Safety nets performance assessment: the encounter-model methodology as a cornerstone to provide quantified results for ACAS and STCA

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- ACAS performance and standardisation
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- Overview of the simulation framework
- (STCA models, ATC surveillance models, pilot and controller models)
- Results on key performance areas of STCA
- Conclusions and future work
Background & context

- STCA & ACAS are two safety nets of different maturity and scope, developed independently from each other.

- STCA standardization is under progress in Europe (e.g. high-level EUROCONTROL specifications)
  - Although not mandatory, STCA is deployed in several States with a wide range of implementation.

- ACAS performance-oriented Standards and Recommended Practices (SARPs) are defined at ICAO level
  - ACAS mandatory carriage exists worldwide and there is a single ACAS compliant equipment (i.e. TCAS II version 7).
Framework for evaluating the safety benefits of ACAS

- Safety benefits afforded by ACAS expressed in terms of ‘risk ratio’ measured using a set of models replicating the environment in which ACAS is operating: safety encounter model, altimetry error model and pilot response model.

- Radar data → Safety encounter model → Underlying risk → ACAS simulations → Logic system risk → Full ACAS system risk → Contingency tree

- Altimetry error model
- Pilot response model

Safety encounter model, ACAS simulations, Contingency tree.
EUROCONTROL I-AM-SAFE framework

- EUROCONTROL I-AM-SAFE framework relied on the safety and ATM encounter models (used in the ACAS field), a simplified STCA model (based on EUROCONTROL specifications) and a set of STCA performance metrics.
Relevance of the simplified STCA model

• Implementation of the reference STCA model proved to be operationally realistic despite its simplicity

• Areas of improvement:
  • Development of optional features described in the reference STCA model (to cope with specific situations like slow closing encounters, etc)
  • Use of surveillance model that would be representative of actual surveillance performances (perfect surveillance was assumed)
Relevance of the ATM & Safety encounter model

• Safety encounter model proved to be more appropriate than the ATM encounter model for evaluating the efficacy of STCA
  – However, due to its focus on risk-bearing situations, the safety encounter model exaggerated the alert rates

• ATM encounter model proved to be more useful for evaluating compatibility of STCA with day-to-day operations

• Areas of improvement:
  – Development of an ATM incident-based encounter model (derived from real incidents observed in European radar data) that would encompass the interest of the safety and ATM encounter models
  – Development of a controller intervention model in response to STCA apart from the encounter model it-self
Relevance of the STCA performance metrics

- Alert statistics demonstrated to be influenced by:
  - Encounter characteristics and STCA configuration

- Evaluation of different warning time metrics using either:
  - ‘Actual trajectories’ or ‘Predicted trajectories’

- Areas of improvement:
  - More sophisticated metrics required to take into account controller reaction in response to STCA
Enhanced framework for STCA performance evaluation

- ATC incident data
- SSR / RDPS performance data
- Controller response model
- Pilot response model
- ATC surveillance model
- Altimetry error model
- ATM incident-based encounter model
- STCA simulations
- ACAS simulations
- Underlying level of safety (without STCA nor ACAS)
- Level of safety achieved with STCA
- Overall level of safety with ACAS

Safety nets contribution
Encounter modelling (1/3)

• Encounter
  – Traffic situation (operationally realistic) involving two aircraft

• Safety encounter model
  – Close encounters (with almost no horizontal miss distance) with actual or potential risk of collision
  – About 1 close encounter every 6,000 flight-hours (or every 2 days of observation by a typical en-route radar)

• ATM encounter model
  – Encounters occurring in routine operations including ATC intervention to preserve separation
  – About 4 encounters per flight-hour ≈ about 18 encounters per sector hour
Encounter modelling (2/3)

- Modelling of observed encounters (statistical distributions of encounter properties derived from radar data analysis)

![Diagram](image)

- **HMD**
  - convergence angle
  - turns: timing, heading change, bank angle

- **VMD**
  - vertical manoeuvres: timing, initial and final rates, acceleration, altitude, vertical rate

**Plan view**

**Vertical profile**
Encounter modelling (3/3)

• Five altitude layers with distinct proportions of aircraft performance classes

Most typical aircraft class below FL50 (light piston)

Most typical aircraft class over all altitudes (medium jet)
Pilot response modelling (to ACAS RA)

- Derived from operational airborne recordings
- Continuum of responses around ICAO standard response
  - 5s delay, 0.25g acc., 1,500fpm vs

Most typical pilot response (5s delay, 0.15g acc., 1,300fpm vs)

Non responding pilots
Enhanced modelling and analysis, synthesis and guidelines (1)

- Performance and safety Aspects of STCA – full Study (2008-2010)
  - 3-year EUROCONTROL project led by Egis Avia (France) in partnership with Deep Blue (Italy), DSNA (France), and QinetiQ (United Kingdom)

- A comprehensive framework, that includes a series of models to simulate operationally realistic scenarios of SNET environment and use, is now in place

- These models consist essentially of
  - Encounter models, but also
  - Models of ACAS and STCA systems,
  - Controller and pilot responses to SNET alerts, and
  - Aircraft behaviour

- The set of available models covers all key factors influencing SNET performance
Enhanced modelling and analysis, synthesis and guidelines (2)

- A range of realistic operational scenarios (with and without ground-based SNETs) for both TMA and en-route airspace has been defined

- With different human behaviours as observed during monitoring activity

<table>
<thead>
<tr>
<th>Scenario for Human Performance</th>
<th>controller’s input of CFL</th>
<th>controller’s response to STCA</th>
<th>pilot response to AI</th>
<th>pilot response to RA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>delay reaction time</td>
<td>type of AI</td>
<td>use of avoiding phraseology</td>
<td></td>
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<tr>
<td>standard</td>
<td>100%</td>
<td>average (6s)</td>
<td>H or V</td>
<td>sometimes</td>
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<tr>
<td>standard with nominal phraseology</td>
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<td>average (6s)</td>
<td>H or V</td>
<td>never</td>
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<tr>
<td>optimal</td>
<td>100%</td>
<td>prompt (4s)</td>
<td>H or V</td>
<td>always</td>
</tr>
<tr>
<td>relaxed</td>
<td>95%</td>
<td>slow (10s)</td>
<td>H or V</td>
<td>never</td>
</tr>
<tr>
<td>typical</td>
<td>95%</td>
<td>typical</td>
<td>mix of H and V</td>
<td>sometimes</td>
</tr>
</tbody>
</table>

- **CFL stands for Cleared Flight Level**
Enhanced modelling and analysis, synthesis and guidelines (3)

- Several STCA “families” have been identified during monitoring activity with different parameters and optional features
  - More or less time-critical parameters and more or less reduced separation thresholds
  - Distinction between “basic”, “standard” or “advanced” implementation
Enhanced modelling and analysis, synthesis and guidelines (4)

- A comparative analysis of STCA performances in terms of likelihood, relevance and efficacy of alerts, as well as level of interaction with ACAS has been conducted
  - To evaluate the influence of key factors like STCA configuration and parameters, encounters characteristics, CNS characteristics, controller and pilot behaviours in response to alert
  - In support to the determination of possible minimum / recommended performance requirements for STCA, including compatibility with ACAS
Enhanced modelling and analysis, synthesis and guidelines (5)

- The operational safety assessment of hazards related to collision prevention by ATCO assisted by STCA, including undesired interaction with TCAS RA, has been completed
  - Consolidate event-tree analysis of hazard effects / severity
  - To derive safety objectives (following apportionment of ATM safety targets compliant with ESARR4)
  - Consolidate fault-tree analysis of possible causes
  - To derive possible safety requirements on STCA
Overview of the STCA and ACAS simulation framework

- Encounter model
  - Generated encounters
  - Scenarios
  - STCA simulation
  - Encounters with the effect of STCA
    - Assumptions about airspace characteristics
    - Assumptions about ATC surveillance means
    - Assumptions about STCA and ACAS systems
    - Assumptions about Human Performance (controller & pilot)
  - TCAS simulation
  - Encounters with the effects of STCA & TCAS
  - STCA performance metrics & level of safety with STCA
  - STCA / ACAS performance metrics & overall level of safety
Key performance areas of STCA

• Likelihood of STCA alerts (number of alerts per flight hour)
• Operational relevance of STCA alerts
• Efficacy of alerts (time remaining for ATCO intervention)
• Level of STCA and ACAS interaction (relative timing when the 2 SNET are triggered)
Results on the likelihood of STCA alerts

- The ANSP strategy when implementing and fine-tuning STCA has a direct impact on the likelihood of STCA alerts.
- All investigated STCA configurations show comparable alert rates for the most severe encounters.
- For less severe encounters, STCA configurations designed for collision avoidance only show an alert rate 100 less than STCA configurations designed for « separation protection » as well as « collision avoidance ».
- All STCA configurations issue unnecessary alerts (no loss of separation).
- The quality of the surveillance data used by STCA also has a small effect on the STCA alert rate (factor <1.6).
Results on the operational efficacy of STCA alerts

• The various STCA configurations provide fairly similar WARNING TIME performances. Optional features (turning prediction filter, use of CFL or SFL) improve the separation margins in the most time-critical alerts.

• Safety benefits?

• Ratio of (separation infringements with the effect of STCA) versus (Separation infringements without the effect of STCA.)

The less conservative STCA families appear to be less effective than the other families to maintain or restore separation. However, all but one STCA family reduce the number of separation infringements for severe encounters by a factor of at least FIVE (Ratio <20%)
Project close-out and further work

- PASS Final study report (November 2010)

- PASS Dissemination workshop on 23rd of November 2010 (Brussels)

➔ A step further towards a consistent overall concept for ground-based and airborne safety nets in coordination with appropriate bodies

➔ SESAR Operational Project 4.8.1 (*Evolution of Ground-Based Safety Nets*) will use the report and the methodology to express *Operational Requirements, Safety and Performance requirements* in support of the development of an industrial prototype by the SESAR Technical Project 10.4.3 (*Safety Nets adaptation to new modes of operation*) in 2010-2011.

➔ It is anticipated that the operational validation of the STCA prototype would be conducted in the 4th QTR 2011.
Thank you for your attention

Any question?