ACAS II on Helicopters

- Harry Hutchinson
- 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 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

Risk ratio

- 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 5,700kg
    - AS332 Puma, Sikorsky S76 Spirit
- Typical performance based on principal types

class	max. speed	max. climb	max. descent
light	102 kt	1,000 fpm	1,220 fpm
medium	130 kt	1,280 fpm	1,500 fpm
heavy	170 kt	1,969 fpm	2,230 fpm

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

class	number	total hours/year	average hrs/yr per aircraft	typical number airborne
light	277	42,246	153	6
medium	813	156,630	193	24
heavy	69	64,640	937	10
overall	1,159	263,516	227	40

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

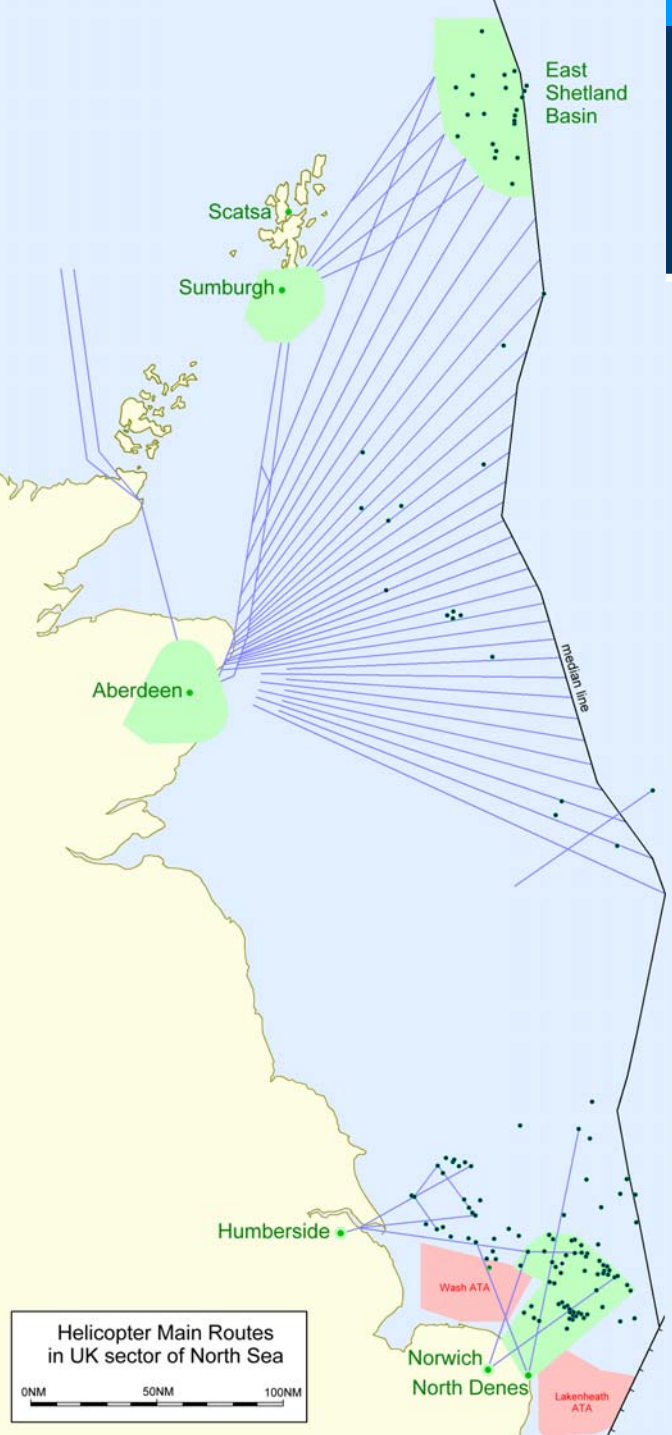
Logic risk ratio results

- ‘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 ratio results

- ‘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

EUROCONTROL

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)

class	number	total hours/year	average hrs/yr per aircraft	typical number airborne
medium	25	19,024	761	3
heavy	53	56,763	1071	9
overall	78	75,788	972	12

- 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