Low Altitude RA Virtual Pilot Tabletop

Preliminary Results Summary

Presented to RTCA SC-147 – Low Altitude RA Tiger Team

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Background

- Primary Objective: Collect pilot feedback on current and proposed ACAS Xa low altitude RA behavior

- Format: virtual tabletop session via Teams; lasted ~4 hours per session
  - Held 5 sessions with 12 pilots total
  - Session started with quick overview of objectives and ACAS Xa explainer
    - Included details on current & proposed RA altitude inhibits
      - 900’ vs 500’ on approach; 1100’ vs 400’ on departure
  - Presented 11 unique scenarios (7 approach, 1 go around, 2 departure, 1 ‘enhanced TA’)
    - Short questionnaire and 2 open-ended discussion questions followed each scenario
  - Semi-structured debrief held at end of session
    - Collected overall impressions of low altitude behavior

Scenario Overview

						ACAS Xa Alert Progression		
Scenario	Phase	Inhibit Alt.	Ownship Alt.	Intruder Alt.	Description	1st Alert	2nd Alert	3rd Alert
A1	Approach	900’	2000’	1000’	Nominal intruder with current inhibits	TA at 1600’	**Climb RA** at 1500’	
A2	Approach	900’	1500’	500’	Low altitude intruder with current inhibits	TA at 990’		
A3	Approach	500’	1500’	500’	Low altitude intruder with proposed inhibits	TA at 1000’	**Climb RA** at 750’	
A4	Approach	900’	2000’	1100’	Descend RA on approach with current inhibits	TA at 1200’	**Descend RA** at 1100’	**MVS RA** at 1000’
A5	Approach	500’	2000’	1100’	Descend RA on approach with proposed inhibits	TA at 1200’	**Descend RA** at 1100’	**MVS RA** at 1000’
A6	Approach	900’	2000’	700’	Climb RA on approach suppressed by altitude inhibit	TA at 1100’	**Climb RA** at 950’	
A7	Approach	900’	2000’	700’	Same as A6, but applying ‘hysteresis’ to Climb RA	TA at 1100’	**Climb RA** at 950’	
A8	Go-Around	400’	300’	1300’	Level Off RA issued following go-around	TA at 250’	**LO RA** at 500’	
D1	Departure	1100’	300’	1800’	Level Off RA issued on departure with current inhibits	TA at 900’	**LO RA** at 1100’	
D2	Departure	400’	300’	1200’	Level Off RA issued on departure with proposed inhibits	TA at 300’	**LO RA** at 600’	
E1	Approach	900’	1500’	500’	‘Enhanced’ TA aural alert issued on approach with current inhibits	TA at 850’		

Scenarios & Format

- Depicted encounters were **not** exhaustive or exact – intruder position/vertical rate was notional and may, in the real-world, have resulted in different alerting
  - Tried to avoid diving into whether specific intruder geometry would have resulted in certain type of alert
  - Focus instead on fostering understanding of nuances of low altitude behavior

- Assumed VMC for all scenarios and that conflicting aircraft was unequipped with TCAS/ACAS and will otherwise not react to the conflict
  - Intruder is equipped with ADS-B, providing improved range/bearing information and directionality

Approach Scenario 3 (A3)

- RA Inhibit Threshold: **Proposed** reduction to 500’ AGL
- Distance from Airport: 4.7 nmi
- Altitude: 1500’ AGL
- Traffic display: 1000’ below at about 2 o’clock

Scenario A3 – *Proposed* Inhibits

Situation Perspective

N123FG	Descending on instrument approach Tfc 1000 ft below
MBA Tower	N123FG has been cleared to land
Time to CPA	00:01:00

2000 ft

N123FG
1500’ | 145 kts
↓ 760 FPM

1000 ft

Descend RAs inhibited

N123FG VSI

500 ft

All RAs inhibited

Scenario A3 – *Proposed* Inhibits

Situation Perspective

N123FG	**TRAFFIC ADVISORY** is triggered
MBA Tower	N123FG has been cleared to land
Time to CPA	00:00:25

2000 ft

1000 ft

500 ft

Descend RAs inhibited

All RAs inhibited

TRAFFIC, TRAFFIC

N123FG VSI

N123FG
800’ | 145 kts
↓ 760 FPM

Scenario A3 – *Proposed* Inhibits

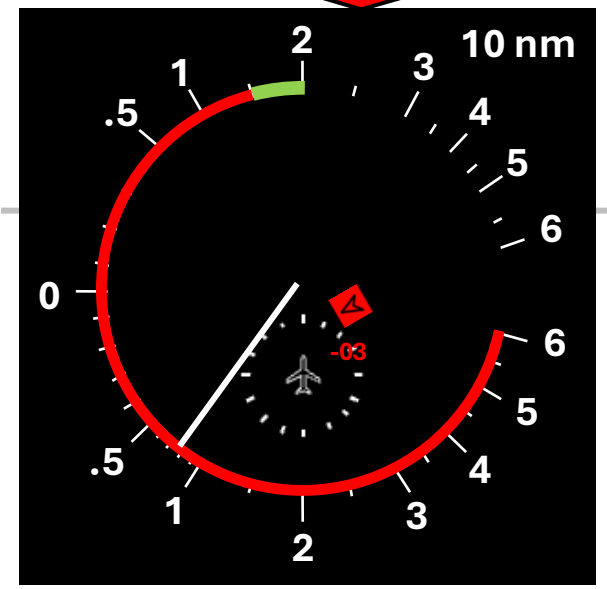
Situation Perspective

N123FG	The TA has upgraded to a **RESOLUTION ADVISORY**
MBA Tower	N123FG has been cleared to land
Time to CPA	00:00:15

2000 ft

1000 ft

CLIMB, CLIMB



N123FG VSI

Descend RAs inhibited

500 ft

N123FG
600’ | 145 kts
↓ 760 FPM

All RAs inhibited

Scenario A3 – *Proposed* Inhibits

Situation Perspective

N123FG	PF disengages AP and executes 1600 fpm climb PM informs Tower climbing in response to an RA
MBA Tower	Aware of N123FG maneuvering for traffic
Time to CPA	00:00:10

2000 ft

1000 ft

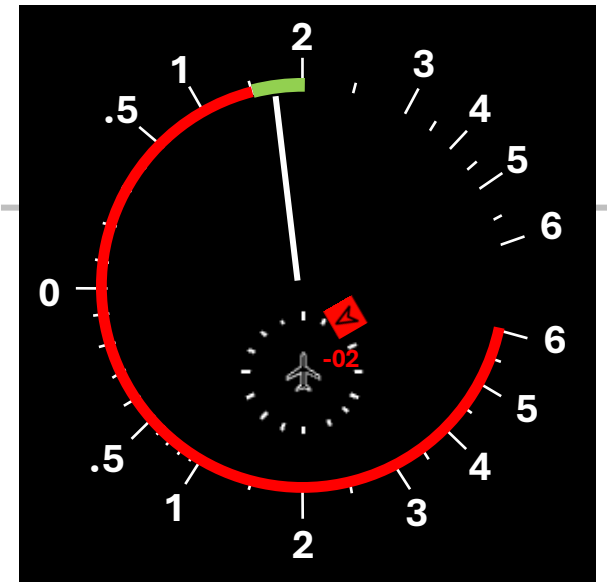
Descend RAs inhibited

"N123FG maneuvering for RA"

500 ft

All RAs inhibited

N123FG
500' | 145 kts
↑ 1600 FPM



N123FG VSI

Scenario A3 – *Proposed* Inhibits

Situation Perspective

N123FG	ACAS Xa announces “Clear of Conflict”
MBA Tower	N123FG has avoided the traffic
Time to CPA	N/A

2000 ft

1000 ft

500 ft

N123FG
1500’ | 145 kts
↑ 1600 FPM

Descend RAs inhibited

“N123FG clear of traffic”

All RAs inhibited

Clear of Conflict

N123FG VSI

Results

- Pilot demographics
- Post-scenario questionnaire responses
- Post-scenario open-ended responses
- Post-tabletop questionnaire responses
- Post-tabletop open-ended responses

Demographics

- 12 active airline/business jet pilots
  - Age range: 27 to 73 years (51 years old avg.)
    - 9 male, 3 female
  - Most were US-based; some with international experience; 1 Airbus pilot

- 126,000 total flight hours across all pilots (10,500 hours/pilot)
  - Min: 1,520 hours
  - Max: 22,820 hours

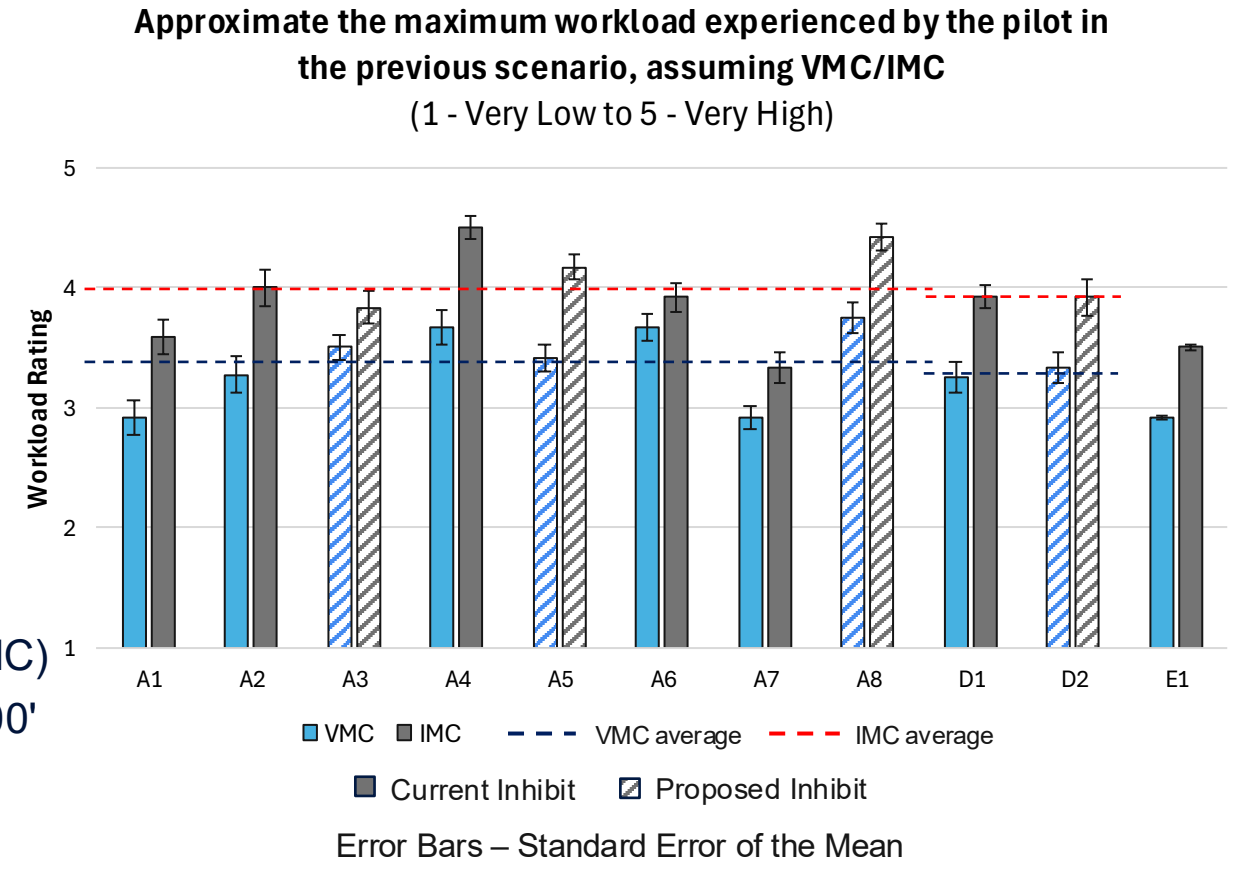
- 11 of 12 pilots self-rated as Familiar to Very Familiar with TCAS II
  - 1 rated as Slightly Familiar
  - Avg. 8,000 flight hours with TCAS II
    - Min: 731 hours
    - Max: 20,000 hours
  - 8 of 12 had experienced an RA in flight before

Post Scenario Questionnaire Responses - Workload

- Workload across all scenarios was rated as moderate to high
  - Workload scores on average 17.8% higher in IMC vs VMC

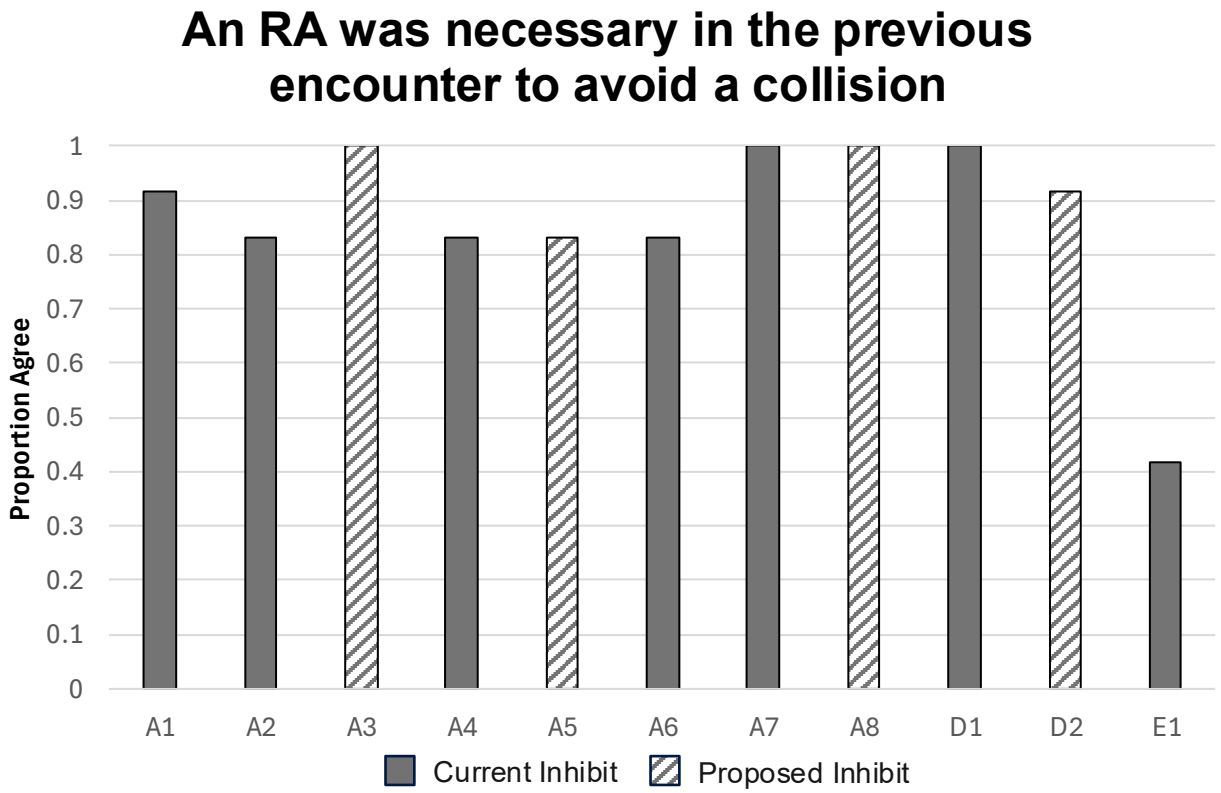
- Workload scores increase with proposed inhibits
  - Approach Scenarios
    - +8.14% (VMC), +7.04% (IMC)
  - Departure Scenarios
    - +2.56% (VMC), +0% (IMC)

- Above-average (> 1 SE above mean) workload scenarios
  - A4 - Current Inhibit – Descend RA at 1100’
  - A5 - Proposed Inhibit – Descend RA at 1100’ (IMC)
  - A6 - Current Inhibit – Shortened Climb RA at 950’ (VMC)
  - A8 – Proposed Inhibit – LO RA during go-around at 500'



- Across all scenarios, pilots reported **unanimously** that they would have followed the RA as described and depicted.

- Pilots largely agreed that in the scenarios presented, an RA would have been necessary to avoid a collision.
  - Sanity check of scenarios
  - Study based around what we intended to be legitimate alerts



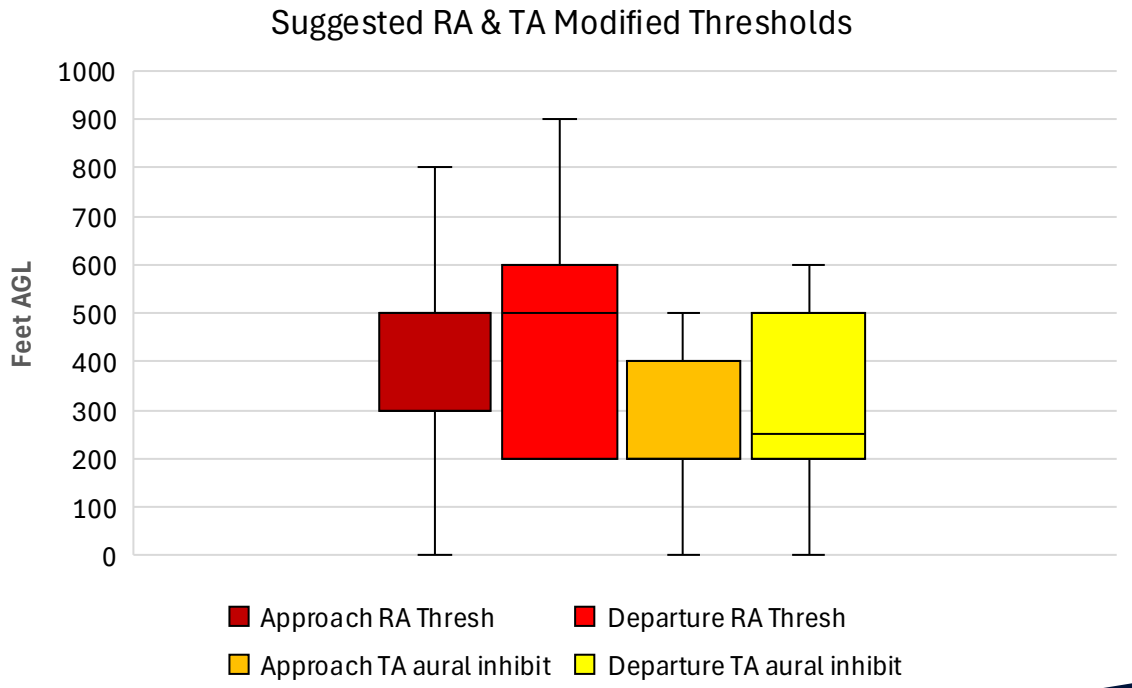
Post Tabletop Questionnaire Responses

- When asked if the RA inhibit altitudes should be maintained at TCAS II levels or modified, **all 12 pilots** responded they should be modified.

- Pilot responses when asked what the modified RA and TA aural inhibit altitudes should be:
  - *Note: 1 pilot did not provide recommended altitudes, and several others expressed concern that they did not have enough information to provide a useful recommendation*

Response Frequency Table

	RA inhibit		TA aural inhibit	
Altitude	Approach	Departure	Approach	Departure
900'	0	1	0	0
800'	1	1	0	0
600'	0	2	0	2
500'	7	4	1	2
400'	0	0	2	1
300'	2	0	1	1
250'	0	0	1	0
200'	0	3	5	4
100'	0	0	0	1
0'	1	0	1	1



Post Tabletop Open-Ended Responses

- Main concerns with maintaining the **current** RA inhibit altitudes
  - Not receiving RA protection at lower altitudes, which can result in severe mishaps
    - Pilots consider low altitude traffic as only becoming more relevant with increases in VTOL/UAM-like operations
  - Currently unclear when/how the systems switches into TA Only mode
    - TA Only mode is not salient enough; not clear to the pilots that an RA *cannot* be produced
    - If no changes are made, pilots believe training needs to be improved
  - Given training to *not* respond to TAs, losing an active RA as you travel below the cutoff altitude gives the impression you are now safe/do not need to respond any longer
    - Allowing the RA to stay active, despite transition below cutoff altitude, was recommended

Post Tabletop Open-Ended Responses

- Main concerns with **modifying/lowering** the RA inhibit altitudes
  - Added nuisance/unwanted alerts – would add workload and degrade trust in system over longer term
    - Losing trust in TCAS/ACAS would be “a disaster”
    - RAs can distract from landing the aircraft (echoes comments in 1989 LIP report)
  - General consensus that the inhibits “gotta be lowered” but lack of strong opinion on where (or how) to determine a new altitude
    - Majority of pilots recommended thresholds of 200-500’ given the need for time/room to maneuver
      - Below 200’ on approach would substantially increase workload for go arounds
    - Several pilots did feel strongly that they should be as low as possible, potentially down to the surface
    - The above assumes nuisance alerts would not be significantly increased with ACAS Xa
      - Pilots recommended further study (fast-time analyses, HITLs, etc.) to more effectively determine impact on alert rate and workload
  - Workload, generally, from lowering RA threshold was **not** a direct concern reported by the pilots
    - Made it clear that an RA to a genuine collision threat overrode any workload constraints upon landing

Post Tabletop Open-Ended Responses

- Alternatives/additional input on changes to ACAS Xa and other airspace elements
  - Make TA Only mode more salient
  - More hands-on training on TAs/RAs at lower altitudes/in more dynamic situations
  - Introduction of Horizontal RAs (mixed reception with pilots)
  - Incorporating Airbus behavior where auto-pilot avoids maneuvers/vspeeds that would cause an RA
  - Showing ADS-B info on the ACAS display
  - Closer look at areas/airports with frequent alerts/close calls
  - Issue an earlier type of alert to avoid onset of RA/severe maneuvers needed for RAs
  - Improve ATC traffic calls – can be hard to discern genuine traffic issues being flagged vs nuisances

- Additional scenarios to consider for future tabletop/HITL studies
  - Parallel approaches
  - Alerts against properly/safely spaced intruders (i.e., nuisance alerts)
  - Conflicts even lower to the ground (below 500’ AGL)

Main Takeaways

- Pilots were unanimously in favor of lowering the RA threshold, if it can be done without drastically increasing rate of nuisance RAs
  - All agreed additional work/investigation was necessary to ultimately determine if a change was viable
- Workload at lower altitudes was not a major concern noted by the pilots
- Current system needs improvement – TA Only mode is not well understood or conveyed

Limitations

- Tabletop itself was framed as a response to the DCA crash, so pilots were extra sensitive to the benefits of providing alerts at lower altitudes
- Pilots were recruited with convenience sampling; not necessarily representative
- Scenarios were biased towards approach conditions and alerts against legitimate traffic threats
  - No nuisance alert scenarios
- Scenarios were very low fidelity and required speculation from the pilots
  - Scenarios did not directly exercise ACAS Xa logic
  - Pilots were reacting to what they would hypothetically do in a situation
  - Format meant some pilots may have been less engaged and/or disinclined to offer contrary opinions during open ended discussion

Next Steps

- Support incorporation of this data into tiger team white paper (if desired)
- If committee moves forward with recommending lowering/modification of RA inhibit altitudes, investigate possible pilot-in-the-loop simulation & coordinate the design with this group