraft in response to traffic advisories (TAs) only;

Note 1.— TAs are intended to alert pilots to the possibility of a resolution advisory (RA), to enhance situational awareness, and to assist in visual acquisition of conflicting traffic. However, visually acquired traffic may not be the same traffic causing a TA. Visual perception of an encounter may be misleading, particularly at night.

Note 2.— The above restriction in the use of TAs is due to the limited bearing accuracy and to the difficulty in interpreting altitude rate from displayed traffic information.

b) on receipt of a TA, pilots shall use all available information to prepare for appropriate action if an RA occurs;

Doc. 8168, part VIII para. 3.2.a, b

Doc. 8168 (4/4)

In the event of an RA, pilots shall:

- 1) respond immediately by following the RA as indicated, unless doing so would jeopardize the safety of the aeroplane;

Note 1.—Stall warning, wind shear, and ground proximity warning system alerts have precedence over ACAS

Note 2.—Visually acquired traffic may not be the same traffic causing an RA. Visual perception of an encounter may be misleading, particularly at night.

- 2) follow the RA even if there is a conflict between the RA and an air traffic control (ATC) instruction to manoeuvre;

- 3) not manoeuvre in the opposite sense to an RA;

Note.—In the case of an ACAS-ACAS coordinated encounter, the RAs complement each other in order to reduce the potential for collision. Manoeuvres, or lack of manoeuvres, that result in vertical rates opposite to the sense of an RA could result in a collision with the threat aircraft.

- 4) as soon as possible, as permitted by aircrew workload, notify the appropriate ATC unit of any RA which requires a deviation from the current air traffic control instruction or clearance;

Note.—Unless informed by the pilot, ATC does not know when ACAS issues RAs. It is possible for ATC to issue instructions that are unknowingly contrary to ACAS RA indications. Therefore, it is important that ATC be notified when an ATC instruction or clearance is not being followed because it conflicts with an RA.

- 5) promptly comply with any modified RAs;

- 6) limit the alterations of the flight path to the minimum extent necessary to comply with the RAs;

- 7) promptly return to the terms of the ATC instruction or clearance when the conflict is resolved; and

- 8) notify ATC when returning to the current clearance.

Note.—Procedures in regard to ACAS-equipped aircraft and the phraseology to be used for the notification of manoeuvres in response to a resolution advisory are contained in the PANS-ATM (Doc 4444), Chapters 15 and 12, respectively.

Doc. 8168, part VIII para. 3.2.c

Doc. 4444 (1/3)

When a pilot reports an ACAS resolution advisory (RA), the controller shall not attempt to modify the aircraft flight path until the pilot reports “Clear of Conflict”.

Doc. 4444, para. 15.6.3.2

Doc. 4444 (2/3)

Once an aircraft departs from its ATC clearance or instruction in compliance with an RA, or a pilot reports an RA, the controller ceases to be responsible for providing separation between that aircraft and any other aircraft affected as a direct consequence of the manoeuvre induced by the RA. The controller shall resume responsibility for providing separation for all the affected aircraft when:

- a) the controller acknowledges a report from the flight crew that the aircraft has resumed the current clearance; or
- b) the controller acknowledges a report from the flight crew that the aircraft is resuming the current clearance and issues an alternative clearance which is acknowledged by the flight crew.

Note.— Pilots are required to report RAs which require a deviation from the current ATC clearance or instruction (see PANS-OPS, Volume I, Part III, Section 3, Chapter 3, 3.2 c) 4)). This report informs the controller that a deviation from clearance or instruction is taking place in response to an ACAS RA.

Doc. 4444 (3/3) – RA phraseology

... after a flight crew starts to deviate from any ATC clearance or instruction to comply with an ACAS resolution advisory (RA) (Pilot and controller interchange):

PILOT: **TCAS RA;**

ATC: **ROGER;**

... after the response to an ACAS RA is completed and a return to the ATC clearance or instruction is initiated (Pilot and controller interchange):

PILOT: **CLEAR OF CONFLICT, RETURNING TO (assigned clearance);**

ATC: **ROGER (or alternative instructions);**

... after the response to an ACAS RA is completed and the assigned ATC clearance or instruction has been resumed (Pilot and controller interchange):

PILOT: **CLEAR OF CONFLICT (assigned clearance) RESUMED;**

ATC: **ROGER (or alternative instructions);**

... after an ATC clearance or instruction contradictory to the ACAS RA is received, the flight crew will follow the RA and inform ATC directly (Pilot and controller interchange):

PILOT: **UNABLE, TCAS RA;**

ATC: **ROGER;**

Doc. 9863 - Airborne Collision Avoidance System (ACAS) Manual (1/2)

5.2.1.14 If an RA manoeuvre is inconsistent with the current ATC clearance, pilots shall follow the RA.

5.2.3. The following ACAS good operating practices have been identified during the use of ACAS throughout the world.

5.2.3.1 To preclude unnecessary transponder interrogations and possible interference with ground radar surveillance systems, ACAS should not be activated (TA-only or TA/RA mode) until taking the active runway for departure and should be deactivated immediately after clearing the runway after landing. To facilitate surveillance of surface movements, it is necessary to select a mode in which the Mode S transponder can nevertheless squitter and respond to discrete interrogations while taxiing to and from the gate. Operators must ensure that procedures exist for pilots and crews to be able to select the operating mode where ACAS is disabled, but the Mode S transponder remains active.

Doc. 9863 - Airborne Collision Avoidance System (ACAS) Manual (2/2)

5.2.3.2 During flight, ACAS traffic displays should be used to assist in visual acquisition. Displays that have a range selection capability should be used in an appropriate range setting for the phase of flight. For example, use minimum range settings in the terminal area and longer ranges for climb/descent and cruise, as appropriate.

5.2.3.3 The normal operating mode of ACAS is TA/RA. It may be appropriate to operate ACAS in the TA-only mode only in conditions where States have approved specific procedures permitting aircraft to operate in close proximity or in the event of particular in-flight failures or performance limiting conditions as specified by the Aeroplane Flight Manual or operator. It should be noted that operating in TA-only mode eliminates the major safety benefit of ACAS.

5.2.3.3.1 Operating in TA/RA mode and then not following an RA is potentially dangerous. If an aircraft does not intend to respond to an RA and operates in the TA-only mode, other ACAS-equipped aircraft operating in TA/RA mode will have maximum flexibility in issuing RAs to resolve encounters.

Further sources of ICAO ACAS related provisions

- Annex 6 part I and part II
- Annex 10 vol. 4
- Doc 7030 (Regional and Supplementary Procedures)

These documents as well as the documents referred to earlier in this presentation can be obtained from ICAO and national regulatory authorities.

Relevant extracts of ICAO documents can be found on the EUROCONTROL ACAS website www.eurocontrol.int/acas

Additional training resources

[EUROCONTROL training publications](#)

[EUROCONTROL ACAS II Bulletins](#)

[RITA2 training tool](#)

Additional training resources (1/3)

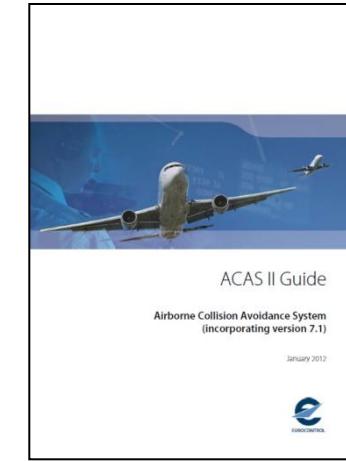
EUROCONTROL training publications



TCAS II version 7.1 for pilots
(presentation)



TCAS II version 7.1 for air traffic
controllers (presentation)

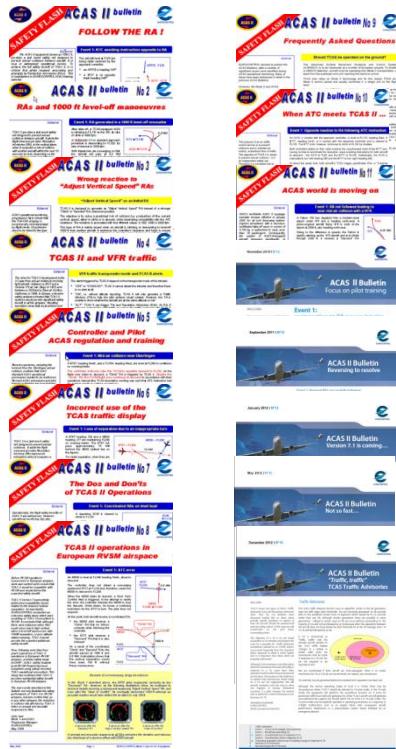


ACAS II Guide (incorporating
version 7.1)

Available from www.eurocontrol.int/acas and www.skybrary.aero

Additional training resources (2/3)

EUROCONTROL ACAS II Bulletins



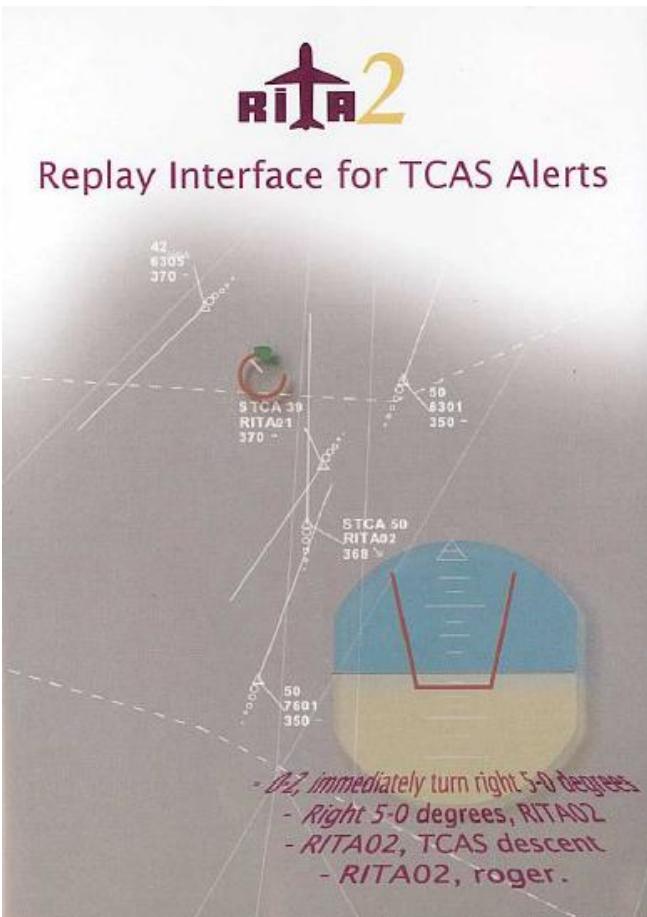
1 - Follow the RA! (July 2002)	9 - Frequently Asked Questions (July 2007)
2 - RAs and 1000 ft level-off manoeuvres (March 2003)	10 - When ATC meets TCAS II (November 2007)
3 - Wrong reaction to "Adjust Vertical Speed" RAs (October 2003)	11 - ACAS world is moving on (May 2010)
4 - TCAS II and VFR traffic (May 2004)	12 - Focus on pilot training (February 2011)
5 - Controller and Pilot ACAS regulation and training (October 2004)	13 - Reversing to resolve (September 2011)
6 - Incorrect use of the TCAS traffic display (March 2005)	14 - Version 7.1 is coming (January 2012)
7 - The Dos and Don'ts of TCAS II Operations (March 2006)	15 - Not so fast... (May 2012)
8 - TCAS II Operations in European RVSM Airspace (May 2006)	16 - "Traffic, traffic" - TCAS Traffic Advisories (December 2012)

The information contained in the EUROCONTROL ACAS II Bulletins is accurate at the time of publishing but is subject to change.

All EUROCONTROL ACAS II Bulletins are available from:
www.eurocontrol.int/acas and www.skybrary.aero

Additional training resources (3/3)

RITA2 training tool



- RITA2 is a PC-based training tool
- Playback of real events
 - ATC view
 - Flight crew instrument view
 - Radio communications transcript
- [RITA 2 Leaflet](#)
- Available to qualified Stakeholders on request:
acas@eurocontrol.int
 Please state your postal address as a CD will be sent by regular mail

Note: RITA2 scenarios do not include version 7.1 cases

Questions?

Need more information?

www.eurocontrol.int/acas

 acas@eurocontrol.int