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**

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

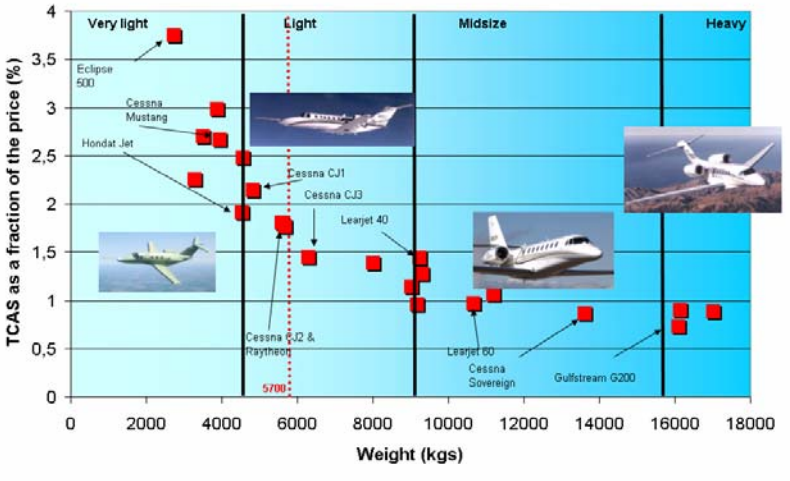
- **For typical IFR operations as observed in the European airspace in 2003, risk ratio = 22%, i.e. a reduction in the risk of collision by a factor of 5**
- **Factors influencing the ACAS II safety performance**
  - ✓ **Traffic characteristics of the airspace**
  - ✓ **Level of ACAS II equipage and 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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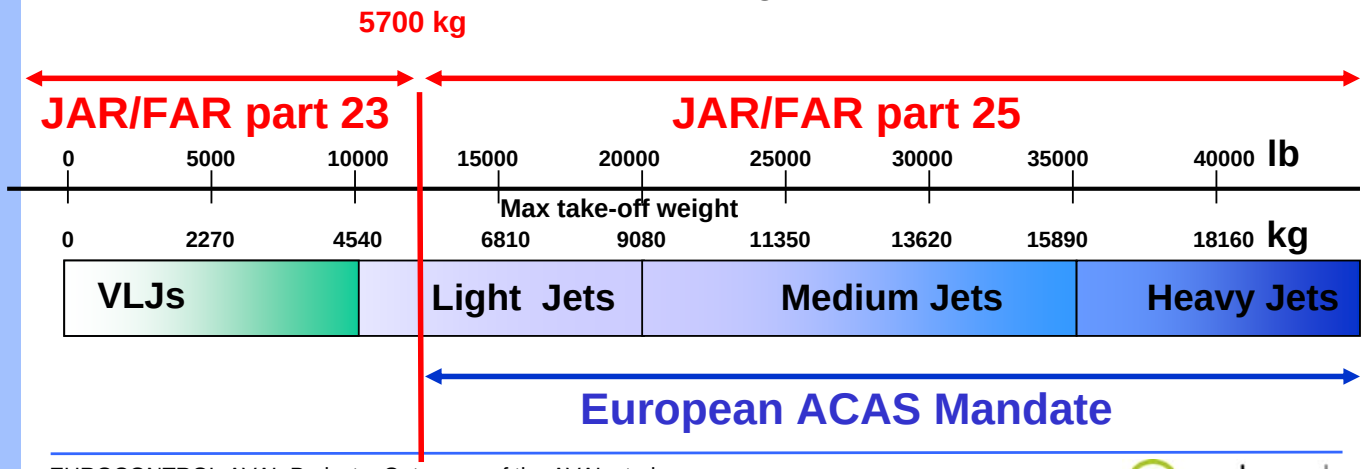
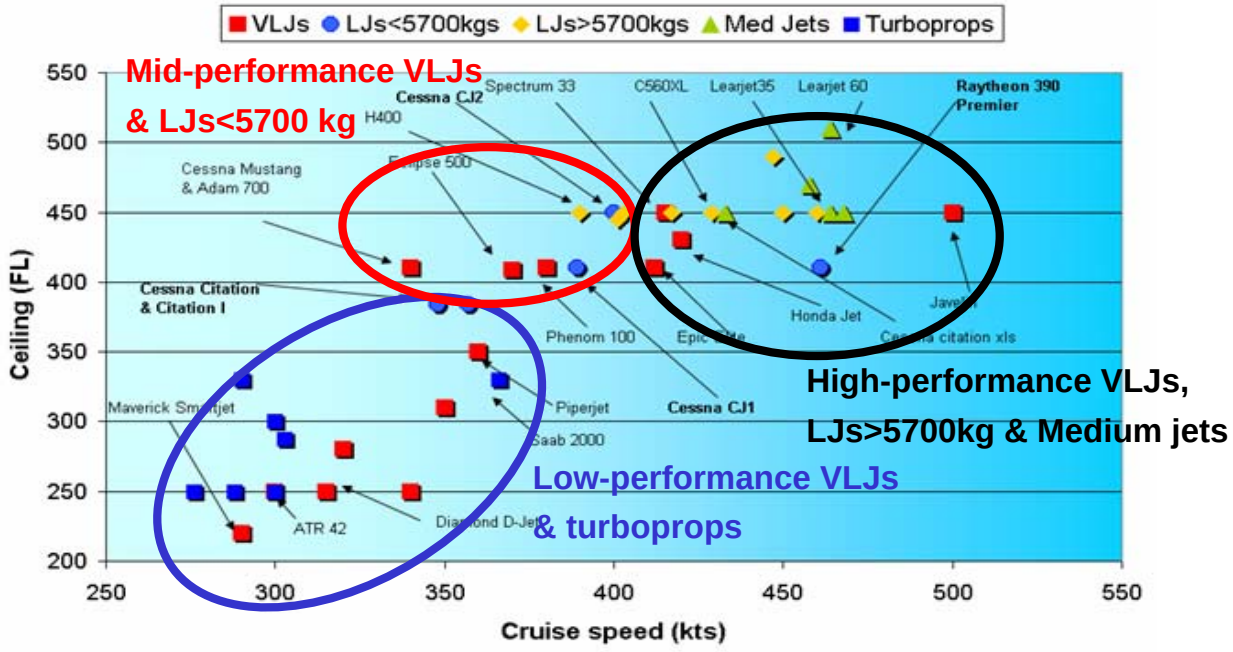
Definition of VLJs & LJs

- 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 < 5,700kg



Performance of VLJs & small LJs

- Three categories of VLJs (based on manufacturer figures)

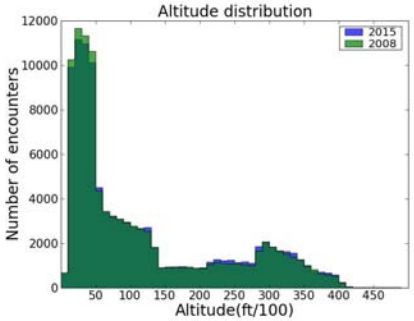


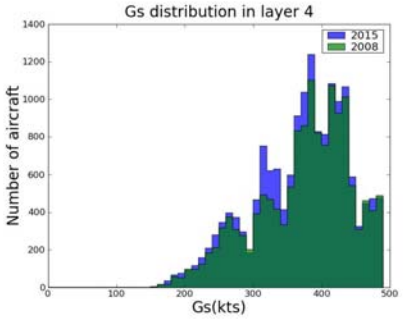
Type of operations of VLJs & small LJs

- **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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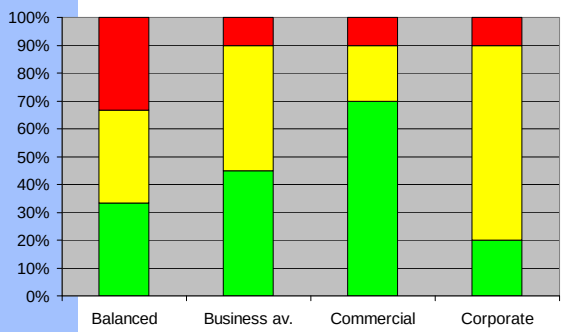
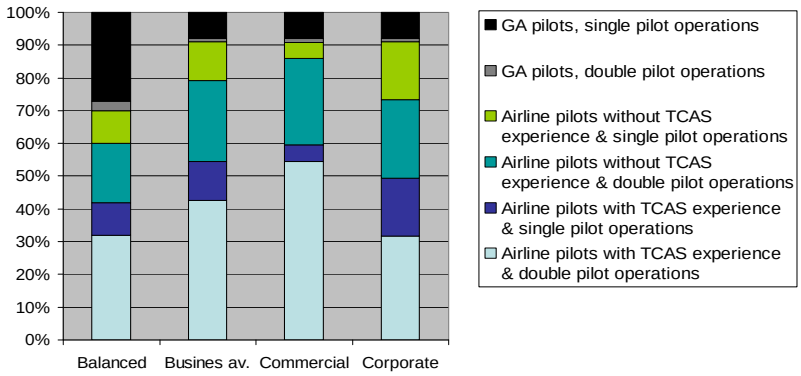
Assumptions on operations

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



Different mix of commercial, corporate and GA flights

Different mix of pilot's background and cockpit configurations

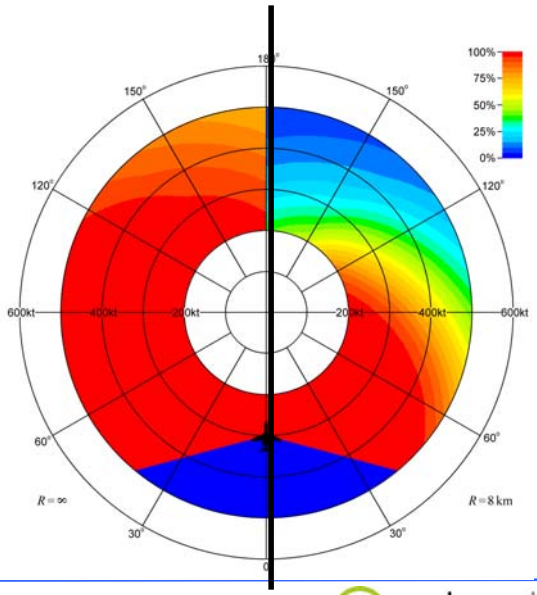


Assumptions on pilots

- **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

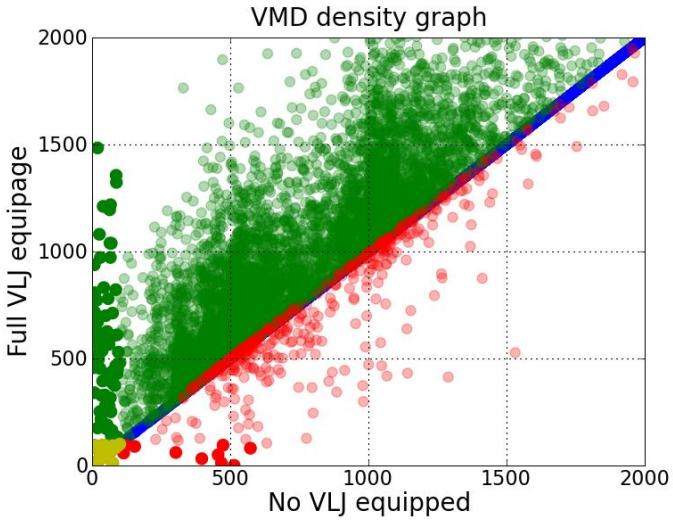
Safety implications of ACAS II equipage (1/2)

- **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**

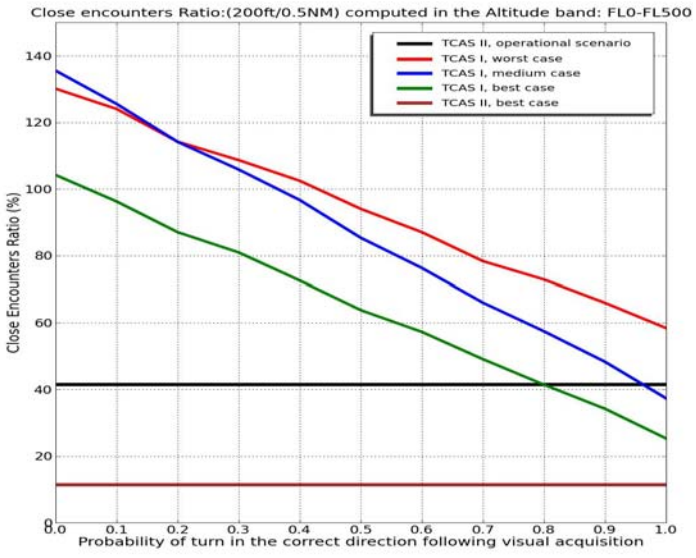


Safety implications of TCAS I equipage (1/2)

- **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**

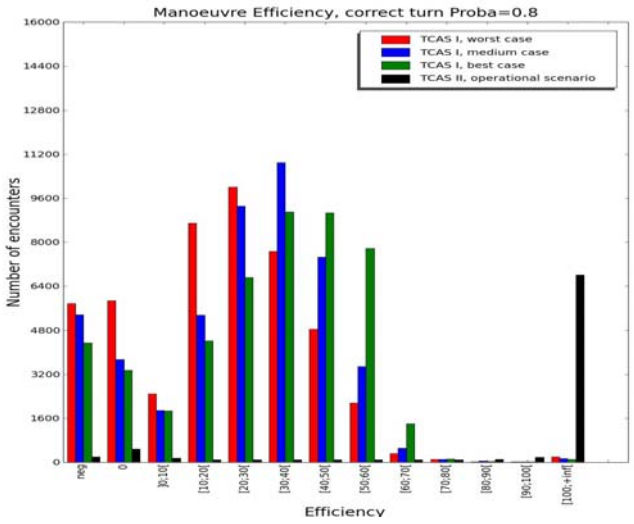
- **For medium case, a rate of correct decision > 95% is required to achieve benefits similar to ACAS II**



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**

$$Efficiency = \frac{\Delta Separation}{\sum Deviations}$$



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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

Criteria	Options for ACAS equipage of VLJs ans small LJs			
	Option 1	Option 2	Option 3	Option 4
	No ACAS equipage	Mainstream VLJs ACAS II equipped	Full ACAS II equipage of VLJs	Full TCAS I equipage of VLJs
Overall safety in Europe	😐	☺	☺	😐
Safety of VLJ operations	☹	☺	☺ ☺	😐
Effectiveness (from ATM perspective)	😐	☺	☺	☹
Relative costs	☺	☹ ☹	☹ ☹	😐
Total score	😐	☺	☺ ☺	😐 😐
Ranking	3	2	1	4

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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**