



Episode 3
D4.4-01 - WP4 Report - En Route Consolidated Assessment

Version: 1.00

EPISODE 3

Single European Sky Implementation support through Validation



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EXECUTIVE SUMMARY

This document provides the consolidated validation exercise report for all exercises performed in Episode 3 (EP3) Work Package 4 (WP4) “En route and Traffic Management”. This document is the deliverable D4.4-01 WP4 Report - En Route Consolidated Assessment for EP3 WP4.4 “En route Results’ Analysis and Report” and contributes to the elaboration of the Integrated Report of EP3 WP2.5.

Episode 3 was tasked with beginning the validation of the operational concept described by SESAR Task 2.2 and consolidated in SESAR D3 “The ATM Target Concept”. The validation process, as applied in Episode 3, is based on the E-OCVM, which describes an approach to ATM Concept validation. However, to date, the E-OCVM has not been applied to validation of a concept on the scale and complexity of SESAR.

EP3 WP4 objectives were as follows:

- Analyse methods and validation techniques to detail the SESAR concept of operation;
- Assess the operational definition and feasibility of SESAR concept elements for the en route execution phase.

Results were obtained through expert group, gaming exercises, model-based fast-time simulations and prototyping sessions. Gaming exercises and expert groups assess the overall feasibility of the process, including roles, rules to be applied, operational procedures and interfaces.

The expert group meetings gave judgements about exercise plans, exercise reports and DOD refinements. The combination of expert group meetings with gaming sessions, especially with paper-based games refined the more immature points of the concept, such as RBT-handling and operability of new defined separation modes. The phased approach of gaming exercises with paper-based game, process simulation and web-based game showed good improvements in clarification of concept definitions.

Fast-time modelling and prototyping sessions have their strengths in analysing in a more representative environment that could impede the workability of these processes (e.g. capacity effects and operability). The operability of CTA facilitation and RBT handling were validated in three prototyping sessions. With the prototyping sessions more mature parts of the concept were further detailed and validated.

Major results were:

- Introducing the Multi-Sector Planner (MSP) to close the gap in the responsibility timeline between the sub-regional manager and the planning controller;
- In nominal cases there is no time to perform a CDM process with airspace users;
- The more capable an aircraft is the fewer constraints it will receive if aircraft with different capability levels fly within the same airspace;
- In a high workload situation controllers will neglect facilitating CTA at first as they concentrate on higher priority separation tasks.



1 INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This document provides the consolidated validation exercise report for all exercises performed in Episode 3 Work Package 4 (WP4) “En route and Traffic Management”. This document is the deliverable D4.4-01 WP4 Report - En Route Consolidated Assessment for EP3 WP4.4 “En route Results’ Analysis and Report” and contributes to the elaboration of the Integrated Report of EP3 WP2.5.

1.2 INTENDED AUDIENCE

The intended audience includes:

- EP3 WP2 System Consistency leader;
- EP3 WP2 Coordination Cell;
- EP3 WP2 Reporting and Dissemination;
- EP3 WP0 Project Management;
- EP3 WP4 En route and Traffic Management.

This document is intended for use by the exercise leader in EP3 WP2.5 “Reporting and Dissemination” as input for the consolidated project Reporting and Dissemination document.

1.3 DOCUMENT STRUCTURE

The document is structured as follows:

- Section 2 introduces the tools, techniques and methodologies used for validation;
- Section 3 describes the operability aspects;
- Section 4 summarises the performance aspects gained from validation approaches;
- Section 5 describes detailing of the concept;
- Sections 7 and 8 provide recommendations and conclusions from en route validations;
- Section 9 lists the references and applicable documents.

1.4 BACKGROUND

The main limitations of the ATM system, with respect to the airspace environment, are identified in the SESAR ATM Target Concept [6] and detailed in “Identification of Limits/Blocking Points for Airspace Environment” [2].

Episode 3 was tasked with beginning the validation of the operational concept described by SESAR Task 2.2 and consolidated in SESAR D3 [6]. The validation process as applied in Episode 3 is based on the E-OCVM [1], which describes an approach to ATM Concept validation. However, to date the E-OCVM has not been applied to validation of a concept on the scale and complexity of SESAR.

The Episode 3 project validation strategy which was managed by EP3 WP2.3 focuses more on establishing consistency of validation process and ensuring that the necessary enablers are in place to allow the effective, concept-focussed validation activity which takes place at the operational phases (Planning phase WP3, en route execution phase WP4 and TMA & Airport execution phase WP5).

EP3 WP4 objectives were as follows:

- Analyse methods and validation techniques to detail the SESAR concept of operation;
- Assess the operational definition and feasibility of SESAR concept elements for the en route execution phase;
- Consolidate the results of WP4 (this report) and deliver it to EP3 WP2 for a system integration and system assessment;
- Consolidate the detailed operational requirements in accordance with results and proposed associated changes to the concept, and deliver these to EP3 WP2 for an integrated update of the concept elements;
- The emphasis is on obtaining a first assessment of the ability of different concept elements to contribute to the defined performance benefits in the 2020 time horizon corresponding to ATM Capability Level 2/3 and the Implementation Package IP 2.

The sub-work packages in EP3 WP4 were structured as follows:

- EP3 WP4.1 *Management of WP4*: to organize the tasks inside WP4 and with Episode 3 project management office;
- EP3 WP4.2 *Validation Strategy, Support, and Operational Concept Refinement*: to develop the EP3 WP4 validation strategy (Step 0 and 1 of the E-OCVM), to identify the EP3 WP4 validation requirements (Step 2.2 and Step 2.3 of the E-OCVM), to detail the concept in scenarios and use cases, and to update the concept taking into account validation results;
- EP3 WP4.3 *Validation Exercises*: to develop the detailed experimental plans, to assess whether the concept is addressing and solving the stated problems, to provide the evidence of the operational feasibility of these processes and to produce an exercise report (remaining Steps 2.4 to 2.8 and Steps 3 and 4 of the E-OCVM) for:
 - EP3 WP4.3.1 Expert Group on En route Queue, Trajectory and Separation Management;
 - EP3 WP4.3.2 FTS on 4D trajectory management and complexity reduction;
 - EP3 WP4.3.3 Gaming Exercise on En route Queue, Trajectory and Separation Management;
 - EP3 WP4.3.4 Prototyping on Queue, Trajectory, and Separation Management.
- EP3 WP4.4 *En route Results' Analysis and Report*: to produce this report (step 4 of E-OCVM).

1.5 GLOSSARY OF TERMS

| Term | Definition |
|------|---|
| 3D | 3 Dimensions (i.e. Longitude, Latitude and Altitude) |
| 4D | 4 Dimensions (i.e. Longitude, Latitude, Altitude and Time) |
| AENA | Aeropuertos Españoles Navegación Area (Spanish ATC Corporation) |
| AI-F | AIRBUS France |
| AMAN | Arrival Manager |



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| Term | Definition |
|-------------|---|
| ANSP | Air Navigation Service Provider |
| AOC | Airlines Operations Centre |
| ARDEP | Analysis of Research & Development in European Programmes |
| ASAS | Airborne Separation Assistance Systems |
| ATC | Air Traffic Control |
| ATCO | Air Traffic Controller |
| ATM | Air Traffic Management |
| AVENUE | ATM Validation Environment for Use towards EATMS |
| CATS/OPAS | Complete Air Traffic Simulator / Outils de Planification ATM et de Simulation |
| CDM | Collaborative Decision Making |
| ConOps | Concept of Operations |
| CTA | Controlled Time of Arrival |
| CONOPS | Concept Of Operations |
| DCB | Demand-Capacity Balancing |
| DFS | Deutsche Flugsicherung |
| D/L | Data Link |
| DOD | Detailed Operational Description |
| DSNA | Direction des Services de la Navigation Aérienne |
| EC | European Commission |
| EC | Executive Controller |
| ECAC | European Civil Aviation Conference |
| EEC | EUROCONTROL Experimental Centre |
| EG | Expert Group |
| E-OCVM | European Operational Concept Validation Methodology |
| EP3 | Single European Sky Support through Validation Project Episode 3 |
| ERC | EUROCONTROL Research Centre |
| ESCAPE | EUROCONTROL Simulation Capability and Platform for Experimentation |
| ETA | Estimated Time of Arrival |
| FTS | Fast-time Simulation |
| GE | Gaming Exercise |
| ICAO | International Civil Aviation Organization |
| INECO | Ingeniería y Economía del Transporte, S.A |
| IP | Implementation Package |
| ISDEFE | Ingeniería de Sistemas para la Defensa de España |
| KPA | Key Performance Area |
| KPI | Key Performance Indicator |
| MSP | Multi-Sector Planner |



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| Term | Definition |
|-------------|--|
| NATS | National Air Traffic Services |
| NLR | Nationaal Lucht- en Ruimtevaartlaboratorium |
| NOP | Network Operations Plan |
| OI | Operational Improvement |
| PROMAS | Processes Management Simulator |
| PS | Prototyping Sessions |
| PTC | Precision Trajectory Clearance |
| RBT | Reference Business Trajectory |
| SBT | Shared Business Trajectory |
| SESAR | Single European Sky ATM Research and Development Programme |
| SRM | Sub Regional Manager |
| SWIM | System Wide Information Management |
| TC-SA | Trajectory Control by Ground Based Speed Adjustments |
| TMA | Terminal Manoeuvring Area |
| TMR | Trajectory Management Requirement |
| TTA | Target Time of Arrival |
| WP | Work Package |



2 METHODOLOGIES, TECHNIQUES AND TOOLS FOR VALIDATION

2.1 INTRODUCTION

This chapter describes how the work package exercises relating to EP3 WP4: *En route and Traffic Management* were organized. The methodology is in accordance with E-OCVM [1]. Detailed descriptions of the validation techniques and tools that were used are given in the following sections. Lessons learnt about different validation techniques can be found in chapter 6.

2.2 APPROACH

The main aim of EP3 WP4: *En route and Traffic Management* was to assess the SESAR concept corresponding to the tactical phase on the day of operation at the level of traffic management, air traffic control (including separation management) and stakeholder processes en route.

This was done by:

- Detailing working procedures for the various actors involved for each of the concept elements, based on a detailed assessment of the SESAR concept's mode of operation;
- Assessing the operational feasibility of SESAR concept elements using a variety of validation techniques and tools.

The approach used in setting out methodologies, techniques and tools for validation for WP4 was as follows:

- The first step was to use the E-OCVM as the basis for developing the WP4 en route validation strategy [7] together with a validation plan framework [13] to give guidance on E-OCVM to validation exercise leaders. This process is described in more detail in section 2.3;
- Second, using the validation strategy and the framework as guides, an exercise plan was developed for each of the WP4 exercises [14][15][16][17]. These plans were formally reviewed to ensure that they were indeed consistent with the validation strategy;
- Finally, as the plans were developed, the validation techniques and corresponding tools that would be used in the WP4 exercises were identified. These are described in sections 2.4 and 2.5. The interactions between the various techniques are illustrated in Figure 1. Note the central role played by the expert group.

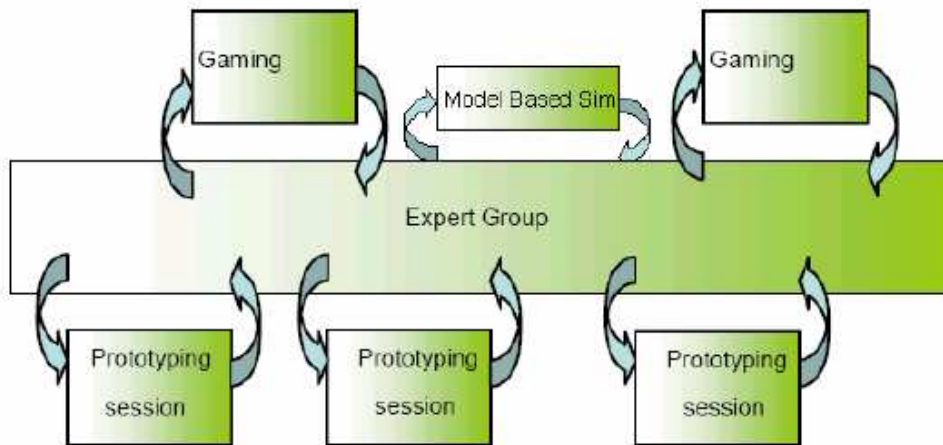


Figure 1: Schematic View of Organisation of Validation Activities in WP4

2.3 VALIDATION METHODOLOGY

The Validation methodology was defined using the tenets of the E-OCVM. The following steps were performed and applied for exercises [1]:

1. Understand the problem – using the SESAR ATM Target Concept [6] and output from SESAR Task 3.2.1, “Identification of Limits/Blocking Points for Airspace Environment” [2] as the main inputs.
2. Understand the proposed solutions – by investigating the SESAR solutions for en route problems.
3. Identify the stakeholders, their needs and involvement – for EPISODE 3; these are the European Commission, the SESAR Joint Undertaking and the project partners, divided into the ANSP and the research community group.
4. Identify the existing information, using the EUROCONTROL ARDEP data on current and recent R&D projects. Projects were recommended to consult the EUROCONTROL Validation Data Repository.
5. Describe validation expectations and outline cases – focusing on:
 - a. Clarification of the concept; recognising that the concept is large and that EPISODE 3 does not have the resources to address all areas and operational improvements (OIs);
 - b. Expanding the repertoire of cost-effective validation techniques (e.g. gaming variants) suited to these early stages of concept validation;
 - c. Consolidating our learning on the application of the E-OCVM to SESAR-scale Concept of Operations.

This step also identified parts of ConOps to be used in the WP4 exercises.

6. Identify concept performance objectives in KPA – specifying that the focus in Episode 3 is on the Societal and Operational Performance KPAs, in particular Safety, Capacity, Efficiency, Predictability and Operability, identifying which exercise would address which KPA.
7. Establish initial validation requirements – by mapping particularly relevant SESAR Operational Improvement steps and Lines of Change to WP4 exercises.



8. Select validation tools or techniques – describing how the expert group would be central to the selection of tools and techniques for use in WP4, and to provide concept clarification, as well as ensuring a link between exercises involving gaming, prototyping, and model-based simulations.
9. Define validation strategy – describing the WP4 selected validation activities. The descriptions include the objectives of the exercise or expert group, the rationale (why) and the expected results grouped per SESAR Key Performance Area (KPA).

2.4 VALIDATION TECHNIQUES

2.4.1 Expert Group

The EP3 WP4.3.1 expert group on En Route Queue, Trajectory and Separation Management was based on the Delphi Method to conduct the expert group. This method consists of the systematic solicitation and collation of judgments on a particular topic through a set of carefully designed sequential questionnaires interspersed with summarized information and feedback of opinions derived from earlier responses.

A limitation of the Delphi Method is that it does not suggest any meetings where experts are able to discuss some key points, share information and consolidate the results. Since these kinds of meetings are considered important in this context, the present expert group used a modified Delphi method, by including some meetings where the analysed information coming from the questionnaires was further analysed by the participants.

The expert group management method aimed to extract and maximize the benefits that every expert group method presents and minimize its disadvantages. It takes advantage of the synergy of the group discussion and removes undesirable interactions that exist within any group, so that the consensus reached is as reliable as possible. Expert group meetings are dependent on a good preparation and expert facilitation. The expert group Management is based on three main features:

- Anonymity: Various sets of questionnaires were distributed to all experts and the answers of each one gathered prior to the subsequent meeting. The proposals and opinions of each member of the group were anonymous, being disseminated to other experts in an integrated form, without specifying the author of each clarification;
- Controlled feedback and iteration process: There were various rounds of questionnaires plus meetings, which allow the members of the expert group to know other member's opinions and thus modify their own former opinions;
- A report that includes the agreements and the hot spots discussed in the different sessions.

The WP4 expert group was used with the objectives of supporting the WP4 exercises and for en route concept clarification

The feedback to the exercises was performed through meetings of experts and exercise leaders. The meetings took place:

- Before the initiation of exercises as support to their initial approach and assumptions (in some cases this happened before the EP3 suspension);
- During the iteration of exercises;
- At the end of exercises to consolidate their outputs.

The meetings were structured as a set of presentations followed by a workshop. At least one week before the meeting a summary of the WP4 exercise of interest was distributed among the experts together with the list of related documents.



At the meeting, the leader of the exercise presented a summary of the exercise. Members of the expert group presented a summary of the documents related to the exercise. After the presentations the feedback of the experts was collected through different means depending on the needs e.g. workshop with cards, live update of a document.

2.4.2 Gaming Exercise

Three different types of game have been used in EP3 WP4.3.3 "*Gaming Exercise on Queue, Trajectory and Separation Management*". These were: paper-based games, a fast-time process simulation game and a web-based game.

Paper-based Role-play Game

Paper-based games have been used as a technique that promotes non-routine thinking. Gaming provides an additional insight to the findings of the EP3 WP4.3.1 expert group results, whilst validating the principles behind "En route Queue, Trajectory & Separation Management". A Role Game is an exercise where experts assume a role within a designed scenario. The role that the expert has to assume has specific objectives and tools that facilitate their achievement. The scenario is defined according to the objectives of the exercise.

The "game fundamental structure" which identifies and describes the components that constitute a particular game are:

- Actors/Roles of the game;
- Inputs and outputs to/from the game;
- Processes involved in the game;
- Information sets or game packages which consist at least of the following information: rule set, game manager script, participant script;
- Grids to control the game evolution and collect the information;
- A predefined operational scenario.

The paper-based game technique used paper information sets as tools. The gaming design technique was adapted to allow improving the goals that are defined at the initial design of the game (i.e. either by refining them or by changing the processes that lead to them), replacing the goals (if they prove infeasible) or changing the game altogether (if the approach or the results do not prove to be viable). Results of gaming exercise were recorded in detailed storyboards.

Fast-time Process Simulation Game

Fast-time process simulation used the PROMAS platform as a new gaming-compatible technique, to assess complex systems by means of Fast-Time Process Simulations. After analysing the processes used in the paper-based gaming sessions, the relevant gaming part was modelled, and subsequently the process simulations were executed. In the framework of WP4.3.3, PROMAS modelled the processes and provided a first assessment of their viability. The programme performs the role of the components in the scenario and reproduces the system operation activities including processing time of each actor.

Web-based Game

The web-based game was used as an evolution from the paper-based game, without entering into the development of a complete game platform. This technique enabled a better (and more realistic) description of the scenario where the paper-based game takes place, together with a first simulation of the tools used by the different roles. At the same time, the web-based game gives a tighter game structure that limits the possibility of adaptation of the game to the development of the session and makes difficult the improvement of the goals defined in the



initial design of the game. Results of fast-time process simulation are incorporated as detailed interactions between actors and timing dependencies.

2.4.3 Fast-time Modelling

The EP3 WP4.3.2 fast-time modelling studied whether adjusting the departure time of aircraft could lead to a workload reduction, which would enable a traffic increase while still maintaining a sufficient safety factor.

In this context, the objectives of this exercise were:

- Propose and study an algorithm to execute departure time allocation, when 4D flight plans are provided;
- Evaluate the workload reduction that can be obtained according to the time dispersion allowed for takeoffs.

The exercise consisted of a series of fast-time simulations. The fast-time modelling can be described as the following steps:

- Generation of aircraft trajectories from initial demand, using a fast-time simulator;
- Data processing: computation of 3D crossings between trajectories;
- Optimization: allocation of takeoff times;
- Verification: input the allocated takeoff times into the fast-time simulator to verify the correctness of the model and the solution found.

2.4.4 Prototyping Sessions

The work in EP3 WP4.3.4 was organised as a series of three prototyping sessions that took place at the EUROCONTROL Experimental Centre (EEC). Prototyping sessions evaluated the potential for the new functionality and techniques needed to accommodate predicted traffic levels in ECAC en route, in the intermediate timeframe, typically from 2015 onwards.

The focus of the sessions was operability and concept clarification. A prototyping approach allowed an iterative process to be followed, introducing the concept elements step by step, and allowing interactions with the expert group between each step, and feedback from the Operational Controllers to be included in the design of the subsequent sessions.

The introduction of the prototyping approach in Episode 3 was aimed at providing efficient support for clarifying some concept elements.

Its advantages are:

- Reduced cost: small scale focusing on specific issues;
- Iterative process, building from one session to the next;
- Flexibility: implementation of changes from one session to the next.

Its limitations are:

- Limited time to train the controllers (a maximum of 1-1.5 days per session);
- The focus is on operability, so any performance indications are in terms of trends rather than absolute performance measures;
- Limited time between sessions to conduct acceptance tests on the platform.



2.5 VALIDATION TOOLS

2.5.1 Paper-Based Role-Play Game

The paper-based games that were performed were played with experts behaving as actors at a table. The tools used were presentations, papers and pens. The rules of the games were easy to understand, obviated the necessity of training sessions, and focused discussions of the experts on the concept being addressed without closing alternative approaches.

The paper-based game allowed the exploration of concepts in a structured way focusing the experts' attention on the information flow and responsibilities associated with the processes.

The main division was established on human and non-human elements. The human elements in the role-based games were game manager, game assistants, players and spectators. Information sets consisted of the following information: game manager script, assistant script, and participant role sets. Details are described in annex 1 and [20].

2.5.2 Web-based Game

The web-based game use the Flash and Object script programming capabilities to reproduce a SESAR 2020 environment in the execution phase. The different actors were given access to their own tools and screens. A common scenario was presented but each actor had only their partial point of view and was able to communicate only through the tools implemented in the game. Participants were playing different roles and a game manager was needed.

The scenario incorporated real time operations and a more realistic (than paper-based) representation. This realistic representation included also flights that did not take an active part in the scenario.

A game manager oversaw the action, ensuring that the development of the game followed the applicable rules, and resolving technical doubts about the use of the platform.

2.5.3 PROMAS

PROMAS offers a new Gaming-compatible technique, to assess complex systems by means of Fast-Time Process Simulations.

The PROMAS platform was further developed and defined to perform the associated tasks as a gaming compatible platform. This enabled the platform to assess complex systems by means of fast-time process simulations

Process simulations were implemented in PROMAS, which is a tool to represent the operation of any type of organisation or system by means of fast-time simulations based on discrete events. This software provided a detailed event log referring to the system operations. After processing the simulation output data, the required information was extracted to evaluate relevant outputs.

By using one of the multiple capabilities of this application, it was possible to reproduce a game. The program performed the role of the components in the scenario and reproduced the system operation activities.

2.5.4 CATS/OPAS

CATS/OPAS was used as fast-time traffic simulator with an integrated optimization algorithm. Its light structure made it quickly adaptable to the exercise, and it provided support for generating both direct and standard routes for the different runs.

The method chosen for the resolution and optimization of the problem to adequately adjust the departure time of aircraft was a genetic algorithm. This optimization algorithm is based on techniques derived from natural evolution: crossover, mutation and selection.



2.5.5 ESCAPE - Validation Infrastructure Real-Time Simulation Facility

ESCAPE was used as a small scale real-time simulation platform with prototyping capabilities in three prototyping sessions. This tool was also used for TMA prototyping sessions in EP3 WP5. ESCAPE was developed to provide simulation and trials platforms based on components from Industry to support the validation activities of the European ATM Program and the EC Single European Sky initiative. ESCAPE aims to provide a platform for the rapid introduction of new technologies, and has adopted a functional and technical strategy for simulator development that follows standards (AVENUE) defined and accepted at a European level. These standards are designed to ensure that simulator components are interchangeable, no matter where they are developed.



3 OPERABILITY ASPECTS

3.1 INTRODUCTION

The organisation of each exercise to gain operational results is shown in section 3.2. The main results of the en route execution exercises are described in section 3.3.

3.2 APPROACH (HOW THE WORK WAS DONE)

The en route execution phase work package addressed the operability and performance of the processes related to the day of operation when the plan developed through the collaborative planning processes is executed.

The exercises were primarily aimed at refining roles, procedures and working methods of the controllers, and assessing the impact of aircraft adhering to a RBT. The exercises are sequenced to validate different parts of the operational concept [3]. Figure 2 shows the interactions between the activities in WP4.

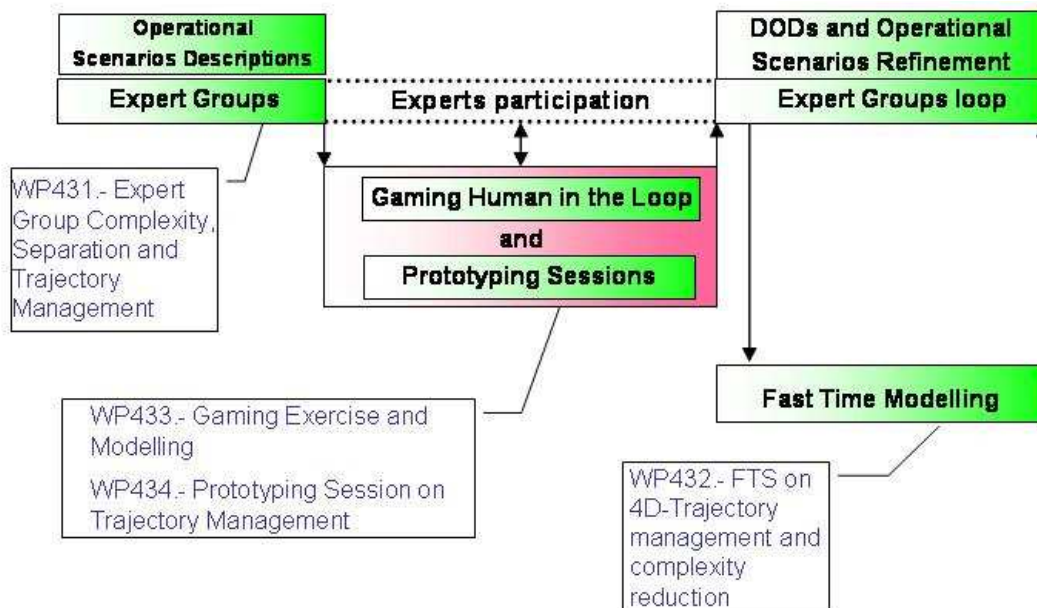


Figure 2: Organisation and sequence of validation activities in WP4

3.2.1 Expert Group

The expert group was the backbone of EP3 WP4. It generated questions/tasks for gaming exercises and prototyping sessions and also interacted with the Fast-time Simulation (FTS), which was a model based simulation. It also produced definitions and clarified main parts of the concept. After completion of validation exercises, the experts contributed to the interpretation of the results of these exercises. The interpretation was given in terms of refinement of the DODs [10], [11], [12] and the overall report of WP4 (this report). Expert group conduct is detailed in chapter 2.4.1 and in the expert group report [18].

3.2.2 Gaming Exercise

The gaming exercises were designed as a three successive step approach to trajectory management in the en route phase.



In the first step, the paper-based game defined different scenarios that covered the complete en route phase. Improvements in the description of roles, tools and processes fed the next scenario and game session. The scenarios are located in the timeframe of 2020. Caveats which appeared during one session fed the expert group questionnaire and were discussed within the expert group. Before each gaming session, the objectives of the game and the main topics that covered the gaming session were presented to the experts.

An information flow was developed in the definition of each scenario. This information flow was updated with the conclusions extracted from the gaming sessions. Depending upon the scenario different assumptions were used. The common ones are:

- All Flights have access to NOP via SWIM;
- All Flights have their own RBTs;
- D/L is the main tool for communications in 2020 but it is not used for critical communications;
- Some of the controllers responsibilities are: ensure safety, avoid problems, establish coordination, avoid open-loop instructions and use D/L for closed loop instructions.

The second step used the PROMAS platform and the processes and information flows described in the paper-based games. The scenarios were composed of the set of rules, actors and the traffic sample, as well as the set of parameters that defined the strategy to be assessed; these scenarios were based on the interim report and the OS-38 [8].

The main assumptions¹ considered in designing the scenarios and running PROMAS were:

- MSPs may have under their responsibility up to 4 sectors at the same time;
- An immediate conflict will be resolved by a planning and an executive controller (with no MSP) in one set of scenarios or by a MSP and an executive controller in another set of scenarios;
- The RBT of the aircraft involved in conflicts may be updated by the flight crew after being agreed and instructed by the executive controller or MSP;
- A conflict that will occur near the entry border of a sector where the aircraft has not entered yet and this sector belonging the MSP Area, will be resolved by the MSP. It may be coordinated with a planner (if any) and an executive controller;
- This type of conflict may be resolved by revision of the RBT by the flight crew after being agreed and instructed by the executive controller. This resolution will imply a change in the RBT at the moment of the detection of the conflict;
- A conflict that will occur outside the measured sector will be resolved by an adjacent MSP;
- This type of conflict will update the part of RBT within the measured sector coordinated by the adjacent MSP via NOP/SWIM.

The last step, the web-based game, develops one scenario based on the scenarios previously developed for the paper-based game. It is developed in a more realistic presentation and interactive tools have to be used through a computer. The simulation includes one scenario divided in two successive stages.

- In Stage 1, the CDM process between Sub-Regional Manager (SRM) and Airspace user takes place;

¹ These assumptions are based on clarifications of expert group and on experimental constraints of PROMAS.



- The MSP is, in stage 2, responsible for the complex area. After evaluation of the situation and proposals of changes to the RBT, the changes are implemented via executive controller or communicated directly to the Flight Crew depending on the available time.

Additional information is given in chapter 2.4.2.

3.2.3 Prototyping Sessions

The first session aimed at refining the controllers' roles, working methods and ATC procedures, and assessed the impact of the Reference Business Trajectories (RBT) on controller tasks. The second session assessed the introduction of an improved environment and Controlled Time of Arrival (CTA). The third session including segregated/reserved areas (military) focused on the impact of CTA on the delivery conditions of aircraft to TMAs. Prototyping sessions used samples of traffic for 2015.

Each measured session consisted of performing eight measured runs. Each run was followed by a post-exercise questionnaire and a collective debriefing. In addition, observers present in the operations room captured spontaneous controller comments on the topics of interest and on problems that occurred. A specific seating plan was made for each session to allow statistical assessments.

3.3 OPERABILITY RESULTS

Multi Sector Planner role. The expert group detected a gap in the responsibility time-line between the sub-regional manager and the planning controller, as well as in the main focus of the responsibility: while the sub-regional manager focuses on traffic flows in their sub-region, planning controllers are focussed in the individual RBTs of flights that are about to enter their sector. The expert group determined that the Multi-Sector Planner (MSP), whose responsibilities are described in SESAR Roles and Responsibilities, covers this gap. The main task of the MSP would be to propose changes to the individual RBTs trying to reduce complexity and minimize conflicts within the sectors, and facilitating the work of the executive controllers. The expert group remarked that if MSP replace several planning controllers, there should be an executive controller assistant sitting at each executive controller for safety reasons.

The Multi Sector Planner role will lead to a decrease in the number of potential conflicts to be solved by the executive controller and will lead to an increase in the capacity of the en route sector under its responsibility.

CDM. In nominal cases, when the MSP has the RBT under his/her responsibility or, for example, the time horizon to operations is less than 30 minutes, there is no time to perform a CDM process with airspace users. This does not mean that a CDM process cannot be implemented even during the tactical phase. The variable which limits the option to implement a CDM process is the time horizon not the phase of the flight.

Regarding the En route execution phase operations, the expert group supports the statement from gaming exercises that the use of Collaborative Decision Making (CDM) processes which include the user is not always effective and desirable. There are processes that although not tactical, should not trigger this CDM process, as they will be repeated several times during normal operation, and the time that the actor, MSP/planning or executive controller, needs to dedicate would prevent him/her from performing the rest of his/her tasks. This does not mean that there will not be CDM processes with users. This means that the period where performing CDM process is not feasible is not limited to tactical interventions. [20]

Aircraft Capability Level. The gaming exercises gave results for aircraft with different Capability Levels which will coexist within the same airspace. The more capable the aircraft is the fewer constraints it will receive. In other words, usually the most penalizing constraints will be assigned to the less capable aircraft. The mixture of the separation modes may result in



airspace not being optimised due to the different equipages and capabilities. It could be concluded that equity will not be maintained.

CTA. Prototyping sessions showed the following result: In a high workload situation. The controllers reported that facilitating CTA will be the first constraint which will be neglected as controllers concentrate on higher priority separation tasks. As the aircraft are flying to target times by using speed control, controllers were, therefore, discouraged from using speed control. A consequence of this is that they felt that one element of the currently available Controller toolset had been removed.

Trajectory Management. In the prototyping sessions, every flight was flying a unique preferred trajectory. This had consequences for the controllers as potential conflicts are now distributed across sectors rather than at defined crossing points. In order to mitigate this it was reported that:

- Information exchange from cockpit to controller is required to help the controller to make an overall assessment of how aircraft will be flown (especially what will be the speed profile and which time constraints exist);
- The airspace and route structure need to be addressed. There needs to be optimisation of the shape of the airspace and structures within it particularly for complex traffic;
- The agreed RBTs must consider vertical profile;
- The agreed RBT profiles should segregate traffic.



4 PERFORMANCE ASPECTS

4.1 INTRODUCTION

An overview of the assessment of performance indicators is given in section 4.2 and in section 4.3 some trends to performance indicators are given. Significant quantitative results for an ECAC wide assessment are not given due to the parallel development of exercises and performance framework and due to the local character of EP3 WP4 exercises.

4.2 APPROACH/METHODOLOGY

An integrated assessment of performance aspects was undertaken in Episode 3 Work Package 2.4.1 [23]. It provided a methodology for future assessment of the SESAR concept on a 2020 ECAC-wide basis.

This methodology allows the aggregation of validation measurements of different levels of granularity, e.g. local versus regional, and uncertainty, e.g. expert judgement versus simulation. The methodology is based on:

- An understanding of the elements that contribute to and influence performance (Influence diagrams);
- An ECAC Model that represents the elements that are linked and the mechanism to combine their influences. (Influence models);
- The definition of a catalogue of common Performance Indicators (PIs) as references to ensure consistency and capture data about the influencing factors from exercises, expert group, current and past studies.

The common references defined in this catalogue of performance indicators were used by the validation exercises contributing to the quantification of performance. The EP3 WP2.4.1 Performance Framework has defined different layers of performance indicators according to SESAR's Key Performance Areas (KPAs). Further details are described in the Episode 3 overall project report [22]. The described performance framework was not applied on the exercises due to parallel development.

4.3 KEY PERFORMANCE AREA RESULTS

Expert group, paper-based and web-based games did not give figures on performance aspects.

The fast-time process simulation provided feedback on four performance indicators selected from the performance framework. Please note that the results are based on local simulations in four sectors of Spanish airspace.

The fast-time modelling technique that was used only allows trends in performance aspects to be identified. Fast-time simulations can provide capacity values, but not with the approach that was used. The applied assumptions were too generic, i.e. unlimited runway capacity.

Prototyping sessions gave results on operability which are described in chapter 3.3.

4.3.1 Capacity

Results from Fast-time Modelling showed that an adequate allocation of takeoff times could contribute to an increase of capacity, by providing de-complexified traffic. However, the study was not ECAC-wide, due to computation limitations.

Results from fast-time process simulation showed CAP.LOCAL.ER.PI 5 measures the maximum number of aircraft that can enter an airspace volume in one hour, based on the



maximum task demand the tactical controller can deal with in this period of time (threshold) [23].

With all these results, it can be concluded that in the scenarios where the MSP is involved, the sector capacity increases in all the sectors.

Also, some of the 4-sector scenarios showed a bigger increase, for example DOM with a increase of 17% in its capacity. On the other hand, sectors PAU and ZMU with a little increase in their capacity (2% and 4%) are border entry/exit sectors of the MSP Area. It can be concluded that this type of sector does not receive as much help as the sectors in the middle of the MSP Area which experience a bigger increase in their capacity (17% and 9%).

4.3.2 Efficiency

Results from fast-time process simulation showed EFF.LOCAL.ER.PI 7: measures the efficiency of routing service - the number of flights that will change their 4D trajectory due to a conflict resolution [23].

The number of flights that will have an immediate conflict will decrease in all sectors, and hence, the number of flights that will change their trajectory due to immediate conflict resolutions will be reduced. The number of conflicts remaining in 2-sector scenarios is higher than in 4-sector scenarios.

4.3.3 Environment

Not assessed.

4.3.4 Flexibility

Not assessed.

4.3.5 Predictability

Not assessed.

4.3.6 Safety

Results from fast-time modelling indicated that an adequate allocation of takeoff times was likely to enhance safety. In all fast-time simulations in the exercise, the algorithm was able to provide traffic with fewer than 5% of the conflicts that would have occurred without any modification.

Results from fast-time process simulation showed SAF.LOCAL.ER.PI 1 measures the number of hours with overloads of ATC workload² [23].

With these results, it can be concluded that the MSP reduces or keeps steady the workload of the executive controllers. In addition, the improvement in the number of overloaded hours of the controllers is higher in the 4-sector scenarios. In scenarios with few sectors, the workload was reduced, because of the conflicts avoided by the MSP. However, this is roughly offset by the workload generated by the "MSP-executive" resolution actions. This means that a scenario with few sectors does not much reduce the workload.

² In this context, to be "overloaded" means that workload of the controller is over 2520 s. (70% of 3600s). Each of the actions of the controllers has been assigned a specific amount of time (workload) and the addition of all the events in every hour has been calculated.



Results from fast-time process simulation showed SAF.LOCAL.ER.PI 3 measures the number of ATC tactical interventions – the number of times an ATC tactical intervention is needed in order to avoid a potential conflict on air; the number of losses of minimum separation³ [23].

It can be concluded that all scenarios benefit from the MSP resolutions (avoiding between 1 and 6 conflicts per resolution in this exercise). However, in one of the sectors the number of conflicts avoided is lower than the MSP interventions, so the ratio is less than one (PAU in the 4-sector scenario. This sector is one of the “border” entry/exit sectors of the MSP Area).

In 2-sector scenarios, DOM and TLU do not benefit as much as 4-sector scenarios and the conflicts avoided in these sectors are matched by the MSP requests for interventions by their executive controllers.

³ The number of tactical interventions that each controller makes in order to avoid any kind of conflict in any sector included in the MSP area was calculated. In addition, these results showed the number of conflicts avoided in each sector due to resolutions from other controllers.



5 CONCEPT DETAILING

5.1 INTRODUCTION

This chapter describes the approach to detail the SESAR concept of operation and summarize results of the exercises in en route execution phase.

5.2 APPROACH

The approach adopted by WP4 towards detailing elements of the SESAR ConOps was as follows:

- Review relevant parts of the ConOps and the ATM Process Model;
- Discuss the concept with the WP4 En Route Expert Group, and Detailed Operation Descriptions (DODs) with the WP2 co-ordination cell;
- Expert group explores issues raised by WP4 exercise leaders;
- Develop Operational Scenarios using results of expert group sessions;
- Exercise leaders develop exercise plans, using operational scenarios, and discuss issues with expert group;
- Exercise plans reviewed for consistency with ConOps, Validation Strategy and DODs;
- Conduct and report on exercises;
- Exercise results used as input to this document, to the Episode 3 Final report [22] WP2.5 report, and to updates of operational scenarios and DODs.

The relevant sections of the ConOps were reviewed – in particular those relating to the new separation modes envisaged in SESAR:

- Precision Trajectory Clearances;
- 2D Routes (PTC-2D);
- 3D Routes (PTC-3D);
- Trajectory Control by Ground Based Speed Adjustments (TC-SA);
- Cooperative Separation (ASAS Separation).

The corresponding section of the ATM Process Model (Manage Execution Phase) was reviewed.

The WP4 En Route Expert Group meetings discussed these elements, and answered relevant questions raised by the other WP4 exercises as they developed their exercise plans. There were also discussions about the DODs with WP2 (specifically the co-ordination cell). The discussions took place via e-mail, face-to-face meetings, and teleconferences.

The output of the En Route Expert Group meetings was used as input to coordination cell discussions, and to the scenarios being developed for the WP4 exercises. OI steps were used as inputs to the scenarios, particularly the OI availability dates. The two scenarios ([8], [9]) were used by the exercise leaders as they developed the plans for their validation exercises. DODs E4 [11] and E6 [12] were reviewed to ensure consistency between scenarios and DODs.

The exercise plans were reviewed to check consistency with the ConOps by members of the En Route Expert Group and by EUROCONTROL experts. WP4 contributed significantly to the elaboration of the EP3 Technical Review and Approval process



The results of exercises were reported ([18][19][20][21]) and used as input by WP2.5 for their report [22], and to update the Operational Scenarios and the DODs.

A number of things contributed to the success of WP4 in developing the concept:

- The Information Navigator was invaluable as a consistent and common source of information on the ConOps, OIs, Lines of Change and enablers;
- There was a constant interchange of information and opinions between WP4, WP5 and the Co-ordination cell by means of e-mail, face-to-face discussions and teleconferences. These debates ensured continuous alignment between ConOps, DODs and scenarios;
- The technical reviews and concept debates were vital in ensuring that the WP4 exercises provided relevant results that would contribute to a greater understanding of the ConOps.

5.3 CONCEPT RESULTS

The SESAR concept was examined in detail. In this section, only the main areas of change to the DODs are highlighted. The impact on DOD E6 [12] was done directly in the expert group.

In the en route execution phase, the use of CDM processes⁴ which include the user is not always effective and desirable. There are processes that although not tactical, should not trigger this CDM process, as they will be repeated several times during the normal operation, and the time that the actor, MSP/planning or executive controller, needs to dedicate would prevent him/her from performing the rest of his/her tasks. This does not mean that there will not be CDM processes with users. It means that the period where it is not feasible to perform CDM processes is not limited to tactical interventions.

The preference of the users will be taken into account through the use of a catalogue of solutions that contains the pre-agreed solutions to problems which are not planned but are likely to occur during the normal operations of the flight. This catalogue of solutions would have been agreed with the users during the planning phase. Controllers are not limited to the solutions in the catalogue.

During the execution phase, the sub-regional manager deals with the optimisation of flows and resources in the area of responsibility, and is the main actor that performs CDM processes with users through the AOC. MSP/planning controllers deal with individual RBTs reducing complexity and minimizing conflicts. Executive controllers ensure separation, if not delegated, and facilitate the execution of the RBT. If planning controllers are replaced by MSP, an executive controller assistant should be introduced at each executive controller for safety reasons. MSP/planning and executive controllers contact flight crews when performing their activities. This is the general basis; exceptions may occur depending on the situation.

The en route management of the execution phase does not generate queues. The queues managed are generated by network operations and the AMAN.

Regarding the AMAN, the WP4 expert group agreed with the expert group from WP5 that short term DCB will smooth the traffic to congested destinations to achieve a low variability of planned arrivals, preventing heavy bunching at airports. This smoothing goes beyond what the NOP alone can achieve.

The use of extended AMAN will facilitate the creation of an enhanced and more consistent arrival sequence increasing predictability and increasing the time available to the executive controller for facilitating the aircrafts' achievement of the TTA issued by AMAN.

⁴ CDM is understood as an electronic exchange (including data link and voice com) with the user.



4D trajectory management is defined as a situation where an aircraft is flying its RBT and can follow one or more time constraints in each route clearance with the required avionics performance, but it is still not responsible for separation in managed airspace which is conducted by the controller, applying the best suitable mode. Experts think that the use of 4D trajectory management will greatly improve Capacity, Efficiency and Predictability. The tools used have to be consistent in the sense of using the same data and should have knowledge of the aircraft performance capabilities to propose and assess RBT changes. The principle of operation in 4D trajectory management is that the best equipped aircraft will be favoured in constraining situations.

Strategic complexity reduction using accurate 4D data will be a method of optimising the airspace, reducing complexity, number of possible conflicts and consolidating sectors. The use of mixed mode of operations in airspace can produce adverse effects in increasing capacity.

During the transition between PTC-2D and the use of ASAS, the system in charge of the ATC (ATCO + tools) will be in charge of safety and the consistency of the air situation with the transmission of the appropriate clearances. This means the delegation of the separation task to the cockpit is temporary and the ground system is in charge of the overall consistency of the air situation. The ground system will be able to intervene and can give clearances to aircrafts flying under ASAS conditions for separation purposes if needed.

The main open points/hot topics are described in chapter 6.1. Further details will be found in chapter 3.3 and in exercise reports [18] to [21]. Detailed storyboards are depicted in the gaming report [20]. All results are integrated in DOD E6 [12] and in operational scenario OS-38 [8].



6 HOT TOPICS AND LESSONS LEARNT

Hot topics of the concept which need further investigation are described in this section as well as lessons learnt about different validation techniques, performance assessment and concept detailing.

6.1 HOT TOPICS

Concept refinements with no common agreement are marked as hot topics and summarized in this section.

- Once an RBT is changed, new adjustments must be done with as a little deviation as possible from the last agreed RBT or to the initial RBT.
- The degree of airspace users' involvement in terms of impact on the SBT/RBT when a route structure area is activated needs to be further analysed. E.g. airspace users can decide if they want to delay the flight on the ground or if they want to enter to the high complexity area taking into account that the MSP has the possibility of making tactical changes to the RBT to accommodate and fine-tune all the flights and facilitate the task of the executive controllers of the transition areas.
- Definitions needed for RBT update and RBT revision. No agreement was reached about the exact definition of the two items, but the general idea of the definition was agreed.
On the one hand, some experts agreed that if changes in RBT are included within the limits of the TMR, there is no need of update. But, who establish these limits? Are these limits the same for all aircraft? And, on the other hand, another group of experts discussed that any change should be updated in the SWIM. Further investigation is needed and should be done in line with DOD E6 [12].
- How will the aircraft return to an RBT after an open loop instruction? The confidence of the downstream portion of the RBT is not clear. After an open loop instruction the RBT will be suspended. The open loop instructions are limited to updates but not used in revisions. There are two kinds of open loops, those that the (ground) system will automatically close, and those that are a permanent open loop (e.g. permanent heading). This last kind will not be used in the SESAR environment. No open loop instructions should be used in SESAR 2020.
- Will "successively cleared" imply a clearance limit with regard to the RBT meaning that the flight crew will need to receive and acknowledge a succession of clearances, or will it imply a seamless process only constrained by the horizon of the controller tools which is transparent to the flight crew?
- The feasibility and the nature of the CDM which includes airspace users during the execution phase itself have been questioned. Further research may be required regarding the effectiveness, or even desirability given the limited time window that might be available for this procedure.
- Definition of TTA. It should be defined which are the time windows related to ETA (if any), TTA and CTA, and the consequences of not achieving them. The applying of each of these constraints should also be defined. To develop a better understanding of TTA, it is proposed to write a small scenario demonstrating its application. The ConOps does not regard a TTA as a time constraint but rather as a goal to be achieved by the Flight Crew. However, for a TTA to be meaningful, there must be seen to be a commitment to achieve the goal and the WP4 EG has proposed that the RBT be managed under these circumstances within parameters of about -2/+3 minutes. In which case does the TTA therefore effectively become a constraint?



- There is a need for a clear definition of 'equity', as different experts understand it in different ways.
- The process of how the Flight Crew unilaterally revise the RBT for self-separation purposes needs further investigation and elaboration. For example, what will be the impact on TMR and the ground version of the trajectory and controller tools?
- One issue detected regarding ICAO legislation is that in this legislation it is written: that only one executive/planning controller can communicate with an aircraft. This phrase should be reviewed if MSP will communicate RBT changes to aircraft, especially if several MSP can modify the same RBT at one stage.

6.2 ISSUES FOR FURTHER VALIDATION

After discussion about results of various exercises some issues for further validations remaining. These points are summarized in this section.

- Air traffic measures to reduce complexity should only be applied if there is sufficient level of accuracy in the prediction of the trajectories (known aircraft). The level of accuracy must be balanced against the necessity of applying the measures as soon as possible to promote their effectiveness.
- In a mixed equipage environment, the expert group detected the need for a clear definition of the different responsibilities, and the possibility that airspace organisers and managers might establish zones where ATM capabilities match the same requirements to decrease complexity and controllers' workload.
- Extended AMAN points that need further investigation:
 - Single airports with overlapping individual AMANs;
 - Single airports with single AMAN;
 - Multiple single airports with multiple overlapping individual AMANs;
 - Multiple airports with single AMANs overlapping with the same type of clusters.
- Further validation is needed in the relationship with military authorities. In really high-complex situations, if a military training area is activated within the airspace concerned, would it be possible to negotiate with the military to get the closure of the area until the complexity disappears? Experts discussed that, according to SESAR, there will be pre-agreed scenarios that include this situation.
- The legal responsibilities in Airborne Separation manoeuvres must be clear before their incorporation in the ATM environment.

6.3 LESSONS LEARNT ON TECHNIQUES

6.3.1 Expert group

It is very important for the correct development of the expert group that experts read all the documentation before attending the meetings. The time needed to read this documentation must not be underestimated, as it may include several documents of the project.

It should be assured that the same experts attend the meetings. This avoids discussing the same issues in different meetings. For this objective, it is necessary to have accurate minutes of the meetings.

The modified Delphi method enables experts who could not attend one session to contribute their opinions. The anonymity of the method was broken as some experts sent their answers to all the participants of the meeting. The performance of meetings decreased the effect of the



desired effect of minimising the impact of influence from other experts. The performance can be increased by issuing three questionnaires between face-to-face meetings instead one questionnaire.

The use of brainstorming in the workshops was useful as a way of presenting all the different ideas, but notes must be taken, as one phrase alone in a board is very difficult to contextualise afterwards.

The composition and field of expertise of the participants greatly influences the expert group and must be carefully chosen.

6.3.2 Gaming

The use of three different gaming techniques has expanded the cost effective validation techniques available. The paper-based technique is adequate to assess and define information flows, roles and responsibilities and detect gaps. It is a step forward in the development of a concept as it asks how the different actors will perform a function. The use of process simulation supports the defined processes with quantifiable metrics. Finally the use of a web-based game allows the validation of the results through the exposition of the scenario to a broader expert community.

The ideal process of the use of these three techniques would have been:

- Conduct of several paper-based games;
- Performance of the process simulation;
- Clarification of issues that appeared when analysing the process simulation outputs, through new paper-based games;
- Update of the process simulation and process flow;
- Performance of the web-based games using the consolidated process flow.

These techniques should be used as an intermediate steps between expert groups, and prototyping.

Regarding the technique of paper-based role-play game, one of the main problems was the number of participants. A maximum of ten persons should attend one gaming session. Another issue was that the participants were not following the diagram of the game moving from one step to the next one due to the size of the group, and that the expert moved from one branch of a game to another following the discussions that come out during the development of the game. This enabled the exchange of different opinions enriching the game, but at the same time made it difficult to manage the game. Parallel sessions can circumvent this problem and present two complementary solutions for one scenario.

The main risks of this technique are that without good guidance the gaming session could become an expert group. Another risk is that the results obtained during the game depend on the participants.

The paper-based game technique combined with the expert group support has proven to be an inexpensive and focussed technique to validate the feasibility of the information flow processes, and to detect gaps and inconsistencies in concept description. Experts gave good feedback on the technique. The combination of the expert group and the gaming sessions in a two day meeting has been agreed as adequate by most experts, although this technique is not feasible for gathering quantitative results from the exercise.

Regarding the use of the web-based technique experts, thought that the capability of the web-based games of being separate from other players gives realism to the game because the communication means are more close to the real ones. This helps the actors to better identify the information flow and tools needed because the communication between actors has to be more precise to ensure the correct understanding of the information. The update of the web-



game with a data base that records the communication, processes, and actions performed by the different actors in the game is recommended.

A general comparison between web and paper techniques was made. Experts consider the paper based games to be more interactive, more flexible and promote discussions, whereas web-based games give more realism, explain better or equally the scenario, and are more straight forward. Experts commented that it would be useful to play exactly the same game with the same actors several times to reach the best way of managing the situation.

The use of a fast-time process simulation as a gaming tool has proved to be complementary to the use of the paper-based technique. The simulation assesses the process flow previously defined and provides a first approach to its viability.

6.3.3 Prototyping sessions

The following recommendations can be made with regard to future conduct of a series of prototyping sessions:

To cope with the limited time available for training, continuity of participants is essential as it enables participants to be trained only on new items and avoid using valuable evaluation time on re-training; note that this continuity also enables the participants to mature the concept between sessions and provide even more grounded feedback session after session.

Allow sufficient time between sessions to enable analysis and refinement of remaining objectives, technical development of new functions, conduct of acceptance test and preparation of briefing and experimental material.

In the perspective of further concept maturation through human-in-the-loop experiments, a recommendation concerns the selection of participants: to clarify an emerging concept, participants need to be sufficiently open-minded to envisage changes in their current working practices, roles and tasks.

As the prototyping sessions were of a short duration and involved a limited number of participants the results should be regarded as trends rather than results backed by statistical evidence.

In the exercise report of the prototyping session [21], additional recommendations can be found to be taken into account for further investigations.

6.3.4 Fast-time modelling

The concept used in fast-time modelling should be integrated into the CATS/OPAS fast-time simulator to assess a tool to measure complexity and to help their reduction. CATS/OPAS already provides built-in conflict resolution measures that can be combined. Implementing this new concept within the simulator would help integrate this 4D planning in a more complex model. Experiments could be carried out, combining different methods for conflict resolution: 4D planning, flight level allocation and vertical/horizontal manoeuvres.

6.4 LESSONS LEARNT ON PERFORMANCE ASSESSMENTS

A workshop generated lessons learnt on performance assessment:

- The use of the performance framework enabled the interaction of KPA and KPI to be understood and will be proven in future exercises;
- It was only possible to get initial performance trends due to the immaturity of the concept;
- Most results were local results and it was not possible to get any global results;



- The capacity KPA were most readily assessed, but even here results were only partial;
- There was a lack of modelling / Fast Time Simulation in order to get more quantified data;
- Obtaining ECAC-wide KPA figures for the SESAR 2020 concept needs further development and definition of methods:
- Performance assessment must be iterative:
 - Initial assessments will be based on more assumptions and estimates but these may not remain for later assessments;
 - An iterative assessment will help improve understanding of where the performance framework needs to be improved;
 - An iterative assessment will help improve understanding of where the concept needs to be improved.

6.5 LESSONS LEARNT ON CONCEPT DETAILING

It can be stated that a general problem was the parallel development of methodology and conduct of validation exercises. Performance framework, scenario creations, traffic definitions and assumption management were not completed before the validation exercises started. Due this situation the exercises took individual assumptions and used their own methodologies. A comparison of results is therefore quite difficult. Concept detailing could be achieved but quantitative measurements are hardly comparable.

A future sequence of activities is depicted in Figure 3. Before expert group activities start, the major framework activities (as performance framework, assumption management, traffic definitions) need to be completed. All exercise plans will be reviewed and judged by the expert group. After an acceptance by the expert group, the exercise will start and will provide results to the experts. An example of a sequence of exercises can be gaming exercise and then division either into fast-time modelling or into prototyping sessions depending on the maturity of the concept or interested parts of it.

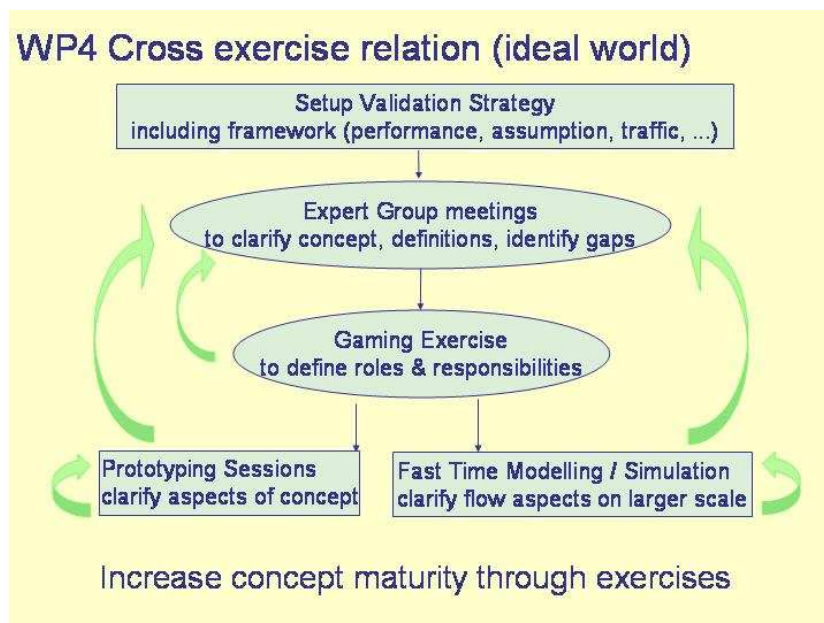


Figure 3: Proposal of Validation Activities



7 CONCLUSIONS

The work package EP3 WP4: “*En route and Traffic Management*” has analysed the concept of operation and selected relevant parts which needed further assessments. Four exercises were defined: expert group, gaming exercise, fast-time modelling and prototyping session. Before suspension of the project in April 2008, two expert groups (complexity management and separation management) were set up. The results of these groups were used in the rescoped expert group and in the prototyping session.

The expert group meetings gave judgements about exercise plans, exercise reports and DOD refinements. The use of the Delphi method within questionnaires helped a lot to clarify various aspects of the concept.

The combination of expert group meetings with gaming sessions, especially with paper-based games refined immature points of the concept, such as RBT-handling and operability of new defined separation modes. The phased approach of gaming exercises with paper-based game, process simulation and web-based game showed good improvements in clarification of concept definitions. The expert group and gaming exercise are mainly looking for validation in step V1 and partly V2 of E-OCVM [1].

The operability of CTA facilitation and RBT handling were validated in three prototyping sessions. The system was enhanced based on the results of preceding expert group meetings. With the prototyping sessions, more mature parts of the concept were validated. The prototyping sessions are looking for feasibility validation in step V2 of E-OCVM [1].

Concept clarification was obtained from the exercises, discussed and recommended by experts. The clarifications are described in this report (chapter 3.3 “Operability Results” and chapter 5.3 “Concept Results”). Areas with no common agreement are marked as hot topics (see chapter 6.1). The hot topics were marked in the associated DODs.

Major results are:

- A gap was detected in the responsibility time-line between the sub-regional manager and the planning controller. The Multi-Sector Planner (MSP), whose responsibilities are described in SESAR Roles and Responsibilities, covers this gap.
- If planning controllers will be replaced by MSP, an executive controller assistant may be introduced at each executive controller for safety reasons.
- In nominal cases, when the MSP has the RBT under his/her responsibility or – e.g. the time horizon to operations is less than 30 min, there is no time to perform a CDM process with airspace users. This does not mean that a CDM process cannot be implemented even during the tactical phase. The variable which limits the option to implement a CDM process is the time horizon not the phase of the flight.
- Aircraft with different capability levels will coexist within the same airspace but the more capable the aircraft is the fewer constraints it will receive.
- In a high workload situation, the controllers reported that facilitating CTA will be the first constraint which will be neglected as controllers concentrate on higher priority separation tasks. As the aircraft are flying to target times by using speed control and controllers were, therefore, discouraged from using speed control. A consequence of this is that they felt that one element of the currently available Controller toolset had been removed.
- Every flight was flying a unique preferred trajectory. This had consequences for the controllers as potential conflicts are now distributed across sectors rather than at defined crossing points.
- The en route management of the execution phase does not generate queues. The queues managed are generated by the Network operations and the AMAN.



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- One issue detected regarding ICAO legislation is that in this legislation it is written: only one executive/planning controller can communicate with an aircraft. This phrase should be reviewed if MSP will communicate RBT changes to aircraft, especially if several MSP can modify the same RBT at one stage.



8 RECOMMENDATIONS

Following recommendations are given:

- Implementation of expert group to review and judge the exercise activities (plan, report, results) as well as defining results for concept detailing. Expert group should be used in step V1, V2 and V3 of E-OCVM [1] validation process.
- Combined methodology of expert group meetings, questionnaires based on Delphi method and gaming sessions for detailing immature parts of the concept. Gaming exercises will be used in step V1 and V2 of E-OCVM validation process.
- Combination of various gaming methods to circumvent caveats of one method.
- Enhanced prototyping sessions to assess operability and Human-in-the-Loop aspects. Prototyping sessions are useful methodologies in step V2 and V3 of E-OCVM validation process.
- Definition of performance framework, assumption management and traffic samples as baselines should already be defined before exercise definition starts. A strong facilitation and monitoring of exercises is recommended to assure the usage of the baselines.
- Recommendations to DODs (i.e. E6 [12], E4 [11], G [10]) are described in chapter 5.3.
- Issues for further clarifications are described in chapter 6.1. These points need clearly definitions for further validations.
- Recommendations to validation techniques are depicted in chapter 6.3.



9 REFERENCES

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10 ANNEX 1: DETAILS ON VALIDATION TECHNIQUES

Paper-Based Role-Play Game

The paper-based games that were performed were played with experts behaving as actors at a table. The tools used were presentations, papers and ball pens. These simple means made the rules of the games easy to understand, obviated the necessity of training sessions, and focused discussions of the experts on the concept being addressed without closing alternative approaches.

The paper-based game allowed the exploration of concepts in a structured way focusing the experts' attention on the information flow and responsibilities associated with the processes.

The main division was established on human and non-human elements. The human elements in the role-based games were game manager, game assistants, players and spectators.

Game Manager: Ensures the rules are followed by the participants and the game evolves towards its objectives.

Game assistants: Play a double role. One is an observer that records how the game develops; these notes will be analysed later by the scenario design team to extract the information sought in the game. The second role is a players' assistant when any doubt regarding the development of the game appears.

Players or participants: The stars of the exercise. Their interactions and how involved they feel in their roles will lead to the success or failure of the exercise. The degree of involvement depends upon two factors; the first one is how real they feel the game is. The second and more essential factor is how interested players are in a game.

Spectators: Ideally all the attendants at the gaming session will play a role. This is not always possible. One way to solve this issue is to assign the same role to two participants who will have to discuss aloud the decisions they make. If, even with this measure, there are still some participants without a role, they must be encouraged to participate in the discussions and express their point of view.

Information sets consisted of the following information: game manager script, assistant script, and participant role sets.

Game Manager Script: The game manager script is the information the game manager needs to know to lead the gaming session; it includes (but is not limited to):

- The scenario description: including roles involved in the game and tools available to each of them;
- Initial information flow diagram. This is a representation of the processes involved in the game linked with the roles that will perform them;
- Time horizon planning. This means when each of the events will happen. The Game Manager can introduce an "unexpected" event to reactivate the game if there are some objectives that have not been reached;
- A summary of the concept(s) issues that are foreseen to appear and those that the game designers would like to see discussed during the game development.

Assistant scripts are distributed differently to facilitate the record of the discussions performed in the game. Typically whilst the Game Manager will have a brief summary of the concept(s), assistants will have a full description and access to the original documents. The EP3 Information Navigator proved to be very useful for this purpose.

Participant script: The participant script includes the role cards that describe the personal objectives and rules applicable for the interaction among players, and the information cards.



One type of information card contains the name of the processes that participants can use - e.g. publish the RBT in the NOP. If no process card exists, but is needed for the exercise, it is created immediately by the participant or the assistants. The other type of information card contains outputs from tools. They simulate the answers that a tool would give. These cards must contain enough information to help the player to take a decision.

Process modelled Game

Fast-time process simulation used the PROMAS platform as a new Gaming-compatible technique, to assess complex systems by means of Fast-Time Process Simulations. After analysing the processes used in the role gaming sessions, the relevant gaming part was modelled, and subsequently the processes simulations were executed. In the framework of WP4.3.3, PROMAS was supplied with the processes defined in the initial role gaming exercises. It then modelled the processes and provided a first assessment of their viability. The programme performs the role of the components in the scenario and reproduces the system operation activities including processing time of each actor.

The PROMAS platform uses processes and information flows described in the paper-based games. The scenario was composed of the set of rules, actors and the traffic sample, as well as the set of parameters that defined the strategy to be assessed; these scenarios were based on the interim report and the OS-38 [8]. The simulation included six scenarios.

The main assumptions considered in designing the scenarios and running PROMAS were:

- MSPs may have under their responsibility up to 4 sectors at the same time;
- An immediate conflict will be resolved by a planning and an executive controller (with no MSP) in one set of scenarios or by a MSP and an executive controller in another set of scenarios;
- The RBT of the aircraft involved in conflicts may be updated by the flight crew after being agreed and instructed by the executive controller or MSP;
- A conflict that will occur near the entry border of a sector where the aircraft has not entered yet and this sector belonging the MSP Area, will be resolved by the MSP. It may be coordinated with a planner (if any) and an executive controller;
- This type of conflict may be resolved by revision of the RBT by the flight crew after being agreed and instructed by the executive controller. This resolution will imply a change in the RBT in the moment of the detection of the conflict;
- A conflict that will occur outside the measured sector will be resolved by an adjacent MSP;
- This type of conflict will update the part of RBT within the measured sector coordinated by the adjacent MSP via NOP/SWIM.

Each time that a MSP takes part in a scenario a number of conflicts (between 1 and 6) are solved in the MSP Area. These conflicts may not happen in the sector where the aircraft enters. In 2-sector scenarios the number of remaining conflicts is higher than in the 4-sector scenarios.

In all the exercises, the results of the scenarios with two sectors are not as good as the scenarios with four sectors. After analysing the different indicators that were assessed, it can be concluded that in 4-sector scenarios the results are always better than in 2-sector ones. It is unknown until when this premise (how many sectors a MSP can deal with without being overloaded) works and further analysis should be developed.

The location of the sectors within the MSP Area in relation to the major flows is important. The results are better in those sectors which are not located at the "borders" of the MSP Area. In the entry/exit sectors of the MSP Area, the MSP needs to coordinate with the executive controller. He balances the advisories received from the MSP and the additional actions to be undertaken. The conflicts avoided are fewer in the sectors of the middle of the area because



in this sector the MSP does not need to call their executives to request clearance or to update RBTs. The paper-based game indicated that this effect would be reduced if the MSP was a general role.

Fast-time Modelling

Twelve different sets of parameters for the exercise lead to twelve different fast-time simulations (although each simulation was run five times to ensure good convergence of the optimization algorithm). In particular, there were six simulations on 2006 traffic and six simulations on 2020 traffic. Also half the simulations were run with standard routes and half with direct routes (here defined as a straight flight from origin to destination). The delay for each flight and the number of remaining conflicts were observed for each simulation.

The results were obtained without any uncertainty in the model. The solutions obtained from this first model were not robust, even towards small perturbations. An enhanced model was proposed to take uncertainties into account. This enhanced model proved to handle small perturbations as expected, but at the cost of a huge increase in the total amount of allocated delay, which is also not suitable for operations. In order to handle that issue, it would be worth trying to couple this allocation method with other de-complexification methods, such as a prior flight level allocation, likely to reduce the size of the takeoff time allocation problem.

The aim of EP3 WP4.3.2 was to obtain a first guess of the efficiency of a takeoff time allocation method. With respect to this objective, a strong assumption was made on aircraft equipment: all aircraft were supposed to be equally equipped with a precise enough FMS, which means that each aircraft was able to follow a defined trajectory in x, y, z and t to the limit measurable in the simulation. An unlimited runway capacity was a prerequisite to exercise.

The simulations showed that the algorithm was able to solve more than 95% of conflicts. The average delay allocated per aircraft is under 3 minutes for 2006 traffic. For 2020 traffic however, the allocated delays have higher values, with an average delay around 6 minutes (10% flights have a delay over 10 minutes).

The percentage of delayed flights is around 55%, with a mean delay per delayed flight lower than 5 minutes.

Direct routes tend to generate fewer constraints than standard routes. It is interesting to observe that the total amount of delay allocated on direct routes traffic is smaller than on standard routes traffic.



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