Action Plans 5/9:
Best Practices and Lessons Learned in Modeling and Simulation
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Overview

- The FAA/EUROCONTROL Research & Development (R&D) Committee was established in December 1995 during the second FAA/EUROCONTROL R&D Symposium, in Denver, Colorado
  - The objective was to reduce R&D costs by finding more efficient ways to design feasible, safe, and operationally beneficial ATM systems.
  - The focus was to define priorities in terms of common actions and agendas of both organizations.
  - The Committee identified areas of mutual interest in R&D and defined several R&D Cooperative Tasks, which are referred to as ‘Action Plans’.
Overview

• The goal of AP5 is to determine a unified strategy for validating and verifying the performance, reliability, and safety of Air Traffic Management (ATM) systems.
• One objective of AP9 is to promote a mutual understanding between the U.S. and Europe on the use and development of fast-time simulation models for modelling of air traffic operational concepts.
• An objective shared by AP5 and AP9 is to develop detailed best practices for performing tasks associated with the verification and validation of ATM systems. Covering:
  – use of metrics
  – data collection
  – data analysis
  – reporting
Action Plan 5
AP5: Validation and Verification Strategy – Objective

- The **objective** of the FAA/EUROCONTROL Action Plan 5: Validation and Verification Strategy (AP5) was to determine a strategy for validating and verifying proposed Operational Concepts taking a performance and stakeholder driven approach.
- The term **performance** alluded to the Key Performance Areas defined by the ICAO Concept Panel, such as capacity, cost effectiveness and environmental issues.
- The **stakeholders** were identified to comprise Air Navigation Service Providers and Military as well as airspace users, industry and airports.
- The **strategies** should allow for the validation and verification of Operational Concepts during the phases of research, development and implementation of airborne and ground-based ATM sub-systems.
AP5: Validation and Verification Strategy – Expectations and Goals

• AP5 was associated with the following expectations:
  – ...to *implement operational concepts* in a *timely* and *effective* manner
  – ...to facilitate the *synchronization of the plans* for the development of next generation ATM systems (*NextGen/SESAR*)

• This was translated into two goals for AP5:
  – ...to develop *common goals and principles* for operational concept validation and verification (strategy)
  – ...to facilitate *effective collaboration* between the US and Europe on the validation and verification of operational concepts of common interest
AP5: Validation and Verification Strategy – The Beginnings

• Activities in the 90s:
  – European Air Traffic Control Harmonisation and Integration Programme (EATCHIP):
    EUROCONTROL completed the *EATMS Validation Strategy Document* in 1998
  – The FAA completed the *Operational Concept Validation Process* document in 1999

• During the production of these documents, the FAA and EUROCONTROL mutually exchanged views and experiences under AP5
AP5: Validation and Verification Strategy – Terminology and the VDR

- In line with the EATMS Validation Strategy, EUROCONTROL developed a **Validation Data Repository** (VDR)
- Both parties started to collaborate in this area, initially by discussing the functionality and agreeing on a common **terminology**
- AP5 resulted already in significant cross-fertilization and a common understanding of **principles and vocabulary** had been achieved at that time
- The VDR collaboration was intensified; on request and with budget of the FAA specific functions where added to the VDR; FAA started to input their validation results into the VDR
AP5: Validation and Verification Strategy – Strategy Document (OCVSD)

- In 2000 AP5 participants were asked to compare their respective validation strategies and create a common strategy.
- The resulting Operational Concept Validation Strategy Document (OCVSD) addressed this request:
  - It established a common understanding of the context, purpose, and scope of validation.
  - It presented a set of general principles underlying the approach to be taken.
  - The document was approved by the chairmen of the FAA/EUROCONTROL R&D Committee in June 2002 and served as a common point of reference ever since.
AP5: Validation and Verification Strategy – Strategy Document and Workshops

• AP5 participants identified the need to enhance the strategy with a collection of *best practices workshops*:
  – Best Practices for *Human-in-the-Loop* (HITL) Exercises (March 2002, Atlantic City)
  – Best Practices in the Development of *Simulation Scenarios* for Validation Activities in FTS and RTS (March 2003, Rome)
  – *Scenario Use* in Concept Validation (November 2004, San Jose)

• Workshops were held in collaboration with Action Plan 9 and workshop results were appended to the OCVSD
AP5: Validation and Verification Strategy – Workshop Results: Atlantic City (2002)

Recommended practices concerning:
1. Role of HITL exercises in the validation process
2. General overview of HITL simulation process
3. Managing HITL exercise
4. Scope and fidelity considerations
5. Experimental design considerations
6. Airspace and scenario characteristics
7. Subjective and objective data collection
8. Sources of error and variance
9. Statistical and operational significance of results

Scenario Design:

- Terminology
- Scenario uses/objectives
- Drivers for scenario development
- Steps in scenario design
- Data sharing/re-use in RTS/FTS
- Development considerations
- Building traffic
- Event scripting/inducing
- Scenario information in the VDR
Three main objectives:

- What do typical scenarios cover (performance, behaviors) at each level of development?
- What are the components of a scenario at different maturity levels?
- How can the ability to compare results across projects and concepts be fostered (i.e. what aspects of a scenario can be standardized)?
AP5: Validation and Verification Strategy – Meanwhile in Europe... New Impulses

- *Experience* in applying the OCVSD was gained in the US and Europe.
- The European Commission (EC) and EUROCONTROL joined forces to develop the *European Operational Concept Validation Methodology (E-OCVM)* based on OCVSD principles.
- *OCVSD was updated* in 2005 with new material:
  - Role of *operational scenarios*
  - Relationship between concept validation and *requirements*
  - Refined methodology of a traceable, transparent, and accessible *validation process*
AP5: Validation and Verification Strategy – Preparing for the Future

- Both the OCVSD and the collaboration in the VDR were well established in the ATM validation communities in Europe and the US in 2007

- FAA and EUROCONTROL started drafting the future ATM systems:
  - US started the Next Generation Air Traffic System (NextGen)
  - Europe started the Single European Sky Air Traffic Management (ATM) Research (SESAR) Programme

- OCVSD and VDR activities continued until 2008/2009 in parallel with E-OCVM developments
AP5: Validation and Verification Strategy – What happened since then?

- In Europe several projects worked on the E-OCVM and updates of the document under guidance of a supervisory board (ValFor-SB):
  - **CAATS**: valuable input for case-based studies
  - **VARTAN**: reporting *templates* and automation for *database* (VDR) inclusion
  - **RORI-OCV**: role of *systems engineering* approach and *requirements* management

- **E-OCVM Version 3 was the latest update** and was *handed over to SESAR* for application in the SESAR Programme (2009/2010)
  - SESAR based its own approach to validation on the E-OCVM
  - Template and database approach was followed as well (DOORS, SE-DMF)
  - Architecture model was included (EATMA, MEGA)
AP5: Validation and Verification Strategy
Short Wrap-up of what’s in there...

• The E-OCVM offers 3 perspectives
  – **Concept Lifecycle Model:**
    Top-level framework for *R&D Context and Planning*
  – **Structured Planning Framework:**
    Low-level framework describing a stepped approach for carrying out *Validation Exercises*
  – **Case Based Approach:**
    Cross-level framework for finding *Evidence* at different levels of expertise (business, safety, human factors, environment etc.)
AP5: Validation and Verification Strategy – Concept Life Cycle Model

• Validation of ATM Operational Concepts:
  – Follows identification of ATM needs in validation phase V0
  – Prepares for industrialisation in validation phase V4
  – **Focuses on R&D issues** around concept definition, feasibility assessments, and pre-industrial development and integration in validation phases V1 to V3
Repeat until **Transition Criteria** are met → Then go to next Phase

**Transition Criteria** define the scope and level of information and evidence which must be available to demonstrate that the activities within a **Validation Phase** can be considered complete.
AP5: Validation and Verification Strategy – Structured Planning Framework

• Adaptable to scale and scope of concept
  – Different management levels in the *Structured Planning Framework* (SPF):
    Programme → Project → Exercise
  – Single concept elements → Concept clusters

• In large-scale programmes (SESAR):
  – Political, social or intercultural constraints and issues are NOT considered
AP5: Validation and Verification Strategy – Case Development

• Cases are used to:
  – *Group information* into clear structure
  – Describe the *potential* of the proposed concept
  – Provide *feedback* to concept developers
  – Support key stakeholders in *decision making* (investment, implementation)

• E-OCVM describes *5 cases*:
  – *Business* Case
  – *Safety* Case
  – *Human Factors* Case
  – *Environment* Case
  – *Standards and Regulation* Case
AP5: Validation and Verification Strategy –
Short Wrap-up of what’s in there...

• The E-OCVM provides a common structure...
  ...but it does NOT influence *Decision Making*.
• The E-OCVM is about Operational Concept Validation...
  ...and it is NOT a *System Development* methodology.

*The E-OCVM provides Guidelines, Context,*
*Harmonized Vocabulary and Processes,*
*and Support in carrying out Large-Scale Validation Activities*
AP5: Validation and Verification Strategy – So where are we now?

• SESAR-2020 - Exploratory Research - Call 4 - Topic 26 - Work Area 2 identifies *shortcomings in the current validation methodology* applied in SESAR

• Proposals were received addressing, among others, the following improvements:
  – Incorporating lessons learned from SESAR 1, SESAR-2020 Wave-1
  – Including current *industry best practices* (agile, scrum etc.)
  – Feedback from current *case-based approaches* (unconsidered cases?)
  – *Stakeholder commitment, decision processes, life cycle phase transition*
  – Methods to achieve more *realistic benefits*
  – New *validation techniques* (VR/AR etc.)
  – Applicability to large-scale programmes
  – Parallel *technology requirements management* processes
  – *Validation phases* currently *beyond the scope* of research and the E-OCVM
AP5: Validation and Verification Strategy – What does this mean for a possible Action Plan?

- **Re-alignment of the OCVSD**
  - Contents of current OCVSD needs to be checked against E-OCVM V3 – OCVSD was never fully aligned

- **Further development** of E-OCVM/OCVSD
  - If ER-4 Topic-26 WA2 proposals will be granted:
    - US (or AP) representative in (methodology) supervisory board
    - Update with current FAA best practices, validation techniques, NextGen feedback
    - Consult US (aerospace/software) industry for best practices in technology development
    - ...
AP5: Validation and Verification Strategy – High-level View and Outlook
Action Plan 9
AP9: Air Traffic Modeling of Operational Concepts

Started in June 2003 with the objective to:

• Promote mutual understanding between US and Europe of the use and development of Fast Time Simulation Models for modelling of Air Traffic operational concept.
• Identify areas for practical cooperation in use and development of Fast Time Simulation models
• Build upon on-going effort in the US and Europe to develop modelling capabilities.
• Support inter-connectivity of models and the use of standard input data for models where appropriate
• Promote best practices and lessons learned in the use and development of Fast Time Simulation models by US and European partners.
Catalogue of Papers Produced


Capability assessment of various fast-time simulation models

• Focus
  – To provide model developers with a forum to present their current and future modeling capabilities
  – Identify and capture existing fast-time modeling capabilities
  – Identify current and future modeling techniques
  – Identify gaps in current fast-time modeling capabilities
  – Identify sponsoring organizations needs and requirements.
Capability assessment of various fast-time simulation models

• Findings
  – Functionalities presented in the surveys are well represented
  – Gaps or areas with few responses need further consideration
    • Aircraft routing around moving weather cells
    • Environmental concerns (emissions/noise/icing)
    • Enablers (communication, navigation, surveillance, and information flow)
    • Human modeling
    • Dynamic aspects
    • Flow management.
  – Responses also indicated it would be difficult to add certain capabilities to their tool
Traffic Flow Management (TFM) in Fast-time Simulation

• Objective: Identify the current and future state of Traffic Flow Management (TFM) in Fast-time Simulation
• This was achieved by focusing on these three areas:
  – Survey existing model and methods for TFM
  – Identify future TFM concepts that might be considered for fast-time modeling
  – Assess whether existing models can be extended to address these future concepts
Traffic Flow Management (TFM) in Fast-time Simulation

Many of the capabilities needed to model TFM operations are already developed and implemented

- Slot allocation schemes, ground delay and ground stop programs, route or waypoint in-trail restrictions, changes to flight routing
- Consider applicable separation standards
- Investigate various “what-if” scenarios, including new airspace sectorization scheme, new routing schemes and restrictions, changes in demand, etc.

The results also revealed that they do not live within a single tool
Traffic Flow Management (TFM) in Fast-time Simulation

Critical areas of improvements in TFM modeling capabilities:

• Sector capacity as a function of the complexity of traffic flows
• More realistic severe weather movement and impact
• Uncertainty in flights’ 4D positions and their ability to meet expected times of arrival to a waypoint/airport
• More realistic modeling of a non-compliance with a traffic management initiative
System wide modeling in fast-time simulation

Many areas have been developed and implemented, including but not limited to:

- Modeling en-route and terminal airspace structure, restrictions and operations
- Modeling 4D aircraft trajectories
- Modeling conflict detection and resolution between aircraft, aircraft re-routing around severe weather cells, and capacity-demand imbalances
- Simplified modeling of the uncertainty in flight positions, typically as an error in lateral or horizontal position of a flight
- Simplified modeling of the controller workload and tasking as a potential limitation to sector capacity
- Modeling changes to departure time, slot allocation schemes, ground delay and ground stop programs
- Modeling airport operations
- Modeling variable levels of aircraft equipage and the resulting differences in performance.
System wide modeling in fast-time simulation

Some of the Insufficiencies

- Objective sector capacity evaluation as a function of controller workload, traffic complexity, separation standards, and weather conditions;
- More realistic interaction between airports and surrounding airspace
- More realistic conflict resolution capabilities, based on the applicable separation standards
- More realistic severe weather avoidance capabilities
- More realistic TFM and CDM modeling capabilities (especially the negotiations between the cockpit, ANSP and AOC)
Air traffic modeling of operational concepts – performance measures and metrics

• Focus
  – Determine the current state of performance measures and metrics usage in fast-time simulations.

• Key objectives
  – Research and document performance measures and metrics used in fast-time simulations
  – Identify common practices in metrics usage
  – Analyze and classify the metrics according to the International Civil Aviation Organization (ICAO) key performance areas (KPAs).
Air traffic modeling of operational concepts – performance measures and metrics

ICAO Concept Panel Measures and Metrics
1) Access & Equity
2) Capacity
3) Cost Effectiveness
4) Efficiency
5) Environment
6) Flexibility
7) Global Interoperability
8) Predictability
9) Participation
10) Safety
11) Security
Air traffic modeling of operational concepts – performance measures and metrics

• Findings
  – Due to the lack of standards, there were no two similar studies that assessed the same metrics.
  – No metrics were identified in the areas of Participation, Global Interoperability, and Security with respect to fast-time simulation
  – Very few metrics were gathered for the following key performance areas: Access & Equity, Cost Effectiveness, Environment, and Flexibility
  – Very few metrics were gathered for certain concept areas such as Communication, Navigation and Surveillance, and Traffic Flow Management
  – A more comprehensive list of metrics that covers noise, air quality, climate change and monetary impacts is necessary
• Safety
  • Most fast time simulation studies measure safety through conflict counts or indirectly through workload
  • Comprehensive quantifiable metrics to measure accidental risk, human performance and operational errors are necessary to conduct safety performance assessments of any new technology or concept
Air traffic modeling of operational concepts – performance measures and metrics

• Common Practices
  – Airspace redesign studies, which are typically to reduce controller workload, are lacking of metrics assessing the impacts on the flexibility and access & equity to the ATM users by the airspace design changes.
  – Very few papers were reviewed for CNS concepts
    • Common practice included capacity (controller workload), efficiency (flight time, delay and flown distance) and safety (conflicts)
    • None of the papers reviewed addressed impacts of better CNS capability on flexibility, access & equity or predictability.
  – Validation and verification of fast-time simulation tools and models covered a wider area of metrics encompassing all system performance related areas as well as safety.
  – Notably missing in the metrics assessing the impacts of routing and trajectory prediction analysis is flexibility, access and equity, predictability and environment
  – Although few metrics were gathered for TFM analysis it would be beneficial to include metrics to assess predictability and access and equity performance areas
Air traffic modeling of operational concepts – performance measures and metrics

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Achievements

• During almost 6 years
  – 6 papers
  – 7 interchange meetings and interviews with more than 30 ANSP, tool developers, universities and ATM R&D Centres.
  – 40 tools for different ATM and TFM analysis were identified and studied in detail.
Fully engaged
Royal Netherlands Aerospace Centre