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

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RÉPUBLIQUE FRANÇAISE
ministère de l'Écologie du Développement et de l'Aménagement durables

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- Background on STCA and ACAS
- ACAS performance and standardisation
- Encounter models
- 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

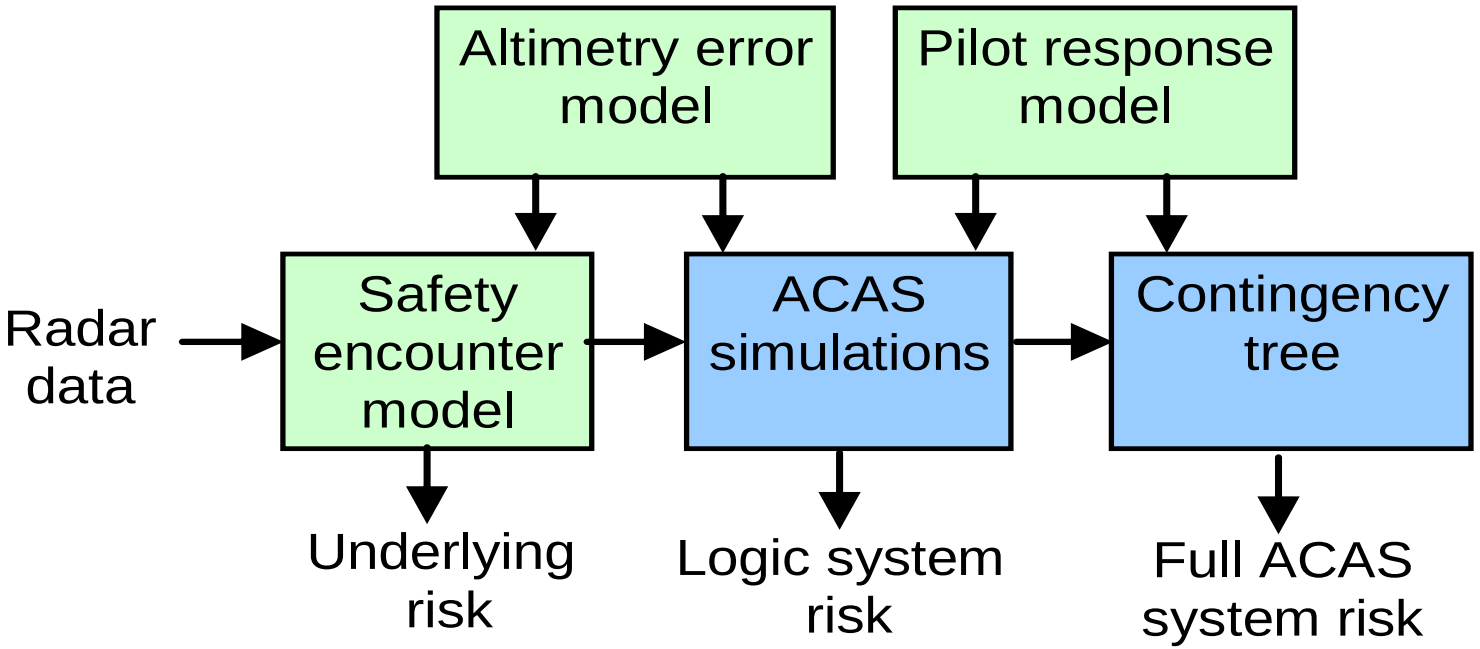
- STCA & ACAS are two safety nets of different maturity and scope, developed independently from each other

- 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)

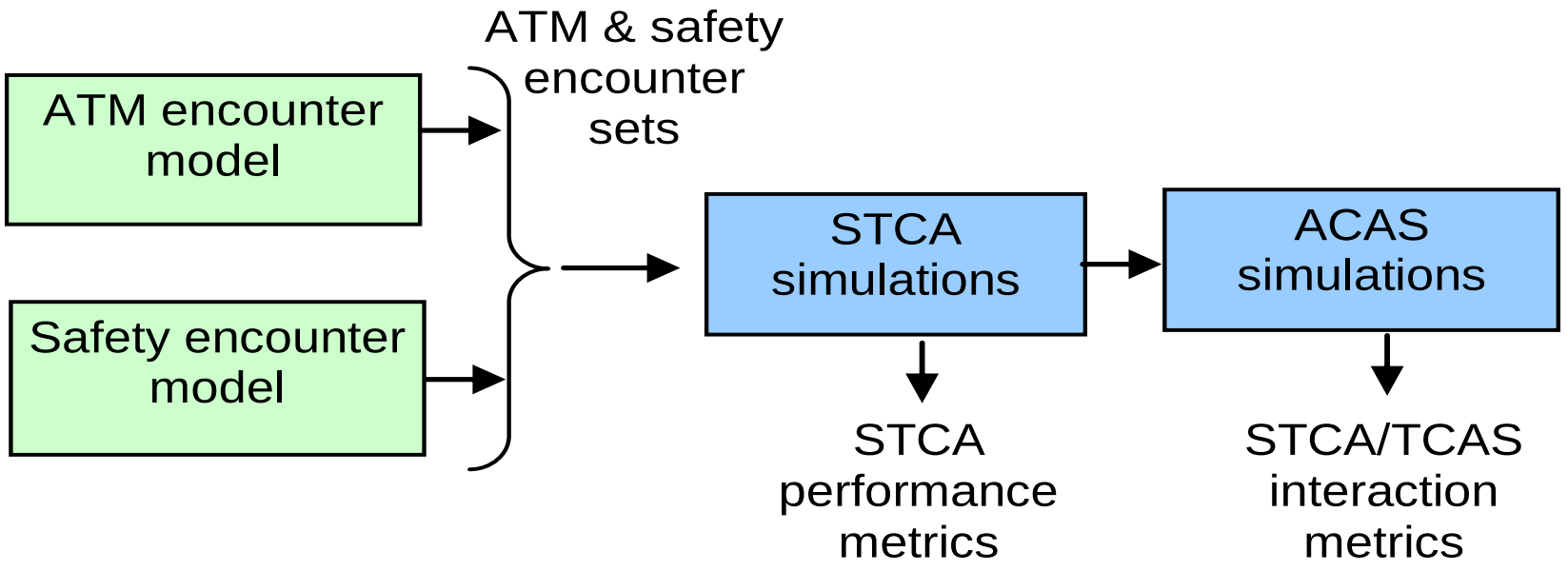
Framework for evaluating the safety benefits of ACAS

- 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.

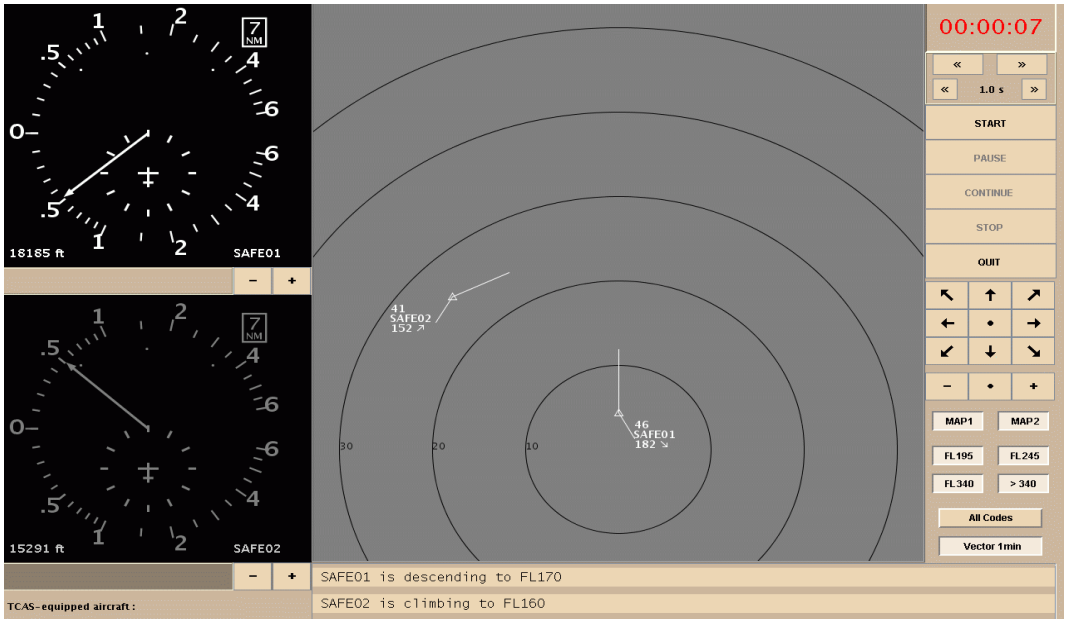


EUROCONTROL I-AM-SAFE framework

- 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)

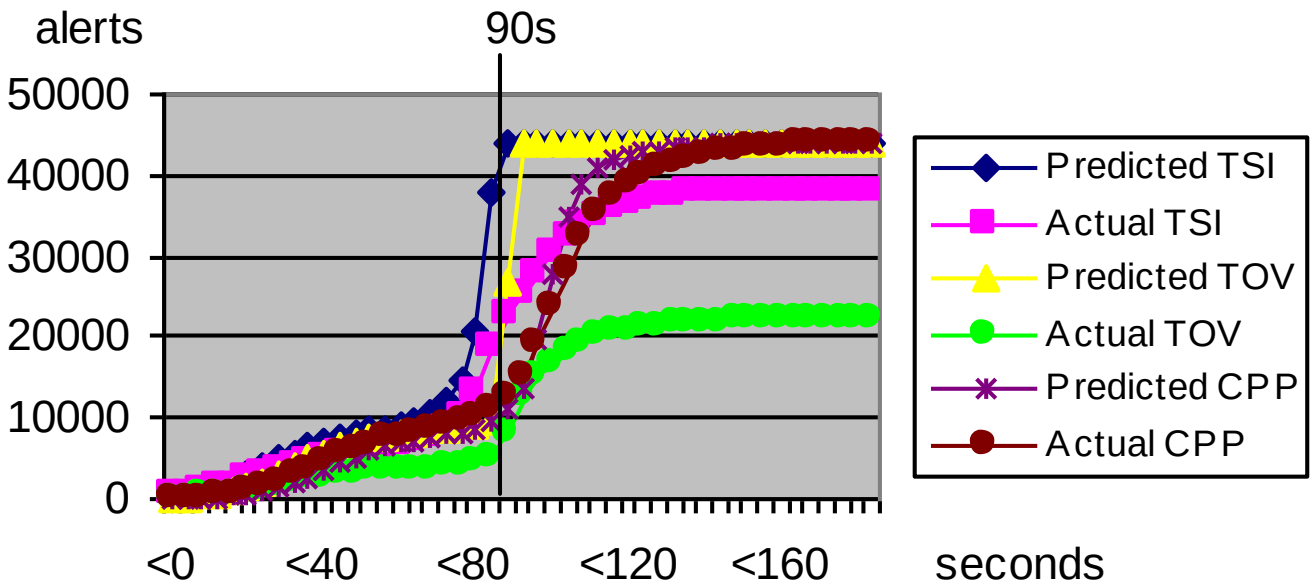
Relevance of the ATM & Safety encounter model

- 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

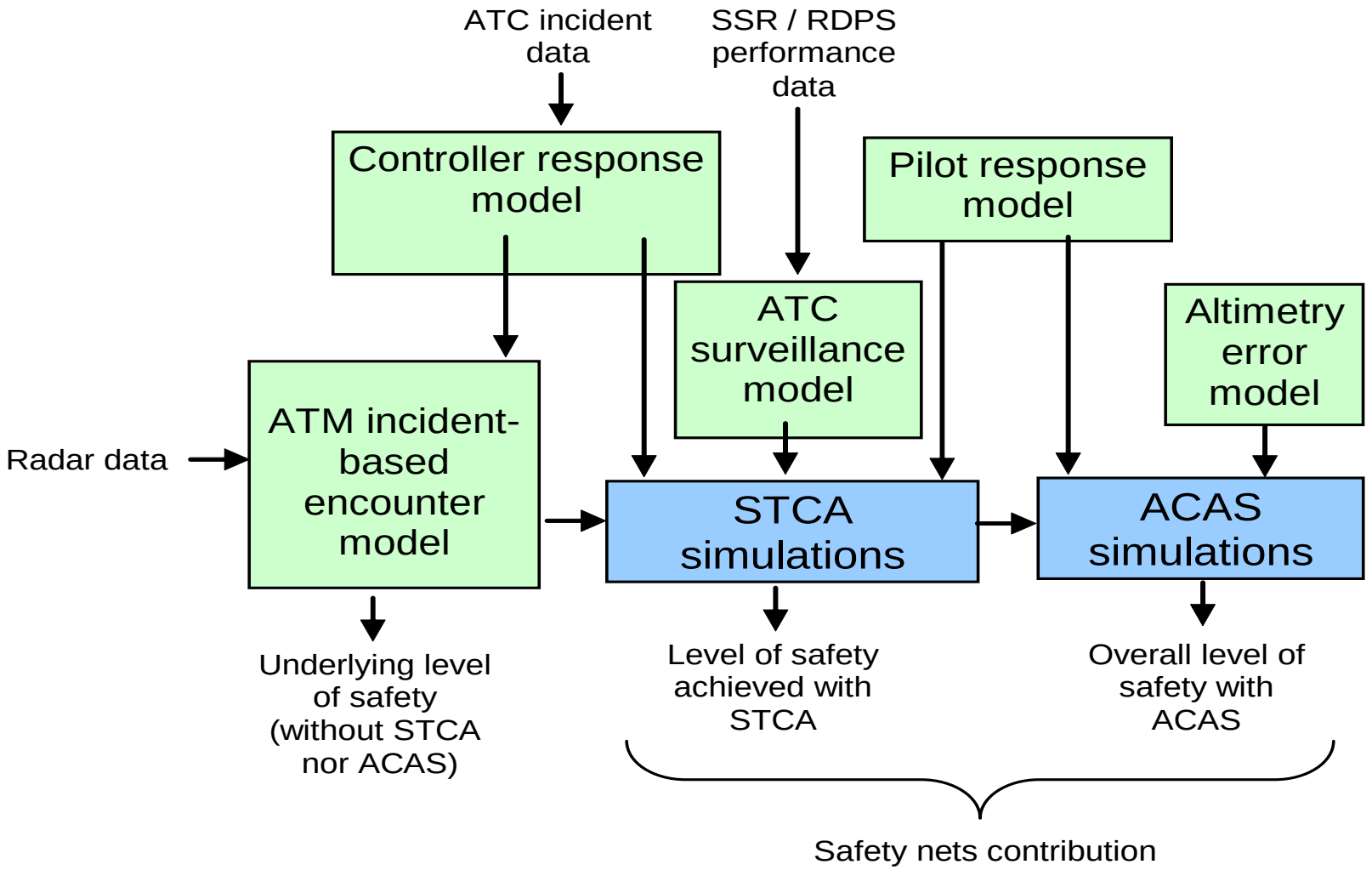
- Areas of improvement:
  - Development of an ATM incident-based encounter model (derived from real incidents observed in European radar data) that would encompass the interest of the safety and ATM encounter models
  - Development of a controller intervention model in response to STCA apart from the 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'
  - 'Time of Separation Infringement', 'Time of separation Violation' or 'Time of Closest Approach'
- Areas of improvement:
  - More sophisticated metrics required to take into account controller reaction in response to STCA



Enhanced framework for STCA performance evaluation

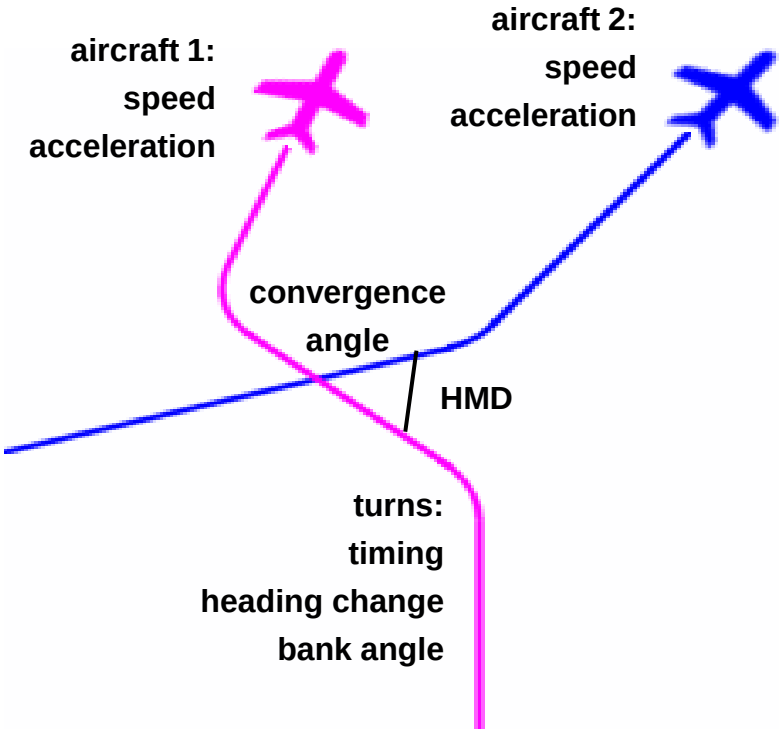


Encounter modelling (1/3)

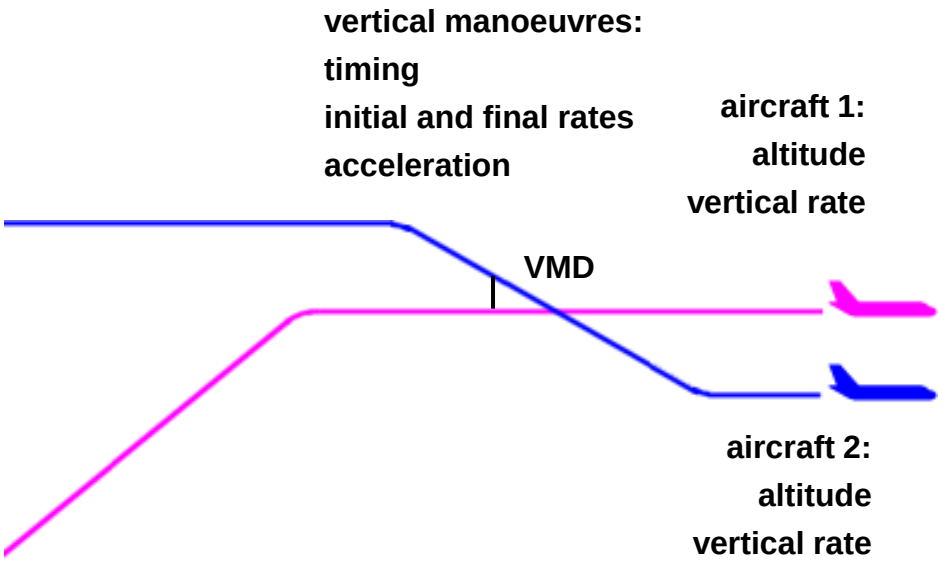
- Encounter
  - Traffic situation (operationally realistic) involving two aircraft
- Safety encounter model
  - Close encounters (with almost no horizontal miss distance) with actual or potential risk of collision
  - About 1 close encounter every 6,000 flight-hours (or every 2 days of observation by 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)



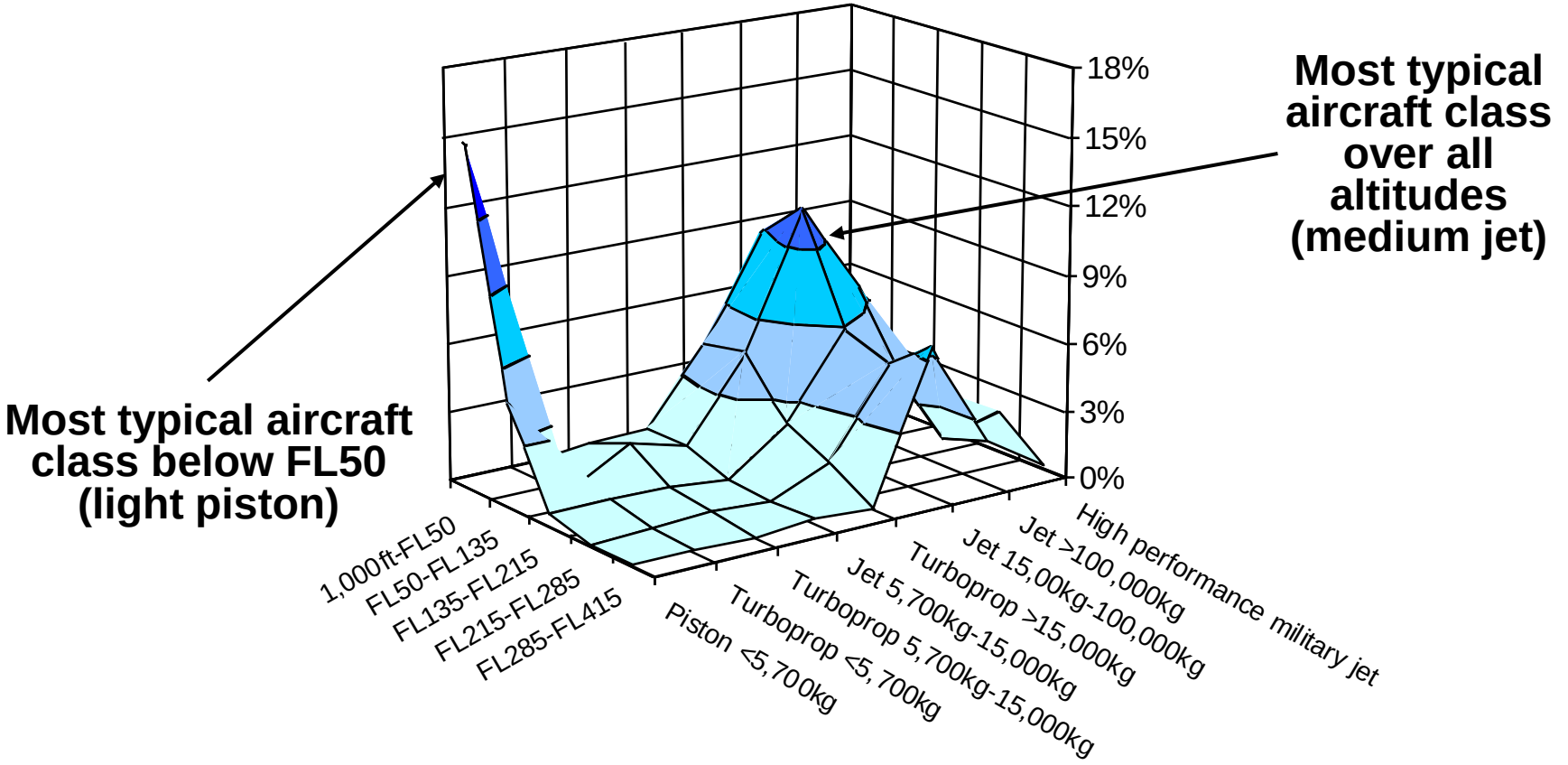
plan view



vertical profile

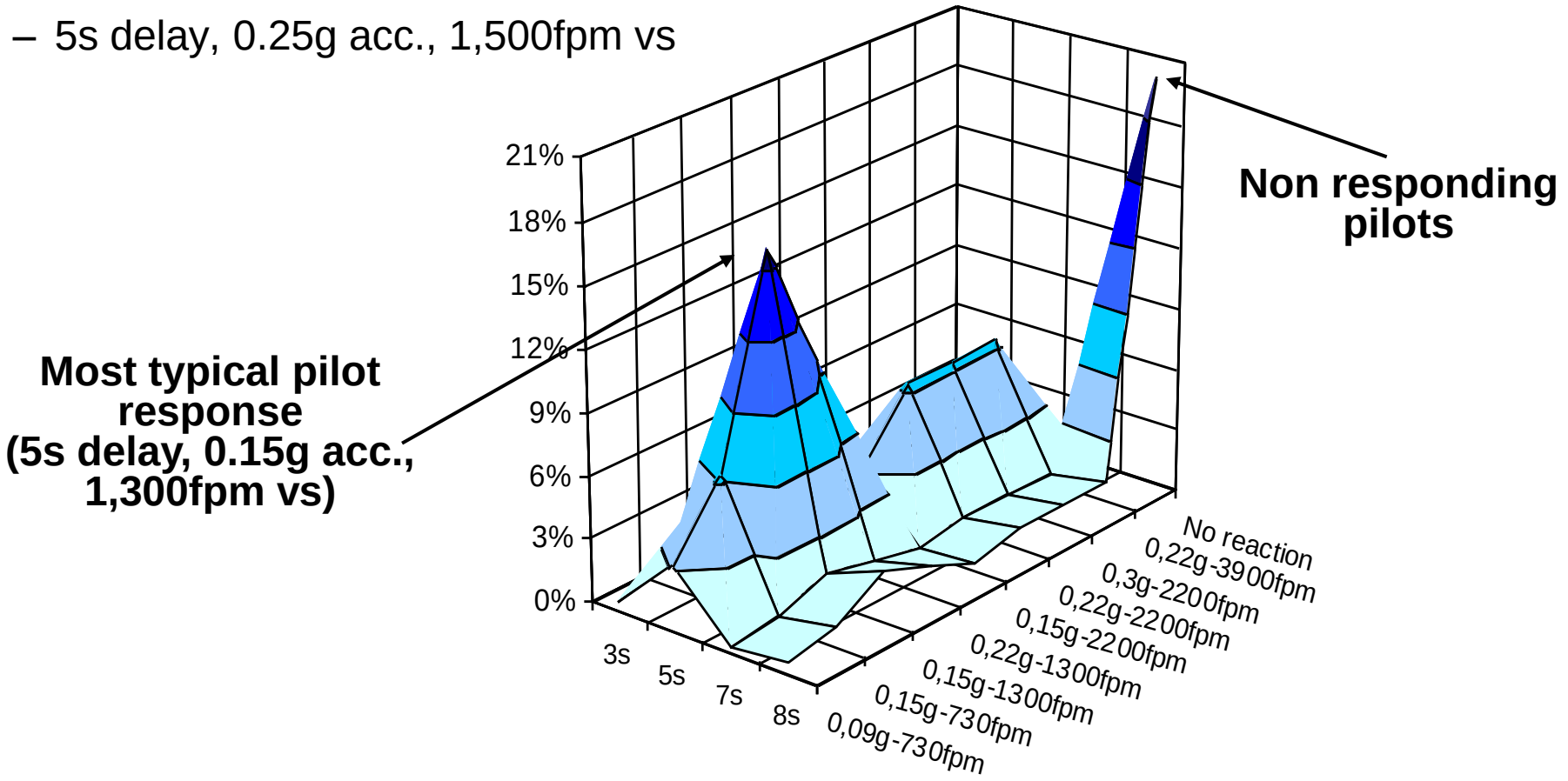
Encounter modelling (3/3)

- Five altitude layers with distinct proportions of aircraft performance classes



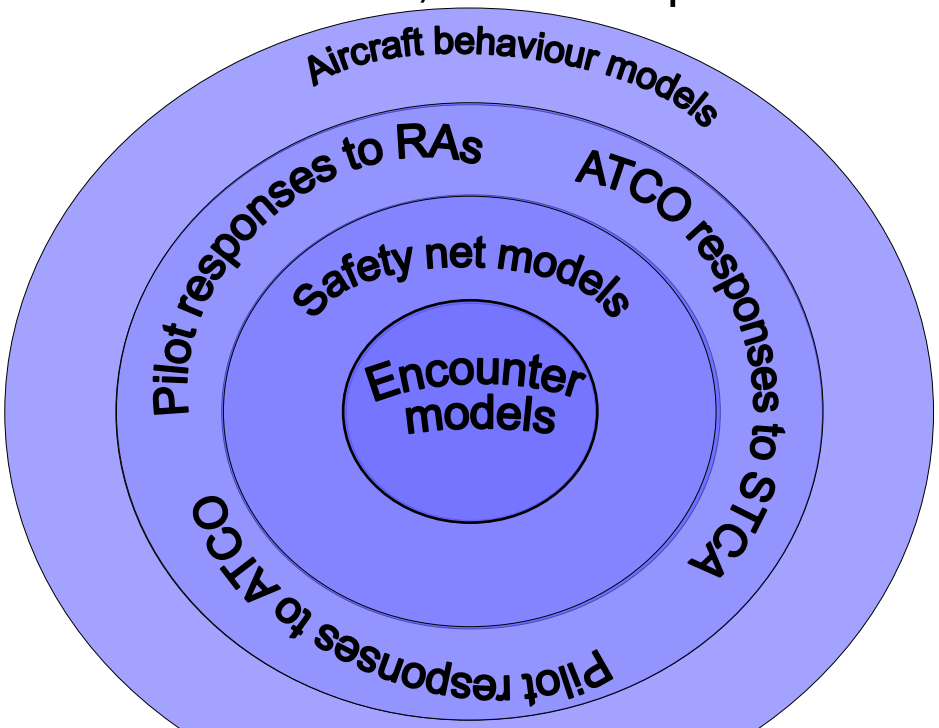
Pilot response modelling (to ACAS RA)

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



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)

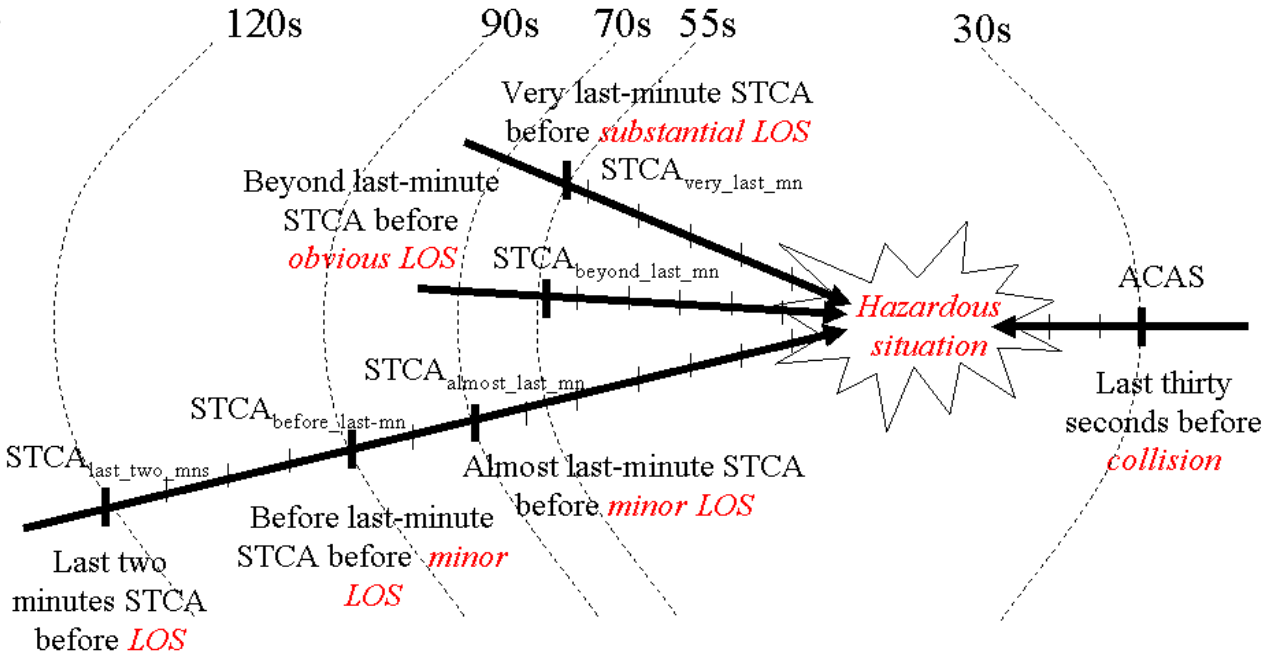
- A range of realistic operational scenarios (with and without ground-based SNETs) for both TMA and en-route airspace has been defined
- With different human behaviours as observed during monitoring activity

Scenario for Human Performance	controller's input of CFL	controller's response to STCA			pilot response to AIs	pilot response to RAs
		delay reaction time	type of AI	use of avoiding phraseology		
standard	100%	average (6s)	H or V	sometimes	standard	standard
standard with nominal phraseology	100%	average (6s)	H or V	never	standard	standard
optimal	100%	prompt (4s)	H or V	always	standard	standard
relaxed	95%	slow (10s)	H or V	never	standard	standard
typical	95%	typical	mix of H and V	sometimes	typical	typical

- *CFL stands for Cleared Flight Level*

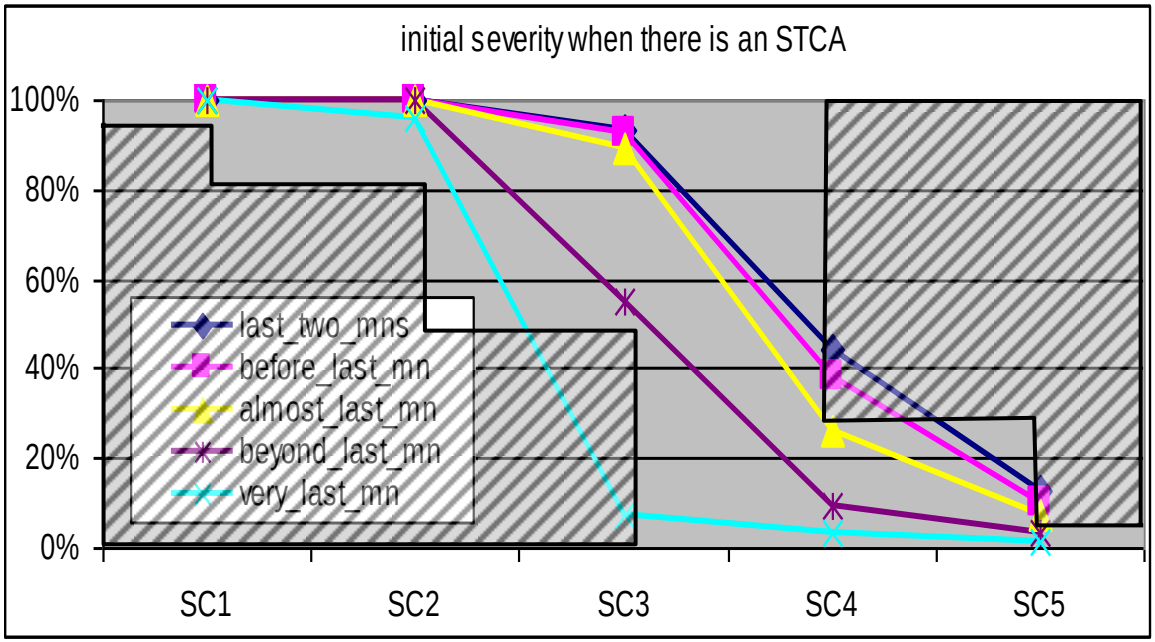
Enhanced modelling and analysis, synthesis and guidelines (3)

- 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



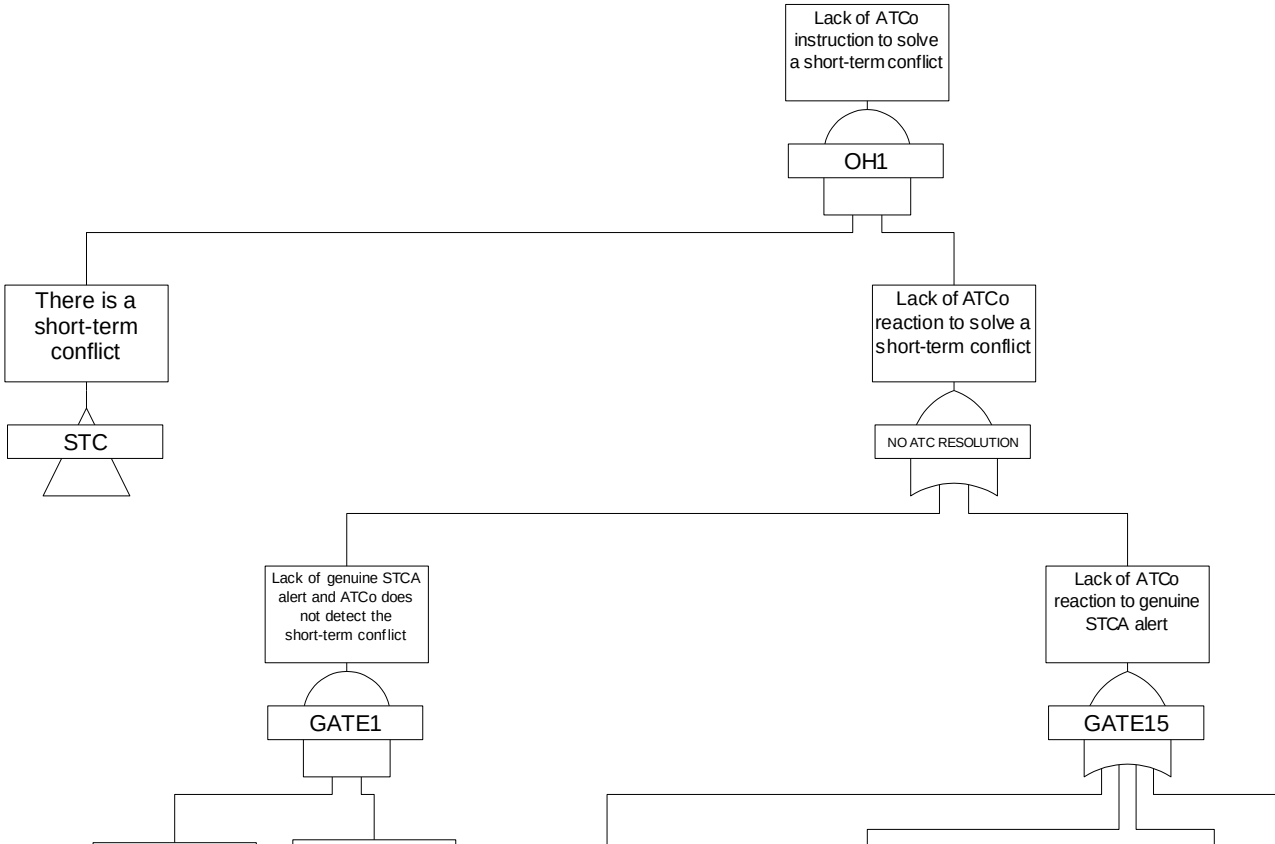
Enhanced modelling and analysis, synthesis and guidelines (4)

- 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

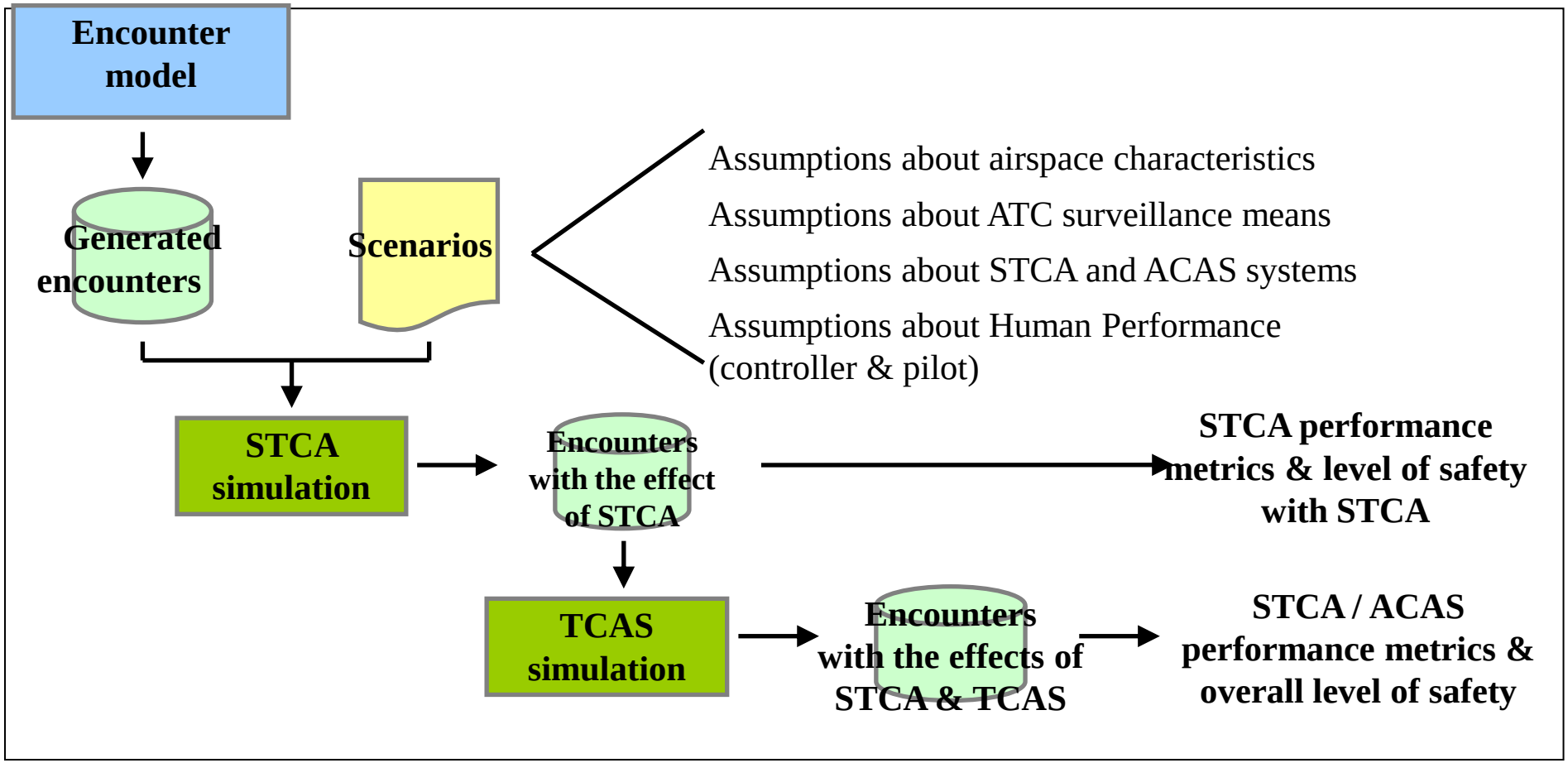


Enhanced modelling and analysis, synthesis and guidelines (5)

- 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



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 23th 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 ?