Interoperability of Airborne Collision Avoidance Systems

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Review of Airborne Collision Avoidance systems

- Traffic Alert and Collision Avoidance System (TCAS) on aircraft since 1980s

- Datalink (ADS-B) based conflict detection system proposed
  - Airborne Conflict Management (ACM)
  - Currently being evaluated in operational tests by UPS/FAA
    - Leapfrog TCAS requirement for cargo airlines
  - Initial specifications & design issues being investigated by RTCA subcommittee

- Will the two systems operate harmoniously?
Conflict between Multiple Alerting Systems

Dissonance may occur whenever a given state maps into two different alert stages or two different resolution commands or when the time-derivatives of these mappings differ.
TCAS---Traffic Alert and Collision Avoidance System

- Designed to alert flight crews to potential mid-air collisions
- Range, range rate, altitude and altitude rate between two aircraft available through radar
- Includes TA (Traffic Advisories) and RA (Resolution Advisories)
  - TAs direct the crew’s attention to a potential threat, but no avoidance information is provided
  - RAs provide avoidance commands such as “Climb” or “Descend”
- Maximum look ahead limited by lack of good trajectory information (~30 seconds)
Graphical Relationship Viewed from Above (TCAS)

- Alert Based on estimated time to reach DMOD separation

At level 5
Altitude: 9500ft-20500ft
DMOD_TA=0.75 nmi
DMOD_RA=0.55 nmi
Tau_TA=40s
Tau_RA=25s
ACM---Airborne Conflict Management

- The state vector and intent available through ADS-B (data link-based)
  - Improved trajectory information (velocity vector, way points, etc.)
  - Enable longer look ahead than TCAS
  - Enable new procedures (in-trail spacing) using enhanced display

- Basic assumptions of ACM
  - ACM will function properly during other applications such as visual approach or approach spacing
  - ACM will be installed on A/C with TCAS as well as A/C without TCAS
Graphical Relationship Viewed from Above (ACM)

Protected Aerospace Zone (PAZ) alert threshold

Collision Avoidance Zone (CAZ)

RTCA proposed thresholds:
PAZ: <2min to 3NM separation
CAZ: <1min to 0.15NM separation
ACM/TCAS Interoperability Amongst Aircraft

- “Interoperability” refers to the successful, simultaneous of the two systems

- Operation of TCAS will not be changed (ACM is an add-on similar to EGPWS)

- TCAS and ACM surveillance information are different
  - TCAS measures relative range and bearing
  - ACM receives the broadcast state vector and intent

- Any possible relationship and interdependence between ACM TCAS must be investigated
ACM and TCAS Installed on Same Aircraft

- In an integrated TCAS/ACM system, it is important to display one real-time target for each actual aircraft.

- It’s been proposed by RTCA that an alert will be presented to crew when issued by either system until there is no alert by system.

- The information and advisories generated by the ACM and should not conflict with each other, or cause pilot confusion.

- Need to prevent dynamic conflict between ACM and TCAS:
  - TCAS → ACM
  - ACM → TCAS
ACM on One Aircraft and on the Other

- Both aircraft can detect each other with their respective ADS-B available on both aircraft, but different systems may be issuing resolution advisories.

- Problem exists if the systems issue incompatible resolutions.

- An analysis must be performed to determine if there is a significant probability that the ACM would issue resolution advisories incompatible with TCAS advisories.

- An analysis must be performed to prevent dynamic conflict between ACM and TCAS.
  - ACM on one aircraft ➔ TCAS on another aircraft
  - TCAS on one aircraft ➔ ACM on another aircraft
Unresolved Issues in the Integration of TCAS and ACM

- **TCAS/ACM Conflict Alert Integration**
  - Does the crew need to know which system is generating the alert?
  - How to handle ACM alert which becomes TCAS alert? (& vice-versa)
  - Will TCAS alert when ACM says there is no problem?

- **TCAS/ACM Resolution Integration**
  - How much coordination is required between systems installed on the plane, or on conflicting aircraft?
  - What is the goal of PAZ Resolution Advisories?
    - To maximize miss distance
    - To get out of PAZ as soon as possible
    - To minimize the likelihood of TCAS alert
Scaled TCAS and ACM Logic

- Both aircraft opposite direction at 300 knots each.
Required Minimum Maneuver to Avoid TCAS Alert following ACM Alert (Turn)

Model: Opposite direction aircraft at the same altitude
With 200 knots for each aircraft

\[
\begin{align*}
\psi & \text{ Heading} \\
\phi & \text{ Bank Angle} \\
\tau & \text{ Time Delay}
\end{align*}
\]
Turning Maneuver for PAZ to Avoid TCAS TA
Turning Maneuver for PAZ to Avoid TCAS RA
Turning Maneuver for CAZ to Avoid TCAS Alert

![Graph showing required heading vs bank angle for different delays (0s, 5s, 10s) for TA and RA.](graph.png)
Required Minimum Maneuver to Avoid TCAS Alert following ACM Alert (Climb)

**Model:** Opposite direction aircraft at the same altitude with 200 knots for each aircraft
Climb Maneuver for PAZ to Avoid TCAS Alert

Required Climb Rate (ft/min) vs. Load Factor ($g$) for 0s, 10s, and 20s delay for TA and RA.
Climb Maneuver for CAZ to Avoid TCAS RA

To avoid TCAS TA

Need 1.6g load factor with Clime Rate=2500 fpm and 0s delay

Required Climb Rate (ft/min)

*g (Load Factor ft/s^2)
Summary

- Initial suggestions for PAZ & CAZ dimensions do not appear to allow responding to ACM alert without later receiving a TCAS (must be aggressive)
  - Longer look ahead would reduce required maneuver but increase alert rate
  - Does it make sense that CAZ alert nearly always becomes a TCAS alert

- Potential for TCAS False Alarm with no ACM alert
  - Worse as closure rate increases

- Future Objectives
  - TCAS alert affect ACM alert needs to be examined
  - Apply the formal model to the analysis of TCAS/ACM