ACAS on VLJs and LJs – Assessment of safety Level (AVAL)

Outcomes of the AVAL study
(presented by Thierry Arino, Egis Avia)

Presentation content

- Introduction
- Background on Airborne Collision Avoidance
- Analysis and modelling of the future European ATM environment with VLJs
- Evaluation of the safety implications of ACAS equipage by VLJs and small LJs
- Pros and cons of ACAS equipage by VLJs and small LJs
- Conclusion & recommendations
**Study context**

- **ACAS II (TCAS II) reduces the risk of mid-air collisions**
- **Mandated in 2 phases in Europe**
  - 1st January 2000: MTOM > 15,000 kg or more than 30 passengers
  - 1st January 2005: MTOM > 5,700 kg or more than 19 passengers
- **Would there be safety benefits from extending use of ACAS II to lighter jets?**
  - VLJs & LJs with MTOM < 5,700 kg

**Study scope**

- **AVAL project objectives**
  - Assess the impact of VLJ and LJ operations on the safety benefits delivered by ACAS II in the future European environment
  - Determine the best approach for ACAS equipage on VLJs and LJs
- **AVAL Phase 1 (completed in March 2008)**
  - Determined that there was a need for further investigation
  - Phase 1 findings presented at VIP/4
- **AVAL Phase 2 (completed in October 2009)**
  - Full safety study (including the option of TCAS I equipage as an alternative to ACAS II)
  - AVAL final report available
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“See-and-avoid”

- ICAO Annex 2 - Rules of the Air
  - Principle by which the pilot conducts visual scan in order to detect hazards including collision threat, and undertake any necessary avoiding manoeuvre
  - There are many known limitations to “see-and-avoid”, which is a very last line of defence
    - Particularly without the aid of traffic display or alerting device
  - “See-and-avoid” is in no way a substitute to ATC or ACAS II
ACAS II performance

- Last resort safety net independent from the means of separation provision providing 2 levels of alert (TA & RA)

- Safety benefits of ACAS quantified through a safety metric

  \[
  \text{risk ratio} = \frac{\text{risk of collision with ACAS}}{\text{risk of collision without ACAS}}
  \]

- For typical IFR operations as observed in the European airspace in 2003, risk ratio = 22%, i.e. a reduction in the risk of collision by a factor of 5

Factors influencing the ACAS II safety performance
- Traffic characteristics of the airspace
- Level of ACAS II equipage and operating mode
- Pilot behaviour in response to RAs

TCAS I

- TCAS I only provides TAs
  - Developed in the US for small, low performance, aircraft

- Neither ICAO nor any ICAO member State (except the US) requires TCAS I

- No published guidance in Europe for the use of TCAS I
  - Abuse, or incorrect use, of TCAS I traffic display can degrade safety

- TCAS I safety benefits supposed to result from an improvement of the probability of visual acquisition
  - Enhancement of “see-and-avoid”
  - Although no quantitative evidence exists
TCAS related costs

Costs related to TCAS installation

- TCAS II installation represents a small, yet not negligible, part of the price of a light jet aircraft (no greater than 3.8%)

- TCAS I installation is cheaper as it represents from 1/5 to 1/2 of the price of TCAS II installation

Whatever the option of TCAS equipment, additional costs will be related to pilot’s specific and recurrent training

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**Definition of VLJs & LJs**

- No internationally agreed definition of a VLJ category
- In the context of the AVAL study:
  - VLJs = turbofan-powered aircraft with MTOM < 4,540 kg (10,000 lbs)
  - LJs = MTOM between 4,540 kg (10,000 lbs) and 9,080 kg (20,000 lbs)
  - Small LJs = LJs with MTOM < 5,700 kg

**Performance of VLJs & small LJs**

- Three categories of VLJs (based on manufacturer figures):
  - Low-performance VLJs & turboprops
  - Mid-performance VLJs & LJs < 5700 kg
  - High-performance VLJs, LJs > 5700 kg & Medium jets
  - Low-performance VLJs & turboprops
Type of operations of VLJs & small LJs

- Most of VLJs will be operated by a single pilot
  - Some small LJs will be operated by a two-member crew
- For Business Aviation or General Aviation purposes
  - Commercial flights like air-taxi operations, “fractional aircraft” operations, but also “per seat, on demand” service
  - Corporate flights operated by employed pilots
  - Owner-operated flights (for business or leisure purposes)
- Growth forecast for VLJs & small LJs
  - Between 110,000 to 170,000 additional flights each year until 2015
- The full picture of future VLJs & small LJs operations in Europe will depend on many, as yet unknown, factors

Encounters with VLJs & small LJs

- Development of a pre-VLJ and post-VLJ safety encounter model for the 2008 and 2015 timeframe, respectively
  - Update of the European safety encounter model using contemporary radar data
  - Encounters with VLJs extrapolated from current encounters with aircraft of similar performances
  - Annual traffic growth (of about 5%) for VLJs between 2008 and 2015
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Assumptions on operations

- Four operational scenarios under evaluation
  - To cover a wide range of possible options
  - To verify the robustness of the study results

Different mix of pilot’s background and cockpit configurations

Different mix of commercial, corporate and GA flights
Assumptions on pilots

If ACAS II equipped, VLJ & small LJ pilot’s response to RAs likely to be influenced by

- Aircraft operation by a single pilot
- Pilot’s training or past experience on ACAS II

Anticipated VLJ & small LJ pilot’s behaviour based on observed pilot’s behaviour during past and current ACAS II operations

Assumptions on visual acquisition

If TCAS I equipped, visual acquisition by VLJ & small LJ pilots is likely to be influenced by

- Encounter geometry, e.g. closing speed, angle of approach
- Meteorological visibility conditions
- Size of threat aircraft, etc.

Implementation of the visual acquisition model developed by the Lincoln Laboratory (US)

Probability of visual acquisition of A320 for TCAS I equipped VLJ aircraft, by 15s before collision (unlimited visibility on the left; visibility at the limit of VFR on the right)
Options of ACAS equipage

- Option 1 – No change to the current ACAS II mandate
  - No ACAS (neither TCAS II nor TCAS I) equipage requirements for VLJs & small LJs

- Option 2 – Mainstream VLJ equipage with ACAS II
  - Extension of the current European ACAS II mandate to VLJs & small LJs with maximum cruising speed of at least 350 kt

- Option 3 – Full VLJ equipage with ACAS II
  - Extension of the current European ACAS II mandate to VLJs & small LJs with maximum cruising speed of at least 250 kt

- Option 4 – Full VLJ and small LJ equipage with TCAS I
  - Towards a mandate for TCAS I equipage of VLJs and small LJs, as an alternative to the extension of the ACAS II mandate

Safety implications of ACAS II equipage (1/2)

- Assuming no change in current ACAS II mandate (Option 1), ACAS II anticipated to reduce the risk of collision by a factor of about two and half (risk ratio = 40%) in the 2015 timeframe

- Risk reduction afforded by ACAS II in the airspace slightly improved (~1% gain in risk ratio) when equipping VLJs & small LJs (Options 2 & 3)
  - Relative gain of ~2.5% in risk ratio with, at the maximum, ~1.7% additionally equipped aircraft
  - Risk ratio not influenced by the type of VLJ & small LJ operations
  - Risk ratio not influenced by the speed discriminant used for extending ACAS II equipage
Safety implications of ACAS II equipage (2/2)

From the perspective of VLJs & small LJs, ACAS II has a considerable effect as it reduces their risk of collision by a factor that varies between 1.6 and 1.9 (Options 2 & 3)

- If not equipped, risk ratio = 85%
- If equipped, risk ratio varies between 53% and 44%, depending on the speed discriminant used for extending ACAS II equipage

Safety implications of TCAS I equipage (1/2)

From the perspective of VLJs & small LJs, reduction in the number of close encounters enabled by TCAS I (Option 4) varies depending on environmental and human conditions

- Probability of visual acquisition after TA issuance influenced by visibility conditions
- Probability of turn in the correct direction by the pilot

For medium case, a rate of correct decision > 95% is required to achieve benefits similar to ACAS II
Safety implications of TCAS I equipage (2/2)

When considering the efficiency of evasive manoeuvres, TCAS I does not perform as well as ACAS II, and markedly so:

- Operational perspective: number of deviating aircraft is five times greater with TCAS I than with ACAS II.
- Safety perspective: horizontal deviations prompted by TAs less efficient than RAs.

\[ \text{Efficiency} = \frac{\Delta \text{Separation}}{\sum \text{Deviations}} \]

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Decision criteria for ACAS equipage

The criteria, that should help deciding on the best approach for ACAS equipage of VLJs & small LJs, include:

- Overall safety in Europe not degraded following the introduction of VLJs in the airspace
- Conduct of VLJ operations with a level of safety commensurate to that of mainstream operations
- Effectiveness of avoidance manoeuvres by VLJs
- Acceptability of the relative costs

These criteria take into account the expectations of various stakeholders (viz. regulators, airspace users, VLJ’s users & operators, and ANSPs)

Trade-off between the various criteria

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<th>Options for ACAS equipage of VLJs ans small LJs</th>
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<td>Option 1</td>
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<td>Overall safety in Europe</td>
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<td>Safety of VLJ operations</td>
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<td>Effectiveness (from ATM perspective)</td>
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<td>Relative costs</td>
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In summary

- The AVAL study delivered a set of models allowing to simulate the future VLJs & small LJs operations, with or without ACAS II, with or without visual acquisition prompted by TCAS I alerts
- On this basis, the AVAL study performed a comprehensive and quantitative evaluation of possible options for ACAS equipage of VLJs & small LJs in the future European environment (2015 timeframe)
  - TCAS I equipage is the least preferred option: It might be better not to equip these aircraft with TCAS I in order to minimise disruption of ATC and ACAS II operations
  - ACAS II equipage, at least for mainstream VLJ aircraft, seems the most effective option
Recommendations

Based on these AVAL findings, it is recommended

- R1: To extend the current European ACAS II mandate to include all civil fixed-wing turbine-engined aircraft with a maximum cruising speed of over 250 kt
- R2: To give proper attention to ACAS II training for pilots of VLJs and small LJs, regardless of the extension date of the European ACAS II mandate

The study produced no evidence on which to base any recommendation for equipping VLJs and small LJs (not subject to the current ACAS II mandate) with TCAS I. It is nevertheless recommended that

- R3: Before any operator decides to equip with TCAS I, the safety benefits of TCAS I in the European airspace should be demonstrated and quantified, with a particular focus on the potential impact on the mid-air collision risk reduction delivered by ACAS II