ACAS II on Helicopters

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- QinetiQ
ACAS

- **Airborne Collision Avoidance System (ACAS)**
  - uses standard transponder technology to detect and track other aircraft
  - ACAS I - provides Traffic Alerts (TAs)
    - traffic display aids visual acquisition
  - ACAS II - provides TAs and Resolution Advisories (RAs)
    - RAs advise the pilot how to regulate of modify vertical speed to avoid collision

- **Traffic alert and Collision Avoidance System (TCAS)**
  - implementation of ACAS concept
  - TCAS II Version 7 - mandatory in European airspace for fixed-wing aircraft with MTOM > 5,700 kg or seating for more than 19 passengers
Safety benefit to fixed-wing aircraft

- ACAS II designed as a last resort safety net against the risk of midair collision
- Operational experience and studies based on simulations confirm expected safety benefits of European ACAS mandate
  - ACASA and ASARP studies commissioned by EUROCONTROL
    - ACASA (2002) developed methodology and evaluated safety pre-RVSM
    - ASARP (2006) has refined tools and evaluated safety in RVSM
- Benefits not automatically enjoyed by helicopters that equip with ACAS
  - hardware - issues with antennas, displays
  - software - implicitly designed for fixed wing aircraft
  - helicopter performance - not necessarily able to comply with RAs
Issues with ACAS on helicopters

- Is surveillance of sufficient quality to support collision avoidance?
  - structural/aerodynamic considerations mean siting of antenna may be non-ideal
  - particular problem with reflections from main rotor and tail rotor
- Is collision avoidance logic effective given helicopter flight-profiles?
  - e.g. helicopters can have arbitrarily low ground-speed, high turn rates
- Can helicopters climb and descend sufficiently rapidly?
  - failure to comply with required vertical rates renders RAs ineffective and can cause positive harm in coordinated encounters
- Interference limiting algorithms ineffective when ACAS units cluster
  - clusters of helicopters could cause unacceptably high RF interference and effect surveillance of other units outside the cluster
- Surveillance nulls may contain third-parties
  - vertical polarization gives blind-spots directly above and below - helicopters (unlike aircraft) can manoeuvre in these directions
Current study

- Preliminary study
  - Concerned solely with ability of ACAS to avert risk of midair collision:
    - through RAs and pilots’ response to them
    - through ability of TAs to prompt contact with controller and to prompt visual acquisition of threat
  - Factors specific to helicopters included
    - surveillance performance typical of what can be achieved on helicopters
    - flight profiles of helicopters and the threats they typically encounter
    - helicopter aerodynamic performance - speeds, climb and descent rates

- Study does not consider:
  - use of traffic display for situational awareness
  - multiple encounters
  - effect of helicopter equipage on RF environment
Tools used

- Current study has employed approach used in ACASA and ASARP studies
  - encounter model captures characteristics of risk-bearing encounters
    - profiles of types of encounters involving helicopters
    - performance limitations of helicopters taken into account
  - large number of encounters generated
    - ACAS simulated, pilot response modelled
    - vertical separations with and without ACAS recorded
    - altimetry error model used to calculate probability of collision
    - ‘logic risk’
  - ‘contingency tree’
    - combines results of simulations (logic risk) with external factors to give ‘full-system’ risk
ACAS not designed to achieve any specific Target Level of Safety

- rather, systems and procedures must be designed to achieve the TLS without invoking ACAS
- it is then sufficient to demonstrate that ACAS reduces risk of collision
- ACAS performance is measured through comparative measure called ‘risk ratio’

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

- *N.B.* risk ratio will be different in different airspaces
Helicopter types

- Classified (for this study) on basis of Maximum Take-off Mass
  - Light - less than 750 kg
    - Robinson R22, Rotorway Executive (principal types on UK register)
  - Medium - 750 kg to 5,700 kg
    - Bell 206 (and variants), Robinson R44
  - Heavy - more than 5,700 kg
    - AS332 Puma, Sikorsky S76 Spirit

- Typical performance based on principal types

<table>
<thead>
<tr>
<th>class</th>
<th>max. speed</th>
<th>max. climb</th>
<th>max. descent</th>
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<tbody>
<tr>
<td>light</td>
<td>102 kt</td>
<td>1,000 fpm</td>
<td>1,220 fpm</td>
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<tr>
<td>medium</td>
<td>130 kt</td>
<td>1,280 fpm</td>
<td>1,500 fpm</td>
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<tr>
<td>heavy</td>
<td>170 kt</td>
<td>1,969 fpm</td>
<td>2,230 fpm</td>
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</table>
Civil helicopter fleet

- About 30,000 helicopters worldwide
- About 3,500 registered in ECAC states
  - UK - 1,159, France - 809, Italy - 515, Germany - 371, Norway - 151
  - light - 600, medium - 2,500, heavy - 400
- United Kingdom airspace selected for further study

<table>
<thead>
<tr>
<th>class</th>
<th>number</th>
<th>total hours/year</th>
<th>average hrs/yr per aircraft</th>
<th>typical number airborne</th>
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<td>42,246</td>
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<td>medium</td>
<td>813</td>
<td>156,630</td>
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<td>24</td>
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<td>heavy</td>
<td>69</td>
<td>64,640</td>
<td>937</td>
<td>10</td>
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<td>overall</td>
<td>1,159</td>
<td>263,516</td>
<td>227</td>
<td>40</td>
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</table>
Airprox analysis

- Recent UK air proximity hazard reports involving helicopters analysed
- All incidents occurred below 5000ft AGL
  - below 1000ft AGL no ACAS RAs
  - nominal ACAS warning times: TAs up to 30s, RAs up to 20s
- Helicopters engaged in normal forward flight
- All threats were fixed wing aircraft
- Majority of incidents involved military jets
  - 64.5% - military fast jets
  - 15.3% - civil aircraft, MTOM less than 5,700kg (not ACAS equipped)
  - 19.8% - civil aircraft, MTOM 5,700kg to 15,000kg (Phase II ACAS mandate)
  - 0.4% - civil aircraft, MTOM greater than 15,000kg (Phase I ACAS mandate)
Collision rate

- Minimal benefit to helicopters from Phase I of ACAS mandate
  - less than 0.5% intruders equipped

- Some benefit to helicopters from Phase II of ACAS mandate
  - more than 20% of intruders equipped

- Estimate in UK airspace
  - 7.7 NMACs per year (aircraft and helicopter within 100ft and 0.1NM)
  - one mid-air collision involving helicopter every 13 years
  - one mid-air collision every 4 million helicopter flying-hours
  - confirmed by experience - two most recent incidents in UK:
    - 23/06/1993, Cumbria, Bell Jet Ranger struck by RAF Tornado - 2 killed
    - 06/07/2004, Hertfordshire, Robinson R22 collided with microlight - 2 killed
  - By comparison, helicopter is 40 times more likely to be involved in some other fatal airborne accident
Logic risk ratio results

- ‘Logic risk’
  - Assumes that all intruders operate transponders and report altitude
  - ACAS surveillance tracks all intruders
  - Pilot complies with all RAs (irrespective of controller instructions or visual acquisition)

- From perspective of helicopter that equips with ACAS
  - Logic risk ratio = 40.6%
    - Helicopter pilot who operates ACAS and follows the RAs that it generates can more than halve his risk of mid-air collision
  - Induced component = 9.8%
    - For every 100 original collisions we expect ACAS to resolve 69 and be unable to resolve 31
    - However we also expect ACAS to induce approximately a further 10 collisions
    - So if and when an ACAS equipped helicopter is involved in a collision, there could be up to a 1 in 4 chance that the collision is attributable to ACAS
‘Full-system risk’
- Takes logic risk as an input
- Incorporates other effects:
  - Intruders might not be transponding or not reporting altitude
  - ACAS may fail to track intruder
  - ACAS might prompt pilot to contact ATC, or prompt visual acquisition of intruder
  - Pilot might not comply with RA (e.g. preferring ATC instruction or see-and-avoid manoeuvre)

From perspective of helicopter that equips with ACAS
- Full system risk ratio = 51.7%
  - Helicopter pilot who operates ACAS can almost halve his risk of mid-air collision
  - Performance for conscientious pilot who always follows RAs will approach logic figure
- Induced component = 3.8%
North Sea operations

- Extensive use of helicopters to service rigs in the North Sea
  - commercial operators may equip with ACAS
- UK sector
  - limited ATC service provided to helicopters using Helicopter Main Routes (HMR)
  - similar operations in Norwegian, Danish and Dutch sectors
- North Sea also used as military training area
  - 05/02/2004, RAF Tornado came within 50ft of AS332 Puma en-route from Auk to Aberdeen
Statistics for UK sector of North Sea

- Two major operators together own 78 helicopters
- Helicopters typically spend the majority of time cruising at 2000ft-3000ft
  - less than 10% of time flying below 1000ft AGL (where ACAS does not issue RAs)

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<tbody>
<tr>
<td>medium</td>
<td>25</td>
<td>19,024</td>
<td>761</td>
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</tr>
<tr>
<td>heavy</td>
<td>53</td>
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<td>1071</td>
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<tr>
<td>overall</td>
<td>78</td>
<td>75,788</td>
<td>972</td>
<td>12</td>
</tr>
</tbody>
</table>

- Estimate in UK sector of North Sea
  - 1.1 NMACs per year (aircraft and helicopter within 100ft and 0.1NM)
  - one mid-air collision involving helicopter every 78 years
  - one mid-air collision every 6 million helicopter flying-hours
Risk ratios in North Sea

- Logic risk ratio (effectiveness of ACAS algorithms and pilot response)
  - Risk ratio of 29.0%
  - Induced component 9.9%
- Full-system risk ratio (incorporates transponder performance, controller intervention, visual acquisition etc.)
  - Risk ratio of 45.1%
  - Induced component 2.5%
- Overall, equippage of helicopters could reduce collision rate from one every 78 years to one every 170 years
  - 1.1 NMACs per year to 1 NMAC every 2 years
- Individual pilot who is conscientious and allows follows the RAs can expect to achieve a risk ratio closer to the logic figure
  - *i.e.* reduction in collision risk by up to a factor of 3
Summary

- Results of the study are encouraging
- Helicopters receive some benefit from ACAS equippage of other aircraft
  - in 20% of encounters threat will be ACAS equipped
- Deployment of ACAS II on helicopters could further reduce the overall rate of collisions involving helicopters by a up to factor of 2
  - rate of collisions involving helicopters in UK could be reduced from one every 13 years to one every 28 years
- ACAS II shown to be effective in the specific theatre of the North Sea
  - conscientious pilot who always follows the RAs could reduce his own risk of collision by up to a factor of 3
- Only a preliminary study
  - several caveats, indicated on next slide
Caveats

- Study has considered helicopters in forward flight only
  - Has not considered helicopters in the hover or travelling sideways
- ACAS Climb inhibits have not been considered
  - Helicopters might be near service ceiling or unable to climb due to icing
- Vertical rates
  - Study has assumed that helicopters can achieve 1500 fpm for at least 30s and 2000 fpm for at least 20s (for collision avoidance)
  - If individual helicopters are not able to achieve these rates they should not be equipped
- Multiple encounters have not been studied
  - These are rare events for fixed-wing aircraft - might be more common for helicopters
- Effect on RF environment not considered
  - Effects of helicopter equippage on availability of transponders need to be studied
- ACAS is not situational awareness tool
  - ACAS II should not be fitted solely to obtained the (perceived) benefits of situational awareness from the traffic display