# EPISODE 3

Single European Sky Implementation support through Validation

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EXECUTIVE SUMMARY

This document describes the work to be carried out conducting a gaming exercise to evaluate collaborative airport planning, which shall lead to a more efficient utilization of airport resources.

The methodology employed is to simulate reference scenarios i.e. current operations without collaborative planning, then to simulate those scenarios with collaborative planning, allowing comparison between the reference and modified scenarios.

Results from the gaming exercise obtained at the local airport level will be analyzed by a network analysis model to obtain data about the effects of local replanning on the network. This analysis will also provide data that can be used as constraints in the planning at airport level. This will however not be addressed by the exercise.

Collaborative Airport Planning Gaming Exercise

Collaborative airport planning allows all parties involved in airport operations to share planning information and to agree on operating procedures and targets based on a common understanding of the situation. The result of this planning is the Airport Operations Plan (AOP), an en-route-to-en-route-conversion of the Network Operations Plan (NOP), enriched by airport specific data. It ranges from agreed airport performance targets, constraints of the different stakeholders to a detailed event-resource-usage description enabling the airport to be operated as a time ordered system.

The goal of the gaming exercise is to analyse and evaluate the collaborative planning process and get first indications of the benefits that can be achieved. The exercise will also give insight into the usefulness of gaming supported by simulation as a validation tool for advanced operational concepts related to pre-tactical planning.

Network Management in support of the gaming exercise

Through Network Management, the effects of collaborative decision making at airport level on the surrounding airspace network – including other main airports – can be determined. In this analysis, attention shifts from the Airport Operations Plan (AOP) central to Total Airport Management, to the wider operational context: the Network Operations Plan (NOP). The NOP includes the planning of all airports and all flights, and comprises constraints and restrictions on planning and planning changes. A simplified NOP of the kernel network of ECAC-wide operations will be modelled and processed in support of the gaming exercise. This process supports the following functions:

- To provide bunching information on those flights that will run the risk of being delayed and that will need high attention from network operations perspective,
- To provide proposed departure constraints for those flights that are constrained by network restrictions, and
- To process prioritisation preferences generated by the gaming exercise and applicable to the reference airport, i.e. Hamburg. Also, other airports of the kernel network may be emulated to provide similar proposed constraining preferences to the network and to evaluate their effect.
1 INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This document provides the Validation Experimental Plan for EP3 WP 3.3.4 “Collaborative Airport Planning”. This experimental plan is based on a general template that has been produced collaboratively between EP3 WP2.3 and the Validation Strategy and Support Tasks within EP3 WP 3, 4 & 5 (x.2.1) and complementary guidance material for E-OCVM Step 2, as provided by EP3 WP2.3.4 Erreur ! Source du renvoi introuvable. The Experimental Plan mainly covers the steps 2.1. to 2.6 of the EUROPEAN Operational Concept Validation Methodology (E-OCVM) Erreur ! Source du renvoi introuvable. It includes all information necessary to conduct the gaming sessions of Collaborative Airport Planning. This experimental plan is in line with Episode 3 EP3 WP3 validation strategy which covered steps 0.1 to 1.7 Erreur ! Source du renvoi introuvable.

1.2 INTENDED AUDIENCE

This document is delivered through the Validation Management Cell for approval of its content, correctness and alignment with the E-OCVM based validation approach. This document is intended for use by the exercise leaders involved in EP3 WP3 and in EP3 WP2.3 Validation Process Management for the consolidated validation strategy. Moreover, it forms the basis for further elaboration of the detailed EP3 WP3 validation and exercise planning (E-OCVM step 2).

The intended audience includes:
- EP3 WP3 Leader;
- EP3 WP3.2 Validation strategy, support and operational concept refinement;
- EP3 WP3.3.1 Airport Planning Expert Group;
- EP3 WP3.3.4 Collaborative Airport Planning;
- EP3 WP3.3.5 Global Performance at Network-wide level. Macromodel.

1.3 DOCUMENT STRUCTURE

The document is structured in four main parts.
- Section 2 details the scope, justification and objectives of the exercise together with the methodology, indicators and metrics, hypotheses and scenarios to be tested;
- Section 3 describes the activities, resources and time planning;
- Section 4 describes the data collection and analysis methodology;
- Section 5 details the exercise design.
- Annex 1 describes a network analysis processing central network management functions to provide information on constraints on airport planning due to network limitations.
1.4 BACKGROUND

Episode 3 is charged with beginning the validation of the operational concept expressed by SESAR Task 2.2.2 and consolidated in SESAR D3 Erreur ! Source du renvoi introuvable.. The initial emphasis is on providing:

- Detail on key concept elements in SESAR (concept detailing);
- Initial operability through focussed prototyping exercises and performance assessment of those key concepts (operability and performance studies);
- Initial supporting technical needs impact assessment (technical impact);
- Analysis of the available tools and gaps for SESAR concept validation (validation tools); and
- Reporting on the validation methodology used in assessing the concept (validation methodology assessment).

The validation process as applied in EP3 is based on version 2 of the E-OCVM Erreur ! Source du renvoi introuvable., which describes an approach to ATM Concept validation, and is managed and coordinated by EP3/WP2.3.

Validation exercises should provide evidence, preferably measured, about the ability of some aspect of the concept to deliver on some aspect of the performance targets. In order to prepare well the validation exercises, an experimental plan should be produced according to step 2 of the E-OCVM.

The experimental plan in this document describes the validation exercise EP3 WP3.3.4 Collaborative Airport Planning which is done within EP3 WP 3: Collaborative Planning Processes.

As described in the EP3 WP3 Validation Strategy Erreur ! Source du renvoi introuvable., EP3 WP3 will provide not only an assessment of the feasibility of the SESAR Collaborative Planning Processes, but also an initial trend of their impact and influence on the expected level of network performances. Several techniques are combined in a step-by-step process, as shown in the figure below:

![Figure 1: EP3 WP3 Validation Process](image)

As shown in Figure 1, EP3 WP3.3.4 is focused on Gaming Human in the Loop activities (supported by modelling techniques).

1.5 GLOSSARY OF TERMS

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<td>Airport Collaborative Decision Making</td>
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<td><strong>ACCESS</strong></td>
<td>Airport Control CEnter Simulator</td>
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<td><strong>AENA</strong></td>
<td>Aeropuertos Españoles y Navegación Aérea</td>
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<td><strong>AMAN</strong></td>
<td>Arrival MANager</td>
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<tr>
<td><strong>ANSP</strong></td>
<td>Air Navigation Service Provider</td>
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<tr>
<td><strong>AOP</strong></td>
<td>Airport Operations Plan</td>
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<tr>
<td><strong>APOC</strong></td>
<td>Airport Operations Center</td>
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<tr>
<td><strong>ASGARD</strong></td>
<td>Autonomous Simulation of Ground movements, Arrival and Departure</td>
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Chapter 2: Exercise Scope and Justification

2.1 Stakeholders and Their Expectations

The most important stakeholders are the airport and airspace users and their requirements as expressed in SESAR D2. Representatives of these stakeholders will be involved in the experiment. The following stakeholders are anticipated to be involved in the decision making process in the Airport Operations Centre (APOC):

- Representatives of the major airlines at the airport
- Airport Operator
- Ground Handler
- ATC/ANSP
- Network Operations Planner

Ideally all these stakeholders should be involved in the experiment. A minimal set of stakeholder agents for the experiment will consist of at least one airline agent and at least one of the others. Note that pilots will not be involved in the exercise. In the table below, the role of each stakeholder is described in more detail.

In addition to the above mentioned there are also other stakeholders internal and external to the EP3 project involved in this exercise. The following table lists the stakeholders and their involvement and expectation in the exercise:

<table>
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<th>Involvement</th>
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<th>Performance expectations</th>
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<td>Airport Operator</td>
<td>Participation in the gaming exercise and in the 3.3.1 collaborative planning expert group.</td>
<td>The airport operator is interested in making best use of available resources and to ensure smooth and predictable operations of the airport as a whole. With collaborative planning the airport operator can better understand needs and attitudes of other stakeholders. Furthermore an APOC affords an opportunity to concentrate all necessary information at a central place.</td>
<td>Improved collaboration in the decision making process: more stakeholders involved in deciding how to respond to these conditions. Improved situational awareness and better use of available resources. Improved stability of operations.</td>
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<td>Airlines</td>
<td>Participation in the gaming exercise and in the 3.3.1 collaborative planning expert group.</td>
<td>Airlines are interested in transparency in all information having an influence on their flights. With an APOC they have the opportunity to share the same situational awareness with other stakeholders and have a voice in decisions about airport operations through negotiation processes (i.e. commitment to punctuality adjustments).</td>
<td>Benefit from a higher stability of operations and of the whole airport system and enhanced efficiency of fleet operations. Improved predictability.</td>
</tr>
</tbody>
</table>
### Table 1: Stakeholder Expectations

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Involvement</th>
<th>Why it matters to stakeholder</th>
<th>Performance expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSP</td>
<td>Participation in the 3.3.1 collaborative planning expert group.</td>
<td>ANSPs are responsible for the runway utilization and the ARR/DEP ratio at the airport. It will be in the interest of the customers and ANSP to collaboratively decide about the right setting of these parameters. ANSPs play an important role in the decision making process in the APOC by focussing on the effects of proposed decisions on the demand and capacity balancing of the airspace.</td>
<td>Improved situational awareness and better use of available resources. improved stability of operations.</td>
</tr>
<tr>
<td>Ground handler</td>
<td>Participation in the 3.3.1 collaborative planning expert group.</td>
<td>Ground handlers are responsible for an efficient turn-round process. As such they need reliable planning information for their operations.</td>
<td>Improved stability and predictability of operations.</td>
</tr>
<tr>
<td>European Commission</td>
<td>Funding part of the exercise as part of the project budget.</td>
<td>Identification of substantial and sustainable improvements in ATM performance by addressing many of the current day ATM inefficiencies through an initial validation of the SESAR Operational Concept</td>
<td>Expected increment of the air transport system operational capacity and safety.</td>
</tr>
<tr>
<td>SESAR JU</td>
<td>Technical Auditor</td>
<td>Usage of the output of this exercise for initial operability and performance assessments of the SESAR concept.</td>
<td>Exploration of validation methods and to provide learning to the SJU work programme.</td>
</tr>
<tr>
<td>EP3 WP3.3.1 Airport Expert Group</td>
<td>Episode 3 Expert Group</td>
<td>Airport Expert Group has a strong interest in the content and development process of the AOP.</td>
<td>Insight into the process of collaboratively defining the AOP.</td>
</tr>
<tr>
<td>EP3 WP3.3.5 Global Performance at Network</td>
<td>Episode 3 Exercise</td>
<td>Analysis of the impact of the local processes and airport solutions on performance at the ECAC wide level as well as identifying the network effects and the network resiliency.</td>
<td>Expect indications on the impact of the collaborative planning process at airport level on airport and network performance.</td>
</tr>
<tr>
<td>Research and development centres</td>
<td>Represented by EUROCONTROL/DLR as exercise leader</td>
<td>Knowledge of strategies to collaboratively reach decisions in the APOC. Knowledge on the effects of these airport-centred decisions on the surrounding airspace and airport network.</td>
<td>Knowledge of the areas where more research is needed to increase both airport and network capacity.</td>
</tr>
</tbody>
</table>

### 2.2 Description of ATM Concept Being Addressed

In this section, the experiment is linked to the Episode 3 Detailed Operational Descriptions (DODs) and the Operational Concept of SESAR. The following topics are addressed:
The scope of the operational concept of interest, providing links to Lines of Changes (LoCs) and Operational Improvements (OIs),

A detailed outline of the operational concept, derived from the DODs,

The level of maturity of the concept of interest, and

The Key Performance Areas (KPAs) related to the concept of interest, giving indications of relevant areas of potential benefits and performance assessment.

According to the EP3 DOW [Ref. 1, p. 87-88], the experiment shall explore the following elements of the SESAR Concept of Operations:

- Collaborative Airport Planning
- The implementation of an Airport Operations Centre (APOC)

One concept for collaborative airport planning which is fully in line with the SESAR Concept of Operations is Total Airport Management (TAM), a concept that has been jointly defined by DLR and Eurocontrol. TAM is a future “integrated” method of airport management. Within the TAM concept, the Airport Operations Centre (APOC) is seen as the heart of the operation. In the APOC, agents of the above stakeholders will constantly communicate and coordinate, develop and maintain dynamically joint plans and execute those in their respective area of responsibility.

The core information basis of TAM is the Airport Operations Plan (AOP). The Airport Operations Plan is an en-route-to-en-route-conversion of the Network Operations Plan (NOP), enriched by airport specific data. Crucial to the AOP is that all constraints of all stakeholders are brought together: both the airport level and the network level planning constraints. For this reason, the experiment not only addresses the airport-centred operations, but also its repercussions on the network of which it forms part.

Airports are always part of a network. This is what Total Airport Management entails: managing airport operations as a part of the totality of connected airports and airspace sectors. In this way, TAM is expected to lead to a better use of available capacity at an airport, since the external constraining factors are also taken into account. In the experiment, decisions taken at airport level are therefore analysed in terms of their consequences at network level. After all, solutions that may seem good for the airport may lead to large imbalances in capacity and demand in the airspace network as a whole.

Apart from the above elements of the SESAR ConOps to be validated, the experiment will address the following elements, putting airport planning processes within the context of the NOP:

- Improving the interoperability between Network Capacity Management Processes and planning processes at airport level (through Network Management):
- Monitoring ATM Performance (through Network Performance Assessment) and providing alerting information on bunching and/or congestion to planning processes at airport level.

### 2.2.1 Scope of the Operational Concept of Interest

The table below shows the list of OI steps that will be addressed by the exercise. There are some changes with respect to the WP3 Validation Strategy. During the preparation of the exercise it has become apparent that some OIs that were envisioned to be addressed cannot be taken into account within this exercise, as the development for the decision support tool prototype and the detailed simulation scenarios has progressed slower than anticipated. The OIs not addressed now are:

- AO-0602 (Pre-Departure Sequencing)
- DCB-0103 (SWIM enabled NOP)

On the other hand some additional OIs can be addressed:
• AO-0601 (Improved Turn-Round Process through Collaborative Decision Making)
• DCB-0206 (Coordinated Network Management Operations Extended Within Day of Operation)

<table>
<thead>
<tr>
<th>OI Id</th>
<th>OI Title</th>
<th>OI Step Id</th>
<th>OI Step Title</th>
<th>How addressed?</th>
</tr>
</thead>
<tbody>
<tr>
<td>L10-03</td>
<td>Improving Airport Collaboration in the Pre-Departure Phase</td>
<td>AO-0501</td>
<td>Improved Operations in Adverse Conditions through Airport Collaborative Decision Making</td>
<td>In the scenario used in the experiment, an adverse condition will be presented to all actors in the APOC. Next, a CDM process is started to find a commonly agreed solution to the problem of reduced capacity due to the adverse condition.</td>
</tr>
<tr>
<td>L10-03</td>
<td>Improving Airport Collaboration in the Pre-Departure Phase</td>
<td>AO-0601</td>
<td>Improved Turn-Round Process through Collaborative Decision Making</td>
<td>Turn-Round milestones will be used to set TOBT in the simulation and will be used as constraints in the planning process.</td>
</tr>
<tr>
<td>L03-02</td>
<td>User driven Prioritization Process</td>
<td>AUO-0102</td>
<td>User driven Prioritization Process</td>
<td>While not directly addressed the stakeholders inputs during the collaborative planning process will reflect their prioritizations.</td>
</tr>
<tr>
<td>L03-01</td>
<td>Collaborative Layered Planning Supported by Network Operations Plan</td>
<td>DCB-0102</td>
<td>Interactive Rolling NOP</td>
<td>The network analysis part of the exercise (see Annex 1) provides the airport planning actors with information that represents a network with a number of hub airports experiencing planning constraints due to bunching conditions. This reflects overload conditions that are rare in principle but that will occur due to incidental demand capacity balancing problems.</td>
</tr>
<tr>
<td>L04-01</td>
<td>Improving Network Capacity Management Processes</td>
<td>DCB-0206</td>
<td>Coordinated Network Management Operations Extended Within Day of Operation</td>
<td>The improved working relationship is established in the APOC whilst reacting to capacity shortfall situations. Crucial to this coordinated network management operation is the integration of DCB results with airport capacity and demand figures. The network is expected to receive APOC planning and to provide APOC with information concerning constraining conditions.</td>
</tr>
</tbody>
</table>
2.2.2 Detailed outline of the Operational Concept of Interest

Below, an outline is given of the Operational Concept on which the experiment is based. This outline summarises applicable concept elements from the Episode 3 DODs, in particular DOD M1 (Collaborative Airport Planning) and M2 (Medium/Short Term Planning) Erreur ! Source du renvoi introuvable. Erreur ! Source du renvoi introuvable. The conceptual overview is not deviating from SESAR, but presents an overview with the following purpose:

- The experiment cannot be understood without understanding the Operational Concept, this overview provides a minimal summary of the concepts addressed.
- A systematic justification of conceptual improvements helps to support an understanding of the validation process.
- The present description is focused on direct applicability and performance assessment.

Section 2.3 describes how the experiment addresses this operational concept.

Collaborative Airport Planning

Today (2009) in many airports, operational decisions are often made with a limited knowledge of the most pertinent data. In addition, decisions by a given actor are often taken in isolation without reference to other actors who may be impacted by such decisions. Addressing these shortcomings individually brings small improvements but in order to improve the whole complex set of issues, it is necessary to follow the principles of Airport Collaborative Decision Making (CDM).

Airport CDM is embedded in the ATM operational concept as an important enabler that will improve efficiency and punctuality. The CDM elements have been developed through airport trials and are now being widely implemented at many major European Airports.

The basic foundation of Airport CDM is to have improved information sharing and data quality. It is important that the right airport partners get accurate data at the right time in the right place in order for them to make decisions while working together. This will lead to a better use of resources, partners being able to make preferences, improved punctuality and predictability. The accurate and accessible
data is also used for post analysis, which is an increasingly important factor in order to measure success and learn from situations.

In order to reinforce the decision making process and to provide the basis for performance based airport management in 2006 Eurocontrol and DLR wrote the first ideas to a Total Airport Management (TAM) in a concept document (Erreur ! Source du renvoi introuvable.), comprising a CDM approach in an APOC (Airport Operation Center). It was then envisaged that the initial concept shall be further developed and validated, eventually by performing human-in-the-loop simulations, e.g. in SESAR or in activities like Episode-3 related to SESAR. This concept document is still fully in line with the concepts defined in SESAR and the M1-DOD, and so this concept document can still serve as a reference document for the Collaborative Airport Planning concept.

The approach for TAM is the development of a hierarchical structure for an optimized reaction e.g. on predicted or ad hoc capacity shortfalls, an over-demand or lack of punctuality. TAM can also result in an optimized traffic flow during “normal” conditions and increase the punctuality or throughput (e.g. runway system, taxiways, stands). In this way TAM includes an overall macroscopic view with necessary filtered airport information concerning the overall flow, demand and capacity.

The main objectives and benefits of TAM are:

- Improved predictability of the behaviour of the system “airport” within the air transport network, i.e. increased prediction look-ahead-time and reduced variability of schedules compared to today, in order to give the network more time to pro-actively manage the air transport and to become more stable and robust.

- More equal performance of different airports with respect to each other, measured by one common set of performance indicators, the airport shall agree with other stakeholders and the ATFCM on a guaranteed QoS with respect to these indicators – a QoS Contract (QoSC).

- TAM shall provide ways to handle degraded situations in the most appropriate way to ensure that the QoS is fulfilled as well as possible

In terms of the development of a Total Airport Management (TAM), the function allocation between human actors and future assistance systems (for example planning systems) could be realised by the design and use of scenarios. Scenarios describe the behaviour of users and the future system, interaction between the two, and the wider context of use. Scenarios also aid the analysis of multiple aspects of a complex problem more or less simultaneously on a qualitative level.

Use cases describe the system’s behaviour under various conditions as the system responds to a request from one of the stakeholders (the primary actor). Therefore we have a more detailed representation of the work flow. The primary actor initiates an interaction with the system to accomplish a goal. In the TAM concept the main focus can be located in the design of the common decision making processes of actors from different stakeholders. Based on the stakeholder interests potential conflicts should be identified and concepts for conflict solution should be found.

The initiation of a task (every task can be described through a Use Case) starts with the request of an agent in the APOC. Every task corresponds to a definite time window and comprises a deadline, to which the task has to be processed. Every task will be sorted into a task list according to the deadline. At the same time only one task can be processed. It is the task sorted at the first position in the task list.

The definition of the human role in TAM and the resultant interaction of actors is a theme for the collaborative decision making process. The creation of TAM will permit the generation of a global information space derived from a number of local information sources. Aspects are the integration of local information into a global picture or the kind of intermediation between human actors of different organizations with respect to their different goals and intents. Expected benefits of a cooperative working and decision process in TAM could be:

- possibility of direct verbal communication and discussion
representation of information by means of common used displays
common computer aided simulations
transmission of planning orders, action proposals or action instructions
better negotiation and solution of conflicts and communication of interests

The central tool of TAM is the APOC where representatives of all involved stakeholders work (Figure 2). Good communication between aircraft operators, ATC, airport and other stakeholders is decisive for the success of cooperation in the management process of an airport. A main idea of APOC is attaining the best possible cooperation through direct communication between the different stakeholders through their APOC representatives. Future advantages of this central collaborative planning approach are located in possibilities for a faster reaction to arising critical traffic situations and consideration of customer wishes. Furthermore each representative stakeholder will have be aware of the objectives and interests of the other stakeholders, due to the individual contacts amongst them.

Following the TAM approach all APOC operators use shared information and plan base (AOP). The improvement of the general situational awareness supports a better quality for the collaborative decision making process. All parties know the constraints and are able to react to these constraints. Especially the local contiguity of operators offers the possibility to take priorities of ones neighbour into account. The specific information and knowledge necessary for each operator to perform his tasks depending on his specific role could be identified.

The off-line modelling part of the experiment, performed by NLR, will address the interactions and connectivity between the airport under investigation and its surrounding network. This network represents the NOP or part of the NOP and consists of routings, airspace sectors and airports. To determine the mutual interactions and consequences of collaborative decision making at airport level and the surrounding network, the operations of the following conceptual elements are important:
Demand and Capacity Balancing

In SESAR, the Network Operations Plan (NOP) is central to the concept of operations for large airports and their environment. In the NOP, a planning of operations is available that is converging in level of confidence, level of detail and quality of planning towards the executive phase. From the NOP, the Airport Operations Plan (AOP) is derived: an en-route-to-en-route-conversion of the NOP, enriched by airport specific data. Both departure and arrival operations are expected to follow the AOP, being consistent and in agreement with the NOP, and to behave in compliance with this constantly updated planning, making these operations reliable and predictable.

The NOP will comprise information concerning demand, capacity and the proposed and agreed measures to balance demand and capacity. The details on Demand and Capacity balancing are described in the concept of operation of the CNM model in Annex 1, section 6.3.2.

Network Management and Design

The network is considered in the experiment from the point of view of management and control on DCB and throughput analysis only. Network requirements are derived from optimised routings through sectors and airports.

As described under the DCB paragraphs, the network consists of airports, i.e. more than 500 ECAC-wide, and sectors, i.e. more than 2000 ECAC-wide. The experience is that this network determined by capacity of executive controller workload, is super-critical; see e.g. SESAR Performance Assessment, Erreur ! Source du renvoi introuvable... To come to a Network that is manageable from the point of view of DCB and throughput analysis there is a need to identify main- and sub-structures in the network, i.e. the Kernel Network, and to find a strategy to select a less overload-critical structure. Moreover, structuring of the Network can be helpful for better response and enhanced transparency on information provision. Such a Kernel Network is constructed, derived from the ECAC-wide network, that is assessed to provide network constraining information and that is capable to process departure preferences agreed at airport level. The details on Network Management and Design are described in the concept of operation of the CNM model in Annex 1, section 6.3.2.

2.2.3 Level of Maturity of Concept of Interest

Concerning the level of maturity of the concept of interest, the following can be stated:

Collaborative Decision Making (CDM) during planning:

Airport Collaborative Decision Making (A-CDM) is a well defined concept and in operation today at several airports (e.g. Munich, Zurich). These airports operate tools to distribute information between different stakeholders to ensure smooth operations based on consistent data. Hence information sharing and common databases are at a maturity level of V5. These constitute a necessary requirement to feed collaborative planning processes as defined in the SESAR Concept of Operations.

Collaborative Airport Planning and Airport Operations Center:

The concept elements of collaborative pre-tactical planning, the airport operations plan (AOP) and its relationship to the network operations plan (NOP) as well as the airport operations center (APOC) as a central place to manage an airport at a pre-tactical level are new concepts and as such not fully defined. These concept elements are at V2 level.

Demand and Capacity Balancing:

A prototype of a CNM model is used that aims to provide representative information on constraining conditions. This is a modest extension of today's, 2009, performance levels.
The design of the Network is focused on support to the gaming experiment. Emulating network behaviour, derived from present-day operations, is sufficient to support the experiment. (see also Annex, section 6.3)

2.2.4 KPAs related to the Concept of Interest

SESAR has defined a set of 11 Key Performance Areas (KPAs), and within each area a set of Focus Areas (FA) focussing on well defined understandable subjects. The concept of collaborative airport planning is mostly related to the KPA Capacity, and more specifically on the Focus Area “Airport Capacity”.

The operations at airports form the ground segment of the business trajectory. The airport throughput is one of the main processes that determine the on-time performance of the Reference Business Trajectory. The SESAR concept elements addressed in the gaming exercise are primarily related to the KPAs listed below, however, the focus of the exercise is not on demonstrating performance gains from implementing collaborative planning, but rather on analysing the collaborative process itself.

- **KPA Efficiency (punctuality):** The collaborative planning process shall lead to an AOP that in critical situations defines an agreed compromise between achievable punctuality and throughput. This allows the stakeholders to define a level of punctuality that shall be reached throughout the day and throughout critical phases.
- **KPA Predictability (enhanced quality of planning):** The collaborative planning process is expected to lead to improved predictability in adverse conditions, as all stakeholders work together to achieve agreed new targets rather than each stakeholder trying to cope with the situation independently.
- **KPA Access and Equity/Interoperability:** Airlines are expected to benefit from enhanced access to ATM planning information and may profit by interoperable and collaborative flight planning and preparation processes.

In the second part of the exercise, the planning of the airspace segment of the business trajectory is central. In this part, the impact is studied of a collaboratively reached decision at airport level on the overall network surrounding the airport. Thus, the effect of the airport-centred operational improvements, the focal point of part one, is investigated and quantified in terms of network throughput. Network effects are impacting Capacity, Efficiency and Predictability, see further section 6.3.4.

2.3 **EXERCISE OBJECTIVES.**

2.3.1 **High level objectives**

The main objective is to study and assess the process of collaborative decision making in the APOC. It is studied how the actors in the APOC reach an agreed solution to a problematic situation, what information they require for their decision and how this decision making can be supported by specific tools.

As a secondary objective the consequences of a collaboratively reached decision are related to a number of KPIs relevant to the example airport in question. To this end the agreed AOP is "implemented" by a simulation suite capable of simulating all relevant airside processes and also capable of both real-time and accelerated modes. After the AOP is established following the collaborative planning process, an accelerated simulation is performed up to the end of the day of operation and the results are extracted. The aim is to give some very first indication of how collaborative planning might affect the key KPAs related to the exercise.
Thirdly, the effects of this decision making on the airspace network surrounding the example airport are assessed. To this end, the throughput of air traffic through the busiest parts of the European airspace, possibly prioritised by a preferential departure schedule, is being investigated in detail by a modelling experiment. The objective of this experiment is to build a representative kernel European ATM network and to provide an ATM background environment with response similar to real-life operations and to be used to exercise hub airport operations. This network represents the constraining conditions that can be experienced in terms of delays and throughput problems. The emulated behaviour of the network aims to provide air traffic flow constraints information to airport operations and to receive and process flight planning information, agreed at airport level.

Finally, as specified in the EP3 DOW, an important outcome of the exercise is experience in gaming techniques and validation of complex operational concepts.

2.3.2 Specific objectives

The main objective of the exercise is to study the collaborative planning process in an Airport Operations Centre. This high level objective can be further subdivided into the following specific objectives:

- Evaluate a workflow model of the decision process.
- Examine the role of a moderator to support the decision making process.
- Given the APOC and given a realistic scenario demanding a commonly reached pre-tactical decision:
- Determine how actors reach a decision in the APOC (following the chosen negotiation protocol).
- Further examine the information requirements for the continuous planning of the AOP (expanding on the findings of the Airport Expert Group, WP3.3.1).
- Demonstrating and investigating a prototype planning support tool.

The second high level objective is to relate the outcome of the planning process, the refined AOP, to the KPAs relevant for the exercise. This involves simulating the scenario to “implement” the AOP and aggregate the simulation data into measurable KPIs, which are listed in the following section. It should be noted that such performance measures can only give a very first indication and should not be viewed as a full performance assessment of the collaborative planning process.

The third high level objective of the exercise is to establish the effects of commonly reached decisions at the network level.

Finally experience in the use of gaming techniques combined with simulation will be gained from the exercise. This experience will be very valuable in the further validation process of the SESAR operational concept.

2.4 CHOICE OF INDICATORS AND METRICS

Metrics for Gaming at airport level

The exercise will provide some estimates on the benefits to be gained by collaborative decision making. These estimates will be based on the specific simulation scenarios and will only provide an initial guess to the general usefulness of TAM and the APOC. The following indicators and metrics defined in the performance framework document *Erreur ! Source du renvoi introuvable.* will be looked at in the analysis:
CAP.LOCAL.APT.PI 3/4: Total Throughput: Total number of operations (departures + arrivals) along the day;

- EFF.LOCAL.APT.PI 1/2: Departure Delays: Due to two possible reasons:
  - Departure Ground Delay: that would include taxi, apron and gate delays and runway delays;
  - Dependency with arrival/departure flows (mix-mode or dependency between runways):
    - % of departing flights delayed more than 1 minute, 2 minutes, 3 minutes or more;
    - The average departure delay of delayed flights;

- PRED.LOCAL.APT.PI 1/2: Arrival Delays/Arrival Punctuality: Due to two possible reasons:
  - Arrival Ground Delay: that would include taxi, apron and gate delays.
  - Arrival Airspace Delay: for arrivals due to airport capacity restrictions. Note that this indicator will be provided as the total arrival delay along the day, % of flights with arrival delay more than 1 minute, 2 minutes, 3 minutes or more and average delays for delayed arrivals.

- Specific questionnaires are currently being designed to capture important aspects of the planning process. These relate to the information required to reach a decision, the decision support tool, and specific elements of situation awareness, such as being aware of the goals and constraints of the other stakeholders.

**Metrics for Network Management**

The model of the kernel network is assessed for minimal delayed throughput. Throughput is assessed under varying conditions, amongst others impacted by proposed departure constraints, determined by the Optimising ATFCM model (see annex 1, section 6.3.7).

### 2.5 Validation Scenario

Taking into account the objectives of this exercise, a set of gaming exercises will be executed to investigate the decision making process in the APOC. The validation scenario will be based on the following operational scenarios defined within EP3 WP2:

- OS-16: Turn-round management
- OS-18: Airport Operational Plan Lifecycle for Medium-Short-Execution Phases
- OS-19: Severe Capacity Shortfalls impacting Departures in the Short-Term

These operational scenarios set the baseline for the detailed simulation scenarios to be set up for the exercise. The scenario will cover a full day of traffic for one airport, and only the local planning at the airport planning is investigated in the gaming exercise. The airport under consideration will be Hamburg airport, which is also used in other TAM projects at DLR.
2.5.1 Scenario Details

2.5.1.1 Airport modelling

The airport under consideration is Hamburg airport. Hamburg has a system of two crossing runways (see Figure 3). For the validation scenario only one runway configuration will be active, using 23 for arrivals and 33 for departures.

2.5.1.2 Traffic modelling

The traffic used in the gaming exercise is based on one day of real traffic data from Hamburg airport dating from 25th May 2004. Traffic data for this kind of simulation needs a number of data that are not present in the reference traffic produced for EPISODE-3 in WP2. In particular the simulation requires gate and stand allocation as well as references between in- and outgoing flights to be able to model the turn around process, which is a major factor in the airport process model. It is not possible within the given time to add this data to the reference traffic, and hence only the available traffic data can be used in the exercise. This restriction is however fully in line with the stated objectives of the exercise, which is primarily to study the decision making process itself and the usefulness of this type of exercises for concept validation work. For the decision making process the most relevant factors are the available data and the presence of a capacity/demand imbalance.

2.5.2 Hypotheses

The list below contains the main hypothesis identified for this exercise:

H1: Sharing all relevant data within the AOP ensures a high level of situational awareness of the involved stakeholders (high level objective 1).¹

H2: Collaborative airport planning allows stakeholders to agree on a set of performance parameters for the airport to deal with a forecast problem situation (high level objective 1).

H3: Airport stakeholders are able to produce a solution that is better than a do-nothing solution by applying collaborative planning (high level objective 2).

The following three hypothesis are relevant for the network analysis part of the exercise, which is explained in detail in Annex 1:

- H4: The Kernel Network of Europe represents the behaviour of network constraining decision making in a sufficiently realistic way to provide a realistic context of network-wide operations for the APOC and its decision making at airport level.

¹ Exactly what is “relevant data” in this context is still an matter of research and one of the objectives of this exercise is to gain further insight into this question.
• H5: The constraining conditions of the Kernel Network are providing appropriate guidance to the Gaming exercise, which can be used in an effective way to keep delays to an acceptable minimum throughout the Network.

• H6: The departure preferences, agreed at airport level, can be accommodated in an appropriate way by applying prioritisation within the Kernel Network.

Of these hypotheses only H3 and H4 can be related to the KPIs listed above. The other hypotheses will be tested using debriefing and questionnaires to gather input from the simulation participants.

2.5.3 Assumptions

The following statements will not be tested in the scope of this exercise and are therefore set as assumptions:

A1: The agents in the APOC behave in a cooperative way. (Effects of uncooperative behaviour and how to get them to behave cooperatively are to be studied in separate experiments outside EP3).

A2: The negotiation in the APOC is sequentially, i.e. tasks are not negotiated in parallel. (Limitation of the support tool prototype).

A3: All traffic is 4D-controlled (limitation of simulation software used in the experiment).

A4: A moderator or supervisor agent is present in the APOC (currently necessary to technically control the negotiation process and the powerwall display).

A5: The absolute level of traffic is irrelevant for this exercise, the important parameter is the demand/capacity imbalance, hence real traffic data from 2004 can be used.

A6: The simulation suite setup for the experiment including AMAN and DMAN components provides a sufficient degree of reality to evaluate the agreed AOP based on resulting “actual” flight data.

A7: All flights arrive/depart at their scheduled times unless affected by local airport planning. It does not help at this early stage of concept validation to introduce schedule uncertainties into the simulation.

2.6 Equipment Required to Conduct the Exercise

As explained above, the exercise consists of a gaming exercise and a network management exercise.

2.6.1 Gaming Exercise

The gaming exercise requires a facility to use as an airport operations center (APOC). This facility shall provide several operator working positions as well as a means to provide a common overview of the situation to the operators. The experiment will use DLR’s ACCES facility for this purpose. ACCES provides a flexible infrastructure with up to ten operator working positions as well as a large powerwall to show a situation overview to all operators. All working positions are equipped to access different PCs running CDM and stakeholder specific systems as well as VOIP communication.
In addition a suite of real-time simulation tools is required to simulate the airside processes. The setup for this simulation suite is shown in Figure 5. At the top of the figure is the APOC, hosting the SWIM airport database as well as the support tools for the APOC agents, the Total Operations Planner (TOP) with its stakeholder’s clients. The TOP is a pre-tactical planning tool capable of planning all flights of the day taking into account the flight schedules, agreed performance parameters (e.g. capacity, throughput) for the airport as well as user preferences. The TOP plans the day of operation initially at the flow level only, but the final hours before execution time are also planned at the event level. The output of the TOP becomes part of the AOP, once it has been activated by the stakeholders.
The planning data produced by the TOP is then refined at the tactical level by the tactical tools. In this experiment only the Arrival Manager (AMAN) and Departure Manager (DMAN) will be present, but other tools like Turnaround- and Surface-Manager (TMAN, SMAN) can be integrated into the concept. Normally these tools would provide guidance to the tactical controllers how to control the incoming and outgoing traffic, this would be done via voice-communication with the pilots. For the simulation this process must be automated, and hence simple controller models are implemented that directly influence the aircraft in the simulation. Three real-time simulation models provide a realistic simulation of the relevant processes. TRAFSIM is a fully automated traffic generator, simulating aircraft equipped with 4D-capable FMS to automatically follow defined trajectories. This allows simulated aircraft to fly their RBT and to automatically follow RBT changes in response to tactical tools (i.e. arrival sequencing). ASGARD simulates surface movements of aircraft, also providing a very simple SMAN functionality to assign standard taxi-routes from aircraft position to runways and vice versa. The turnaround simulation is an event-based process simulation. The turn around process is divided into a network of subprocesses, and these are simulated taking into account their logical connections, available resources and standard times to complete each step. The model has been refined together with an industrial partner to provide realistic process times and dependencies. All three of these simulation modules are capable of fast forwarding by a factor of at least three, so that after activating a new AOP in the APOC the simulation can rapidly advance to the time at which the new AOP affects the scenario.

2.6.2 Network Management Analysis

In addition to the ACCES simulation facility used in the gaming exercise, two tools are required as equipment to perform the network management exercise. First, a Network Analysis Model (NAM) is used to model the kernel network, representing a network around
the most significant airports in Europe. This network will represent the planning environment of Hamburg airport, and will include this airport. Second, an Optimised ATFCM tool is required to calculate an optimal throughput for this network. See for further details Annex 1, section 6.4.3.

2.7 LINKS TO OTHER VALIDATION EXERCISES

This exercise is closely related to EP3 WP3.3.1, expert group on collaborative airport CDM. This expert group has provided input to EP3 WP3.3.4 regarding elements contained in the AOP and it is expected that results from the gaming will be further discussed and analysed by the experts in this group.

There is also a relation to EP3 WP5.3.2, airport expert group, in that experts for the gaming exercise shall be recruited from this group, which then also allows the experience from the gaming exercise to be fed into this expert group.

Finally, according to the EP3 WP3 validation strategy, the gaming exercise shall also feed into EP3 WP3.3.5, Macromodel. Since the output of the gaming exercise is mainly qualitative information on the collaborative planning process itself and to have a first look at such a process and a tool to support it, no quantitative performance data will be delivered to EP3 WP3.3.5, only qualitative information can be delivered to the macromodel.
3 PLANNING AND MANAGEMENT

3.1 ACTIVITIES

The main activities that are necessary to perform this validation exercise are:

- Preparatory activities:
  - Definition of the exercise, including selection of the SESAR ConOps elements, platform, scenarios. The main output of this activity is the present document (D3.3.4-01 Experimental Plan),
  - The input data pre-processing (airport model, traffic, ...) and the coding of the scenario files for the simulators and pre-tactical planning tools.
  - Creation of a network model of the core airspace of Europe. This model will contain nodes for each airport, sector and outer node\(^2\) of the core area.
  - Aggregation of the network yielding an aggregated network that allows for a rapid but realistic analysis of possible network demand and capacity imbalances.
  - Testing of scenarios to verify that the simulation suit and the network analysis provide reasonable output for a “do nothing” (no collaborative planning) scenario.

- The execution activities include:
  - Simulation execution
    Run gaming experiments as detailed in section 5.1
  - Network analysis
    Perform the network analysis taking the results from the gaming sessions as input
  - Optimised Collaborative Traffic Flow Management

- Post-exercise activities:
  - Output data post-processing
    Extract and convert data from the database and simulation logfiles into useful formats for further analysis.
  - Analysis of these results
    Aggregate the data from the simulation runs into the relevant KPIs and compare these with the do-nothing case.
  - Analysis of questionnaires and other subjective data
    Extract the qualitative information about the negotiation process, which is the main outcome of the experiment. This involves questionnaires, interviews and possible video-analysis of the experiment.
  - Elaboration of final report (deliverable D3.3.4-02: Simulation Report)

3.2 RESOURCES

To perform this validation activity, several skills are required from the participants:

---

\(^2\) An outer node represents the boundary of the core area, to which flights entering and leaving the area are mapped.
• Knowledge of SESAR Concept of Operations
• Experience in operating of involved simulation platforms and planning tools
• Experience in human factors analysis such as workload and situation awareness assessment
• Experience in data analysis.

The following table shows the expected effort in person months to perform all activities described in the previous section.

<table>
<thead>
<tr>
<th>Effort (PM)</th>
<th>Activities</th>
<th>Detail</th>
<th>DLR</th>
<th>ERC</th>
<th>NLR</th>
<th>NATS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREPARATORY</td>
<td>Exercise Definition</td>
<td>1</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Input data pre-processing</td>
<td>2</td>
<td></td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coding of scenario files</td>
<td>3.3</td>
<td></td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EXECUTION</td>
<td>Validation of Scenarios</td>
<td>2.5</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Simulation Execution</td>
<td>2</td>
<td>0.5</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>POST-EXERCISE</td>
<td>Output data post-processing</td>
<td>2.5</td>
<td></td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Results analysis</td>
<td>3</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Final Report</td>
<td>1.5</td>
<td>0.5</td>
<td>1.0</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>TOTAL (PM)</td>
<td></td>
<td></td>
<td>17.89</td>
<td>3.0</td>
<td>5.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 3: Expected Effort

3.3 RESPONSIBILITIES IN THE EXERCISE

This Gaming Exercise has four different partners:

- DLR, as the leader of the Exercise. Its main tasks are to coordinate all activities within the exercise and provide support to other partners of this sub-WP. DLR is responsible for running the gaming exercise in its ACCES facility and for creating the simulation scenarios according to this experimental plan. DLR is also responsible for analysing the data for the local airport point of view and for coordinating the process to write the final report.

- ERC provides their expertise mainly in the exercise definition and analysis and final report. They will also accompany the exercise and provide guidance during exercise execution.

- NLR, responsible for the network analysis supporting the gaming exercise. The airport flight updates resulting from the gaming exercise will be analysed in terms of their impact on the airspace network. The results, including suggested SBT/RBT changes for an optimal flow, will be fed back into the exercise. The entire network analysis and ATFCM optimisation falls under responsibility of NLR.
• NATS will provide their expertise in the data analysis and in preparing the final report.
• Additionally experts from airlines and airports will bring in their expertise representing the stakeholder agents in the gaming exercise.

3.4 TRAINING

The gaming exercise shall be conducted with participants having relevant operational experience. The participants will need special training for this exercise. This training will include an introduction into the TAM concept and the decision support tools used in the exercise. The training is expected to take a few hours. Training material will be prepared by DLR.

3.5 TIME PLANNING

The preparation activities for this exercise started immediately after EP3 DOW 3.0 was accepted. The actual gaming exercise will be carried out in April 2009. Analysis will start in parallel with exercise execution, so that first results for the Macro Modelling will be available by the end of May 2009.

3.6 RISKS

<table>
<thead>
<tr>
<th>Risk 1:</th>
<th>Expert availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>At this time expert availability for the exercise is not confirmed. Discussions are underway with the 5.3.2 airport expert group as well as with Lufthansa and Hamburg airport.</td>
</tr>
<tr>
<td>Impacted Area:</td>
<td>☒ Own Exercise</td>
</tr>
<tr>
<td>Level:</td>
<td>☐ Low</td>
</tr>
<tr>
<td>Possibility of occurrence:</td>
<td>☐ Low</td>
</tr>
<tr>
<td>Contingency Actions</td>
<td>Reduce the number of runs, reschedule additional runs at a later time when experts have been identified.</td>
</tr>
<tr>
<td>Mitigation Actions:</td>
<td>The exercise scheduling will be done according to experts availability.</td>
</tr>
<tr>
<td>Responsible party:</td>
<td>DLR</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Risk 2:</th>
<th>Simulation fast forward not possible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>The simulation suite may not be possible to fast forward at a significant speed. This will then lead to a large dead time between exercise runs.</td>
</tr>
<tr>
<td>Impacted Area:</td>
<td>☒ Own Exercise</td>
</tr>
<tr>
<td>Level:</td>
<td>☒ Low</td>
</tr>
<tr>
<td>Possibility of occurrence:</td>
<td>☒ Low</td>
</tr>
</tbody>
</table>
### Contingency Actions

In case the fast forward does not work the gaming runs (section 5.1.1.3) will have to be slightly modified. In this case there will be no simulation after the first run during the day and only the agreed plan will be analysed. The second run can then be concluded by a simulation running real time.

#### Mitigation Actions:
N/A

#### Responsible party:
DLR

### Risk 3:

**Results affected by negotiation tool prototype**

**Description:**
The negotiation tool prototype is an early prototype and as such the HMI has is not mature and user friendly yet. This may have a negative impact on the negotiation process that could lead to false results.

<table>
<thead>
<tr>
<th>Impacted Area</th>
<th>Own Exercise</th>
<th>Other Exercise</th>
<th>WP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Possibility of occurrence</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
</tbody>
</table>

**Contingency Actions:**
N/A

**Mitigation Actions:**
The questionnaire will include questions that allow to analyse this and see where problems occurred using the tool. This can then be taken into account in the analysis.

**Responsible party:**
DLR

### Risk 4:

**The exercise produces no useful data because of a lack of experience in running games.**

**Description:**
Gaming is a new technique to DLR and so there is a risk that the game does not produce meaningful results.

<table>
<thead>
<tr>
<th>Impacted Area</th>
<th>Own Exercise</th>
<th>Other Exercise</th>
<th>WP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of Impact</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Possibility of occurrence</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
</tbody>
</table>

**Contingency Actions:**
None. If the games are not working, it will probably be too late to use an alternative method.

**Mitigation Actions:**
Preliminary gaming runs are conducted at DLR to gain understanding of the process and the analysis methods.

**Responsible party:**
DLR
<table>
<thead>
<tr>
<th>Risk 5:</th>
<th>Stakeholder agents may not be able to develop a sufficient understanding of the underlying concepts and the simulation environment.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>Collaborative planning is a new concept developed in SESAR and as such the stakeholder agents will not have experience with this concept.</td>
</tr>
<tr>
<td>Impacted Area:</td>
<td>Own Exercise</td>
</tr>
<tr>
<td>Level of Impact:</td>
<td>Low</td>
</tr>
<tr>
<td>Possibility of occurrence:</td>
<td>Low</td>
</tr>
<tr>
<td>Contingency Actions:</td>
<td>N/A</td>
</tr>
<tr>
<td>Mitigation Actions:</td>
<td>Sufficient time is planned into the exercise schedules to allow briefing the operators in the concept ideas and to train them in the simulation environment.</td>
</tr>
<tr>
<td>Responsible party:</td>
<td>DLR</td>
</tr>
</tbody>
</table>

Table 4: Risks
4 ANALYSIS SPECIFICATION

4.1 DATA COLLECTION METHODS

Since the focus of the gaming exercise is on analysing the negotiation process itself, it is important to capture data that reflects the collaborative planning, the behaviour of the agents and their information needs. To this end the following data collection methods will be employed:

- **Video:** the stakeholders will be video taped during the negotiation process, with the camera view on their computer monitors to be able to analyse the interaction of the agent with the support tool.
- **Structured interviews:** The stakeholders will be interviewed immediately after the negotiation process to get their feedback on the process, tool support, and other questions relevant to the gaming exercise. The interview guideline is currently in preparation.
- **Questionnaires:** The stakeholders will also be asked to fill questionnaires to capture their feedback. Questions will be related to situational awareness, the negotiation process and the gaming setup and scenario.
- **In addition data is obtained from information recorded by the Total Operations Planner (TOP) and the simulation tools during each run. These data contain information regarding schedule data, updated flight plans and actual data for in-block and off-block as well as landing and take-off times. These data can be aggregated to provide throughput and delay data as well. Data provided from the gaming exercise will comprise (among others):
  - Per flight data: scheduled and actual times (on-block, off-block, landing, take-off) and delay
  - Aggregated data: Overall delay, average throughput and queue lengths, average punctuality

These data will be collected for the gaming as well as for a do-nothing scenario.

- **Network management analysis takes place by comparing demand and capacity of a today's, i.e. 2006, traffic scenario, used in previous experiments, i.e. SESAR Definition Phase, WP2.3.2, Ref. Erreur ! Source du renvoi introuvable. Demand is specified as ICAO flightplans (32,000) and converted to assumed best possible 4D Shared Business Trajectories (SBTs); Capacity is specified by airport sustainable and peak-capacity loads of 133 major airports and the capacity of roughly 1400 sectors. The applicable performance indicator is Demand/Capacity ratio and network node waiting periods collected from network analysis sessions with NAM.
- **Alerting information is indicative for potential overload conditions and proposed departure delays are the means to solve bunching conditions in the network. This information is gathered to provide input to the gaming exercise.**

4.2 OPERATIONAL AND STATISTICAL SIGNIFICANCE

The gaming exercise is used to study a very general concept, collaborative planning at the airport level in the short term/execution phase. This concept is significant for all major airports where day to day operation is expected to benefit from collaborative planning. Within the scope of the experiment only one particular negotiation scenario will be studied at one airport with one traffic sample, hence it
is not possible to derive statistically relevant data from the experiment. The results expected for the negotiation process itself on the other hand are expected to be of great significance and relevance to collaborative planning in general.

Network Management contributions are meant to provide “realistic” input to the collaborative planning process, which is however not actively used in the gaming exercise. The measure of realism can be controlled by reducing the capacity of the nodes of the network as appropriate. The realism is achieved by comparing today’s performance (2006) with model-processed performance and its expectations. The intention of the experiment is not to assess the performance of future operational conditions, but only to represent constraining network behaviour under varying conditions, i.e. under nominal unconstrained up to delayed and disrupted conditions, caused for example by possible incidental events like bad weather conditions in parts of Europe.

4.3 ANALYSIS METHOD

The video recordings will be analysed using Operation Sequence Diagrams (OSD, Erreur ! Source du renvoi introuvable). OSDs are used to graphically represent interactions between actors. Interactions with the system and verbal interactions with the other actors will be captured in the OSDs, so that the negotiation process and the tool support can be analysed. The quality of communication (neutral, emotional, …) will also be analysed from the recordings.

This analysis then allows to categorize the communication bits into:

- System related communication (questions related to using the tool or the CDM process itself)
- Coordination communication (coordination during the process)
- Task related communication (discussion about the actual situation; actual negotiation)

Further analysis of the OSD diagrams will be done using a Social Network Analysis (SNA, Erreur ! Source du renvoi introuvable), which allows to represent the relations between the actors and to categorize the relative importance of actors in the negotiation.

The feedback from the actors and the questionnaires will be analysed mostly on a qualitative basis to identify bottlenecks in the process and additional information demands for the negotiation. A major parameter will be situation awareness. Here it is of particular importance to capture the awareness regarding other actor’s intentions and the effect a plan proposed by another actor has on one’s own operation. A thorough statistical analysis is of course not possible given the limited number of runs and participants.

In order to gain some estimate of the performance of the resulting AOP the data collected from the TOP and the simulation will be analysed to obtain the total delay, number of flights delayed more than n minutes (n=5,15), and the number of delayed flights for the airline represented in the APOC. This analysis will also be carried out for the proposed AOP changes during the negotiation.

Network management performance is analysed over large amounts of data. Business trajectories (SBTs/RBTs) are analysed over 24 hours accessing the network via planed routes through the network. Bottlenecks and escalating throughput problems are the typical indicators of failing network performance. These indicators are the only ones used, and no others, by lack of means to perform real validation by fast-time simulation.

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3 It is not possible within the scope of the exercise to take this input into account in the collaborative planning process, but it is planned to analyse how this can be done.
4.4 DATA LOGGING REQUIREMENTS

For the gaming exercise the most important data is the feedback of the agents as well as observations of the collaborative process. In addition data must be recorded from the planning and simulation to allow analysis in terms of KPIs. The following data must be recorded:

Observations from the planning: Videotaping, logging of negotiation process (plans suggested to the others, etc.)

Feedback from agents: Questionnaires, interviews

Data from simulation: Scheduled, planned (after replanning) and actual data for relevant flight milestones (landing, in-block, off-block, take-off) for all flights; queue lengths

Network performance is executed by repetitive processing runs. The output of several runs under varying conditions can be compared. Comparison of results of iterative runs leads to selection of the most representative and appropriate scenario to feed the Gaming exercise. This “best” scenario, including analysis results, is input to the gaming exercise, and, depending on final experimental decision making, the traffic, and possibly capacity figures, can be adapted to specific needs of a gaming experimental session.

4.5 REPRESENTATIVENESS

The gaming exercise is expected to give insight into the collaborative planning process as such and it can be assumed that the results are transferrable to any airport in the ECAC area in general.

The support of the Network Management model will be tuned to characteristics of today’s operations. Representativeness of future network operational conditions can easily be achieved if more appropriate, realistic and well-balanced scenarios for the envisaged time period will become available.

It is beyond the scope of the exercise to establish quantitative benefits achievable with the OIs investigated, and hence input into the Macro Model, WP3.3.5, is expected to be limited.

4.6 OUTLINE REPORTING PLANS

The Simulation Report is scheduled to be delivered on the 30th of June 2009 according to the template provided by EP3 WP2.5.

The schema with the minimum content for the reporting plan is the following:

- Aim of the document – the aim of the report is to summarise the performed exercise and to objectively present the key findings. It is not meant to state conclusions about whether or not a concept is worth pursuing;

- Target Audience – A distribution list of the target audience should be drawn up before work commences on the report. This list will typically involve the internal stakeholders and management in EP3 WP3/4/5. This report should always be made easily available to interested parties;

- Scope – The report concerns a particular phase in the development of the concept. The results of the work done during previous phases can be referred to in order to show progress and development. Recommendations for future work should also be outlined;

- Key information – It is not advisable to include all results generated in the body of the report. Only the key results (statistically and operationally) need to be included. Details should be given in Annexes.
5 DETAILED EXERCISE DESIGN

5.1 EXERCISE STRUCTURE

The Collaborative Airport Planning exercise will consist of two parts. First, a gaming exercise will be held to solve pre-tactical planning events at an airport level in the APOC. Second, a network management analysis will be conducted to diagnose the consequences of collaboratively reached decisions in the APOC at a network level. Figure 6 below depicts the general set-up of the Collaborative Airport Planning exercise.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{exercise_setup.png}
\caption{Exercise Setup}
\end{figure}

5.1.1 Gaming Exercise

The gaming exercise will be supported by real-time and accelerated simulation. For this part of the experiment an APOC with working positions for stakeholder agents as defined in 2.1 is set up in DLR’s Airport Control CEnter Simulator (ACCES). All airside processes (aircraft moving in the air and on ground, turn-around process) are modelled by real-time simulations. The landside processes (check-in, security, and boarding) are not included in the scope of this experiment. All simulations shall be capable of running in an accelerated mode to be able to fast-forward the scenario. Tactical operators (ATC, pilots) are simulated as well, since running a full HIL real-time simulation with pseudopilots and -controllers would make it impossible to fast-forward the simulation. The tactical operators are not part of the negotiation process, but are required to ensure that planning changes (revised TOBTs, RBTs) can be simulated correctly.

The TAM concept foresees the use of a Total Operations Planner (TOP), a tool that is constantly revising the daily flight schedules based on available data, such as flight plan updates, priorities set by the airlines and other stakeholders, as well as agreed performance targets. As long as the deviations from the original schedule are within small and agreed bounds the new plan will be activated silently. As soon as such thresholds are violated, a negotiation between the stakeholders is required to find the best solution for the given situation. During the negotiation each stakeholder can perform what-if tests...
using the planning tool, i.e. he can modify any parameter and see how this would affect the overall plan, and of course also how it would effect his own interests. The stakeholders will have a common view on the situation, as all relevant data is stored in a central SWIM database, and they will follow a specific decision making process to reach a decision how to best cope with the forecast problem. This decision making progress will follow a structured negotiation protocol based on well defined use-cases to allow optimal use of support tools.

The simulated scenario will start at 7:00 am with a normal traffic load for the day of operation. There is an early morning departure peak at 9:00 followed by an arrival peak. A heavy thunderstorm warning will lead to a forecast capacity break-in at the same time the departure and arrival peaks are scheduled, leading to the Total Operations Planner (TOP) detecting an expected increase in delays. The APOC agents will be alerted about this and the negotiation process is started.

After the APOC agents have reached a decision the gaming exercise is ended and the participants will be interviewed to get feedback from them. The simulation will continue to run for several “simulated” hours until the recovery from the adverse condition is completed. The data from the simulation will then be analysed to compute the KPIs of interest.

For this analysis, not only the effects of the commonly reached decision for the airport are taken into account, but the effects on the surrounding network as well. To this end, a network management analysis is conducted based on the scenario in question and the proposed flight updates.

5.1.1.1 Actors and Roles

The SESAR Operational Concept calls for all relevant stakeholders to participate in the collaborative planning at the airport level. For this gaming exercise however only a subset is expected to participate. This decision was made since for this very first exercise on the topic the priority is on analysing the negotiation and collaboration process itself rather than looking at the performance benefits it can bring, and this can be better done with a limited set of actors in the scenario. At the same time this reduces the risk of not finding a sufficient number of experts to participate in the gaming exercise.

For the experiment the following actors are planned:

**Airline Agent**

The airline agent will represent the airline operations in the APOC. In the exercise he will attempt to reduce the impact on his operations of the bad weather situation as much as possible. To this end he will be given background information not available to the other agents, such as importance of specific flights, dependencies between flights (of his airline), etc. This will allow him to evaluate the cost of his own solution proposals as well as that of the others to his airline. The agent will be allowed to accept any solution that is better than the “do nothing” scenario, but naturally he shall try to get the best result for his airline.

**Airport Agent**

The airport agent will also be given background material that allows him to evaluate the effect of a given proposal for his operation. He also will not accept a solution that is worse than “do nothing”, so the only accepted solution would bring a benefit to both.

The background information specified for the actors will be such that a solution is possible which brings benefits for both participants.

**Moderator**

The moderator is an agent that is not explicitly called for in the SESAR Concept of Operations, but this role is anticipated in the joint TAM Operational Concept developed by Eurocontrol and DLR. The role of the moderator is to monitor the negotiation process and to ensure that rules are followed. From an experimental point of view he also gets the task of controlling the powerwall display and the negotiation flow in the support
tool. The moderator (supervisor) is supposed to be neutral, but he can also perform what-if probing and propose solutions to the other agents.

For the task selected for this experiment the supervisor can terminate the task when no decision can be reached by the agents, in which case the previously active parameters will stay active.

In the gaming exercise described in this experimental plan the moderator role will be filled by DLR staff. The influence of the moderator on the negotiation process and results is a topic to be analysed in further studies, but it is beyond the scope of the current exercise.

5.1.1.2 Negotiation Process

The gaming exercise will study the process of collaborative planning based on a structured negotiation protocol approach. Only one negotiation task will be studied within the scope and resource limitations of this exercise. The example task will allow the APOC agents to negotiate the relative weights of key performance parameters (throughput, punctuality) and is related to the task “Refine Airport Usage Rules” (A2.2.1.1 of the DoD, Erreur ! Source du renvoi introuvable.). This will primarily affect the setting of the arrival/departure ratio as well as have an impact on stand/gate allocations and queue lengths.

The simulated scenario as described in 5.1.1 contains a forecast capacity breakdown due to a severe thunderstorm. This will lead to the Total Operations Planner (TOP) detecting an expected increase in delays. The APOC agents will be alerted about this and the negotiation process is started.

Negotiation Flow

1. One of the agents (initiator) reacts to the weather forecast and the resulting delays and declares that he wants to change the setting of the “Set Performance Parameter Strategies” within a defined timeframe and with a defined deadline.

2. The Initiator addresses to the Moderator a request for processing of this task “Set Performance Parameter Strategies” in the defined timeframe and within the defined deadline. The initiator may perform a what-if probe to search for a solution that would fit his needs and attach this solution proposal to his request.

3. The Moderator (Decision Maker for this specific task) decides that this task “Set Performance Parameter Strategies” has to be processed.

4. The Moderator enters the solution proposed by the initiator (or the currently active AOP if the request is without a proposed solution) as a request for a collaborative decision making process into the system and according to its urgency into the task schedule and sets a deadline that shall be equal to or earlier than the deadline set by the Initiator. (Moderator can call back to other actors about the urgency of the request).

5. When the task gets priority (which is immediately since in the exercise there are no other active tasks) the Moderator activates the task through setting the timer that indicates how long this task stays active. All information including the solution from the separate what-if probing and the timer setting is sent to the APOC-clients of the participating actors via the system.

6. The participating agents can now study the proposed solution and make own private what-if probes to see if they can find a solution that is better suited to them. They can then accept the proposed solution or propose their own new solution to the others.

7. After each cycle, if no agreement has been reached, the moderator selects one of the other proposed solutions and sends it to the others again. The moderator is also able to make his own what-if probe to find a solution that he thinks fits the needs of all agents and propose that to the others.
8. When all agents agree on one solution, the moderator will activate this. If no agreement can be reached when before the deadline of the task is reached, the currently active AOP remains active (“do nothing”).

5.1.1.3 Length and number of runs

For the gaming exercise two sessions are planned. Each session should be run with a different set of experts.

The exercise itself will take place in the DLR ACCES facility (Figure 4) representing the Airport Operations Center. The main elements of the APOC as a control room are a large powerwall and the stakeholder working positions. Each stakeholder working position provides access to the Total Operations Planner (TOP) by a client interface. Using this interface the stakeholders can perform what-if analyses and participate in the negotiation process. The real APOC will also have interfaces to the stakeholders’ operations centers, these are however out of scope for the current exercise. Apart from the stakeholders the TAM concept also defines the role of a moderator. The moderator shall be a neutral person and shall overview the negotiation process. The moderator can set priorities for tasks or abort tasks if no decision is reached in the available time frame. The moderator also controls the powerwall, which displays an overview of the current situation and the negotiation process to the agents. In the gaming exercise the moderator will be part of the EP3 team running the exercise to provide some consistency during the experiments.

Two groups of experts are planned for the gaming exercise, each group will be needed for two days and perform two gaming runs in that time. This is shown in the table below:

<table>
<thead>
<tr>
<th></th>
<th>Day 1 (Group 1)</th>
<th>Day 2</th>
<th>Day 3 (Group 2)</th>
<th>Day 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Briefing</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Gaming run 1</td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Debriefing</td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Gaming run 2</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Debriefing</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

Table 5: Exercise schedule

Note that the two groups need not be there on consecutive days. The scheduling is at this point not fixed to allow the exercise to be coordinated with experts availability. If more than two teams of experts become available, then more runs can be performed.

The debriefing sessions will be a major part of the experiment, since the most important data will be the feedback from the experts regarding the collaboration process. These sessions will be based on structured interviews and questionnaires.

5.1.2 Network Management Analysis

This analysis starts with the proposed SBT/RBT updates resulting from the collaboratively reached decision in the gaming exercise. Given these updates, a network analysis is produced to calculate the consequences of this decision with respect to the previous planning. Network management takes place in four steps:

1. Input of commonly agreed SBT updates from the gaming exercise. (This input is considered as SBT updates to be added to the kernel network scenario, representing part of the ECAC-wide network including the airport of Hamburg.)
2. **Calculation of the throughput in the network.** Using NLR’s Network Analysis Model (NAM), the resulting incurred delay (“network waiting time”) in the European core network of airports and airspace sectors (including Hamburg) is calculated. The incurred delay will be related to the cumulative delay in the baseline scenario, in which no SBT updates are implemented (the do-nothing option). The incurred delay is a reliable criterion for the network throughput.

3. **Optimisation of the throughput.** This step consists of balancing demand as part of DCB by use of optimised Collaborative Traffic Flow Management (ATFCM) algorithms: by optimising the traffic flow in the network, a better throughput can be accomplished. Using NLR’s Optimised ATFCM tool, certain flights will be given a pre-departure proposed departure constraint to ensure a better flow through the network. To determine which flights should be given this delay, the tool offers a look-ahead feature that allows the user to determine future demand and capacity imbalances. Given these future imbalances, it is possible to trace back which flights should be given a pre-departure delay to ensure optimal throughput.

4. **Output** of (a) the incurred delay and (b) optimised ATFCM constraints to be used for local planning at the airport level:
   a. The incurred delay resulting from step 2 is fed back to the gaming exercise. In case this delay is larger than the delay incurred when no decision is taken (the do-nothing option), the TOP planner delivers a warning to the stakeholder(s).
   b. The optimised ATFCM constraints resulting from step 3 constitute a proposal to minimise network bottlenecks by giving certain flights a proposed pre-departure delay.

The process above represents an isolated update process from agreed planning updates impacting the departure planning at the airport of Hamburg. This can be considered as a sufficient step to feed the gaming exercise. However, for a network representative process, the inputs at Hamburg have to be complemented by a similar feed-back process at all airports of the kernel network. It is optional to feed the kernel network with similar emulated SBT updates for all other airports, and allowing the network to react with proposed departure constraints. Only in that case, it will be possible to get an indicative impression on how much the local collaborative planning process may affect the central network management process.

Representative emulation of agreed SBT updates can be generated for example by running a DMAN process on flightplanning at airport level for each airport of the kernel network. The DMAN process may represent the optimal achievable results regarding minimal deviation from planning for each individual airport, and in the case of Hamburg this result can be compared with results achieved by gaming. However, also other ways can be considered to emulate the result of gaming at airport level.
6 ANNEX 1: NETWORK MANAGEMENT MODELLING IN SUPPORT OF GAMING

6.1 INTRODUCTION

Through Network Management, the effects of collaborative decision making at airport level on the surrounding airspace network – including other main airports – can be determined. The NOP includes the planning of all airports and all flights, and comprises constraints and restrictions on planning and planning changes. A simplified NOP of the kernel network of ECAC-wide operations will be modelled and processed in support of the gaming exercise. This process supports the following functions:

- To provide bunching information on those flights that will run the risk of being delayed and that will need high attention from network operations perspective,
- To provide proposed departure constraints for those flights that are constrained by network restrictions, and
- To process prioritisation preferences generated by the gaming exercise and applicable to the reference airport, i.e. Hamburg. Also, other airports of the kernel network can be emulated to provide similar proposed constraining preferences to the network and to evaluate their effect.

In the present experiment, a stand-alone aggregated network management model is developed. The 3rd function, to process prioritisation preferences, can be tested but can not be implemented in the model yet.

In the following sections the process to develop and build this model is explained.

6.2 EXERCISE SCOPE AND EXECUTION

The most important stakeholders of the gaming exercise are the airport and airspace users and their requirements as expressed in SESAR D2. One representative of these stakeholders is the Central Network Management representative, represented in this experiment by an off-line emulated process.

The most relevant expectations of stakeholders are summarised of network management functionality in support of APOC operations in Table 6.
<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Involvement</th>
<th>Why it matters to stakeholder</th>
<th>Performance expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airport Operator</td>
<td>Participation in the gaming exercise and in the 3.3.1 collaborative planning expert group.</td>
<td>The airport operator is interested in making best use of available resources and to ensure smooth and predictable operations of the airport as a whole. With collaborative planning the airport operator can better understand needs and attitudes of other stakeholders. The APOC affords an opportunity to concentrate all necessary information at a central place, one source of information comes from Central Network Management (CNM).</td>
<td>Network Management: Reduced queuing times for both arrivals and departures as a result of smoothing traffic flows through a collaborative and optimised network management process. Their critical role is to facilitate operations as planned. The airport has an enabling role in adherence to the departure planning and is therefore critical in predictable and undisrupted performance of ATM.</td>
</tr>
<tr>
<td>Airlines</td>
<td>Participation in the gaming exercise and in the 3.3.1 collaborative planning expert group.</td>
<td>Airlines are interested in transparency in all information having an influence on their flights. CNM contributes by monitoring cost-effective, efficient and undisturbed use of the NOP</td>
<td>Network Management: More cost-effective operations through accommodation of user preferences by prioritisation. The concern is if priorities can be acknowledged without a negative impact on network performance. Critical role: Increased throughput and efficient utilisation of available runway capacity (especially in adverse conditions). The concern is if local airport decision making fits with network management constraints. The risk is to create instability.</td>
</tr>
</tbody>
</table>
### Stakeholder Involvement

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Involvement</th>
<th>Why it matters to stakeholder</th>
<th>Performance expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSP</td>
<td>Participation in the 3.3.1 collaborative planning expert group.</td>
<td>ANSPs are responsible for the runway utilization they play an important role in the decision making process in the APOC by focussing on the effects of proposed decisions on the demand and capacity balancing of the airspace. Network Management supports this by balancing demand and capacity and by monitoring and solving capacity bottlenecks.</td>
<td>Network Management: Increased knowledge of the impact and interdependency between airport and network capacity. A DCB process that limits variability of demand reduces the controller load and allows to perform traffic synchronisation in a most effective way. A DCB process allows to ensure safety by accommodating a maximum acceptable amount of traffic demand.</td>
</tr>
<tr>
<td>EP3 WP3.3.5 Global Performance at Network</td>
<td>Episode 3 Exercise</td>
<td>Analysis of the impact of the local processes and airport solutions on performance at the ECAC wide level as well as identifying the network effects and the network resiliency.</td>
<td>Expect indications on the impact of the collaborative planning process at airport level on airport and network performance.</td>
</tr>
</tbody>
</table>

**Table 6 - Stakeholder expectations regarding Central Network Management functions**

### 6.3 Description of the Concept of Interest

The APOC may receive input from a CNM model, representing the constraining conditions imposed by NOP. The following elements, putting airport planning processes within the context of the NOP:

- Improving the interoperability between Network Capacity Management Processes and planning processes at airport level (through Network Management):
  - By issuing proposed departure constraints applicable to flights departing from the airport of interest, and
  - By processing preferences evaluated at airport level, and accepting such preferences as prioritisation constraints,
- Monitoring ATM Performance (through Network Performance Assessment) and providing alerting information on bunching and/or congestion to planning processes at airport level.

#### 6.3.1 Scope of Operational Concept of Interest

The list of OI steps that will be addressed determine the operational scope of interest of the model supporting the Gaming Experiment. The applicable OIs are:

- L10-03 - Improving Airport Collaboration in the Pre-Departure Phase
- L03-01 - Collaborative Layered Planning Supported by Network Operations Plan
- L04-01 - Improving Network Capacity Management Processes
- L04-02 - Monitoring ATM Performance
6.3.2 Detailed Outline of the Operational Concept of Interest

Management and planning of flight operations is derived from the Shared Business Trajectories (RBT/SBTs), the 4D planned flightplans submitted by Airline Operators. Constraints management on these SBTs is based on the monitoring of constraining conditions in the central network of operations as well as constraints on flight preparation and departure planning at airport level. The results are filed as Reference Business Trajectories (RBTs).

The Gaming exercise deals with collaborative planning Airport level, and takes place in the Airport Operations Centre (APOC). The constraints at central network level are provided as input to such a collaborative planning process, and the output of this process will feed and influence the management process at the level of central network management.

The off-line modelling part of the experiment, performed by NLR, will address the interactions and connectivity between the airport under investigation and its surrounding network. This network represents the NOP or part of the NOP and consists of routings, airspace sectors and airports. To determine the mutual interactions and consequences of collaborative decision making at airport level and the surrounding network, the operations of the following conceptual elements are important:

- **Demand and Capacity Balancing**

In SESAR, the Network Operations Plan (NOP) is central to the concept of operations for large airports and their environment. In the NOP, a planning of operations is available that is converging in level of confidence, level of detail and quality of planning towards the executive phase. From the NOP, the Airport Operations Plan (AOP) is derived: an en-route-to-en-route-conversion of the NOP, enriched by airport specific data. Both departure and arrival operations are expected to follow the AOP, being consistent and in agreement with the NOP, and to behave in compliance with this constantly updated planning, making these operations reliable and predictable.

The NOP will comprise information concerning demand, capacity and the proposed and agreed measures to balance demand and capacity.

**Air Traffic Demand:**

- Air traffic demand, stored as Shared Business Trajectories (SBTs), is roughly known half a year in advance and traffic demand is known in detail one day in advance. Nevertheless, RBTs are submitted at the day of operation as well.

- Air traffic demand sets the scene for the capacity and throughput requirements of the NOP. In the experiment, the scenarios will represent the air traffic demand of one day of operations.

**Capacity and the Network:**

- Available capacity and throughput limitations are determined firstly by available infrastructure, i.e. by the capacity of Airports. Possible restrictions in airport capacity are found mainly in the major and hub airports. 60% to 70% of the delays are allocated at the largest 20 airports of Europe, ref. *Erreur ! Source du renvoi introuvable*. and *Erreur ! Source du renvoi introuvable*. These delays are forthcoming from runway and runway throughput limitations but also from airspace limitations. The large flows of departing and arriving traffic to and from the hub airports are creating a major part of the congestion problems at airport level and in the immediate vicinity of the airport, i.e. the TMA.

- Therefore, the throughput capacity of airports sets the scene for airspace throughput requirements as well, not only in the TMA, but thereafter also in ETMA and En-route airspace. This completes the capacity requirements of the NOP.
Due to the critical role of air traffic to and from the 20 largest airports of Europe, the network connecting these airports can be considered to function as a kernel network. However, such a kernel network has to function also as part of the total network and has to provide connectivity therefore to all relevant airports of Europe. The significance of this kernel network is that it can provide a focused view on critical flows and critical nodes in the network.

The network through airspace is determined by the routings, which form a fixed route network structure at present (2009) and which will evolve towards a free route network within the SESAR timeframe may evaluate towards a partly free route network by SESAR. Nevertheless, even then there is a de facto network determined by routings, although probably more refined than today.

The control on the network by ATC is achieved by sectorisation. This sectorisation is mainly determined by the control capability of one executive controller, and a declared capacity figure is associated with each identified sector. This determines the airspace capacity of the network that serves the routing network, and this determines together with the airports the throughput capacity of the NOP. Such a demand/capacity scenario is selected for the network modelling experiment from an ECAC-wide scenario.

Balancing the Network:

RBTs, planned by routings through the network, are passing sectors, whilst departing and arriving at an airport. Assuming the Airline to accomplish an optimal planned routing, and allowing the Airline, if necessary, to adapt the routing to his discretion and to his judgement of optimal deployment of operations, the RBTs are accepted for DCB processing, and not to be subject of re-routing at that stage. If business trajectories are planned and re-planned by Airlines, the planned routings and re-routings shall be accommodated. Further requirements are that the DCB processing functions in a predictive and flight-efficient way. A cost-efficient network will not exist without any overload condition and it is the task of DCB to ensure sufficient capacity available but avoiding incidental overloads of the network under these conditions.

To provide sufficient capacity to the network depends on the capacity of the individual nodes of the Network, i.e. the capacity of airports and sectors. There are problems concerning the capacity of the Network:

- Airport nodes are characterised by an hourly capacity figure, but in reality airport capacity is a more variable and operations-dependent quantity. For example, departure or arrival peaks may cause throughput variations, also the mix of weight categories of traffic and incidental weather conditions may cause variations of capacity figures in time. In addition, airports are critical for overload due to inflexible throughput conditions over the runways, and Airports can be characterised by significant differences between sustainable and peak load capacity. Finally, the capacity can be restricted due to local policies, defining a capacity less than the physically achievable capacity. The network modelling process operates with at most two capacity figures: sustainable and peak load capacity.

- Sectors are mostly dimensioned by the workload capacity of one executive controller. This is not necessarily the ideal dimensioning of a Network. If there are too many nodes, there is a risk that the Network becomes super-critical for sector overload conditions. The ECAC-wide European Network consists of more than 2000 sectors, which is likely to be beyond the optimum. The optimum can be defined as being a condition where most of the sectors, or at least the sectors of busy parts of the network during busy hours of air traffic operations, are characterised by a low and balanced traffic-load/node-capacity ratio for all sectors. If not, some form of sector aggregation may help the Network to become more robust.
The sectorisation of the Network is not designed together with the infrastructure that is supported by the Network and the varying traffic flows through the Network, determined by the half yearly scheduling. At any times, it will be necessary to evaluate capacity balancing along the applicable routings and through the sectors, used by these routings. Throughput analysis through the Network may lead to local sector capacity adjustments which will become beneficial to overall throughput through the Network.

- The Network consists of nodes and the ANSPs together with the Central Network Management actors will ensure sufficient capacity available. However, the required demand as well as the available capacity will vary over the day. In addition, there is no reason to assume that demand through congested nodes is balanced and equally distributed over the network and in time “by nature”. Whatever the capacity adjustments, there will be hotspots and periods of bunches in the network, albeit for reasons of cost-efficiency. The way to equalise traffic demand during bunchy periods is to balance demand as part of the DCB process which may include the application of Collaborative Air Traffic Flow & Capacity Management (ATFCM) algorithms that determine proposed departure constraints on not yet departed traffic.

- The way to deal with proposed departure constraints is left to the user, but in order to be able to manage these constraints, the user must be informed about bunching periods and flights involved in these bunches. In addition, the user must be informed about the status of the network in a transparent way that will allow him to adapt proposed constraints on flight planning.

- The ATFCM process has to suppress bunches in order to protect sectors and airports against overloads and to justify the declared capacity of sectors and to save airports for queuing problems due to runway access limitations. An ATFCM process can be designed such that proposed constraints are least penalising regarding the proposed departure constraints, and least penalising can be defined then as reaching a proposed planning with an average minimum average delay by imposed constraints and a minimum spread of delaying constraints. It should be noted that without the second condition there is a risk that solutions are identified with an optimum that extremely delays some flights for the sake of punctuality of the others, and this is deemed to be judged as a sub-optimal solution.

- Analysing this ATFCM process, it could be feasible and favourable to select penalising strategies that are not equal towards all users. For example, it can be beneficial for a least penalising strategy to select departure constraints with more priority from less congested flows and to promulgate expeditious throughput of high congested flows.

- The airspace users are allowed to propose flightplan changes on their SBTs/RBTs accomplished, negotiated and agreed in a collaborative way at airport level. They are allowed also to reject or adapt flightplan changes accomplished at airport level by local agreement. This requires the ATFCM process to be able to deal with these preferences and to adapt the constraining conditions in such a way that bunches are still suppressed, whilst user preferences are respected. However, this may yield a degradation of network performance regarding average and spread of proposed departure delays.

- Network balancing shall be applied during the processing of planned traffic through the network model. This part of the experiment will consist of:
  - Defining and selecting an appropriate ATM Network of operations,
  - Analysing and balancing the capacity of this Network,
  - Identifying the traffic flows through the Network, and informing the airspace users about hotspots and bunches,
Balancing the demand through the selected Network and informing the airspace users at airport level about proposed departure constraints, and

- Receiving and processing user preferences and accommodating these preferences by prioritising accommodation of the planned target departure times of these flights.

**Network Management and Design**

The network is considered here from the point of view of management and control on DCB and throughput analysis only. Network requirements are derived from optimised routings through sectors and airports. This network is based on:

- City-pair connectivity and to a large extent unconstrained routings,
- Ideal vertical and lateral profiles to reach the destination in the most fuel-efficient way,
- Constraints at departure and destination to follow flight profiles which ensure the required capacity around the airport of interest,
- Constraints that are optimised towards fuel efficiency, but that respect environmental regulations, in particular noise load regulations,
- A routing structure required to build up manageable traffic flows to and from the airport of interest,
- All constraints that meet the requirements of other traffic flows and other flight operations and that establish a best compromise for conflicts of interest.

As described under the DCB paragraphs, the network consists of airports, i.e. more than 500 ECAC-wide, and sectors, i.e. more than 2000 ECAC-wide. The experience is that this network determined by capacity of executive controller workload, is super-critical; see e.g. SESAR Performance Assessment, Ref. [Errer ! Source du renvoi introuvable]. To come to a Network that is manageable from the point of view of DCB and throughput analysis there is a need to identify main- and sub-structures in the network, i.e. the Kernel Network, and to find a strategy to select a less overload-critical structure. Moreover, structuring of the Network can be helpful for better response and enhanced transparency on information provision.

The proposed structuring of the network yields:

- The ECAC-wide area has natural boundary conditions by relatively thin flows of air traffic that leaves and enters the area\(^4\). The experiment selects for reasons of scale a sub-area with less ideal boundary conditions. This area covers part of Western Europe, servicing airport connectivity between 17 large airports of Europe.
- Airports in Europe are split in groups of hub airports (~20), major airports (~110), and other remaining airports. In the experiment, a network is identified with a sub-group of 17 of these 20 large hub airports and the other airports within this area, covered by the connectivity between those 17 airports. The remaining other airports are aggregated to a set of “cluster” airports servicing the geographical area of interest.
- Experience learned from the sectorised network that there are too many thin flows of air traffic and there is too much unbalance in an effective deployment of the capacity of the

\(^4\) A thin flow can be understood here as a flow of traffic with relative modest impact on traffic pattern to other flows moving through the different nodes of the network under consideration.
network. To improve the performance of the Network, aggregation is applied. This means that the least significant parts of the Network are aggregated with their nearest neighbours. Each thin flow of traffic over the day is aggregated with its nearest neighbour by:

- The lowest loaded sector of the Network is aggregated with its nearest neighbour, simplifying the Network by removing a node. This is repeated in an iterative way until an optimal, transparent and/or useful Network is obtained.
- The traffic flows through the aggregated node are added to the more significant flows of its nearest neighbour sector.
- The capacity of the aggregated sector is added to the capacity of its nearest neighbour. Summation is acceptable because aggregation is only applicable to the DCB process, and it can be assumed that flows are re-distributed as much as possible over the applicable sectors later on during flight execution in agreement with their RBT, i.e. by Dynamic Flow Management.
- The aggregation of sectors takes place by creation of a super-sector for DCB purposes only, which is done by creation of a synthesised node in the Network on the centre of gravity of the aggregated sectors.
- The planning of air traffic remains unchanged because all RBTs, i.e. 4D flightplans, are still applicable, not changing any planned waypoint. The only change is the sequence of sectors related to the 4D-planned routing.

It is expected that aggregation not only simplifies the Network but also improves the traffic-load/capacity ratio. The expected result of selection and aggregation for the experiment is:

- The experiment will address a Kernel Network that represents the most relevant areas of hot spots and congestion in Europe in a representative way. Most areas of congestion will be part of this DCB process.
- The selection, together with aggregation, provides a manageable Network which can be experienced with prototyping DCB models without serious and/or prohibitive software performance restrictions.
- The selected and aggregated Network is expected to be more robust and to require less capacity than the super-critical originally sectorised network. Either the sector capacity can be reduced maintaining equal performance levels, or the departure constraining delays can be reduced operating with unchanged capacity figures.
- An optimal level of aggregation regarding the DCB process, may serve as an indicator to identify an optimal distribution between centralised and local flow management activities.

The experiment constitutes an aggregated Network with feasible and acceptable throughput performance characteristics, which is representative for ECAC-wide Network performance at the same time. Model processing is applied on this Network to feed the airport Gaming exercise with network constraints information, and the network is used thereafter to evaluate the impact of user preferences, agreed at airport level, on the Network. However, it should be noted that very likely the impact of user preferences can be evaluated only if all hub airports involved in the Kernel Network are allowed to propose user preferences regarding their departure planning in a similar way. If not, an unbalanced and only partial impact of preferences on the Network is processed.

### 6.3.3 Level of Maturity of Concept of Interest

Work on performance assessment, undertaken in SESAR Definition Phase (Erreur ! Source du renvoi introuvable.), made clear that the Network could not be used for performance assessment in an appropriate way without clarifying the notion of capacity and without being more confirmative in
assessment of criticality of the capacities available in the network. Lack of control on throughput analysis was the major problem in network performance assessment. Therefore, the emphasis is laid here on analysing the availability of capacity in the network.

Concerning the level of maturity of the concept of interest, the following can be stated:

- **Demand and Capacity Balancing:**
  
  DCB is a pre-departure process. The process doesn’t make use of any advanced technology and therefore there are no major transition issues from a technical point of view. The process is in a V3 status, and validation can be consolidated easily, time permitted. Advanced algorithms have to be prototyped, evaluated and validated. However, the most complicated issue might be “agreement” and operational implementation may be mainly dependent therefore on acceptance by the ATM community, i.e. the stakeholders. From the point of view of institutional and regulatory perspective the concept is therefore immature because detailed and comprehensible outlines of concepts of interest are still missing. The concept is in a V2 to V3 status and there is a need for explorative investigations showing alternatives to address optimisation towards minimal delays and maximum user accessibility.

- **Network Management and Design:**
  
  Network Management operates today, i.e. 2009, by elaborate operations on ASM and DCB, coordinated, executed and managed by CFMU. All proposed concepts are refinements to improve performance, interoperability and user access. There are no principal limitations to implement advanced DCB algorithms and evaluation of robust and optimised structured Networks are achievable as well. Again, stakeholder acceptance is the major issue. Therefore, implementation can be considered to be in a V3 status. The dependency on 4D planning puts the concept in a V2 status, whilst also acceptance is V2 rather than V3.

6.3.4 KPAs related to the Concept of Interest

In the CNM model, the planning of the airspace segment of the business trajectory is central. In this part, the impact is studied of a collaboratively reached decision at airport level on the overall network surrounding the airport. Thus, the effect of the airport-centred operational improvements, the focal point of part one, is investigated and quantified in terms of network throughput and punctuality.

The following Key Performance Areas are relevant for the CNM model:

- **KPA Capacity** (throughput): This KPA addresses the ability of the ATM system to cope with air traffic demand and to accommodate a maximum number of flights and an optimal distribution through time and space, as tightly as possible in adherence to planning. Related to Network Management, the focus in the gaming exercise is to make effective use of existing capacity. For given traffic demand, the delay can be minimised by collaborative decision making in the APOC, taking into account possible repercussions on the performance of the network. This aims to lead to an efficient use of existing capacity, maximizing throughput in the global ATM system. Network Management ensures providing the capacity required by the network.

- **KPA Efficiency** (punctuality): The objective of Network Management is to accommodate air traffic as much as possible as planned. The DCB process applied to accomplish this goal, aims to make use of network capacity as efficiently as possible, minimising delays. The collaborative planning process at airport level aims to reach agreement on departure planning amongst stakeholders involved and to express the agreement by planned departure preferences. These preferences are input to the Network Management process to be treated as flight prioritisation indicators. Again the aim of the network management process is to accommodate the extra planning prioritisation preferences as efficiently as possible, i.e. with minimised average delay and minimised spread in delays.
• **KPA Predictability** (enhanced quality of planning, i.e. 4D): A consistent planning in 4D, starting from SBTs and converging to planned and agreed RBTs aims to make effective use of available capacity. Adherence to the planning is the objective of executive services and a feasible and reliable 4D planning by agreed RBTs is the way to support executive services in meeting this goal. Simulation of executive processing of planned flights through the Kernel Network is required to assess the performance regarding predictability, but this is outside the scope of the Gaming/modelling experiment.

The modelling of Network Management is not followed by any quantitative assessment or performance validation, being outside the scope of the experiment. Therefore, results are indicative only. Improved predictability is assumed to be part of the concept; enhanced efficiency and throughput are measured in an indicative way.

### 6.3.5 High level Objectives

The effects of decision making on the airspace network surrounding the example airport are assessed. To this end, the throughput of air traffic through the busiest parts of the European airspace, possibly prioritised by a preferential departure schedule, is being investigated in detail by a modelling experiment.

The objective of this modelling experiment is to build a representative kernel European ATM network and to provide a realistic ATM background environment to exercise hub airport operations. This network represents the constraining conditions that can be experienced in terms of delays and throughput problems. The emulated behaviour of the network aims to provide air traffic flow constraints information to airport operations and to receive and process flight planning information, agreed at airport level.

### 6.3.6 Specific objectives

The objective of the modelling part of the experiment is to establish the effects of commonly reached decisions at the network level. These effects are needed to provide the Gaming exercise with a realistic operational environment regarding network management behaviour under constraining conditions. The objective to generate network effects is complemented now by specific objectives required to realise the functioning of the network management environment by use of functions to feed the Gaming exercise. This objective can be further subdivided therefore in the following specific objectives:

- Determine the bottlenecks of the network caused by an unbalance of demand and capacity (given the scenario and the commonly reached solution to counter this unbalance) and provide information on bunches related to flights departing from the applicable airport, impacting collaborative departure planning processes.
- Determine the best strategy to balance the (required) capacity at critical bottlenecks with the demand. This strategy should accomplish a balance sufficient to accommodate the demand with least penalising proposed departure constraints.
- Determine the impact of demand balancing as part of DCB by applying an optimising ATFCM algorithm on the bottlenecks in the network, by network throughput analysis.\(^5\)

\(^5\) It should be noted that the usual impact of ATFCM measures on flight performance can not be validated in this modelling experiment due to the scope of the project. Validation of flight performance along usual flight performance indicators like queueing delays and workload characteristics requires a network-wide fast-time simulation process. This is not included in this plan.
- Determine an effective prioritisation mechanism to accept collaborative decided flight planning preferences and to evaluate adapted constraining departure planning conditions.
- Determine the impact of prioritisation by departure preferencing on the throughput of flights in the network.

The modelling experiment emulates behaviour of Network Management. The output is determined by the quality of applicable optimisation algorithms. There is no requirement to evaluate direct benefits of applying the algorithm on the NOP, or part of the NOP; however, the outcome should represent future NOP behaviour under SESAR. The quality of emulation of the NOP is determined by overall network throughput behaviour, measured in terms of waiting periods to access network nodes. These values are measured by network throughput analysis and not by fast-time simulation! Moreover, only so-called “waiting periods” are measured and no delays!

The specific objectives described above are addressed by advanced planning and coordination procedures, achieved in a collaborative and interoperable way. The expectation is to improve planning in a cost- and flight-efficient way against lowest possible costs. The benefits are assessed by comparing the results of Gaming and DCB processing and their impact on planned air traffic with the original operational conditions provided by the scenario before intervention.

### 6.3.7 Choice of Indicators and Metrics for Network Management

The model of the kernel network is assessed for minimal delayed throughput. Throughput is assessed under varying conditions, amongst others impacted by proposed departure constraints, determined by the Optimising ATFCM model.

Applicable KPIs are summarised in Table 7: KPIs relevant to Network Modelling.

<table>
<thead>
<tr>
<th>KPI description</th>
<th>SESAR framework Identifier</th>
<th>EP3 framework identifier + description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total daily throughput</td>
<td>CAP.LOCAL.ER.PI 1</td>
<td>Total number of aircraft controlled in the en route airspace volume during the day</td>
</tr>
<tr>
<td>Maximum hourly throughput</td>
<td>CAP.LOCAL.ER.PI 2</td>
<td>Maximum number of controlled aircraft per hour in the airspace volume</td>
</tr>
<tr>
<td>Departure Delays (IMC) (proposed by Central Network Management)</td>
<td>CAP.LOCAL.APT.PI 12</td>
<td>This indicator is considered as an Efficiency Indicator: This indicator will be provided as the total departure delay along the day, % of flights with arrival delay more than 1 minute, 2 minutes, 3 minutes,.... and average delays for delayed departures.</td>
</tr>
</tbody>
</table>

Table 7: KPIs relevant to Network Modelling

### 6.4 EXPERIMENTAL DESIGN FOR COLLABORATIVE AIRPORT PLANNING

The Collaborative Airport Planning exercise consists of two parts. First, a gaming exercise is held to solve pre-tactical planning events at an airport level in the APOC. Second, a network management experiment is conducted to diagnose the consequences of collaboratively reached decisions in the
APOC at a network level. These consequences are fed back to the decision makers in the APOC, supporting them in making better decisions in response to the simulated planning events. Figure 7, below, depicts the general set-up of the Collaborative Airport Planning exercise.

**6.4.1 Network Management Exercise**

This exercise starts with the proposed RBT updates resulting from the collaboratively reached decision in the gaming exercise. Given these updates, a network analysis is produced to calculate the consequences of these decisions with respect to the previous planning. Network management takes place in four steps:

1. **Input** of commonly agreed RBT updates from the gaming exercise: This input is considered as trajectory planning updates to be added to the kernel network scenario, representing part of the ECAC-wide network including the airport of Hamburg.

2. **Calculation of the throughput in the network**: Using NLR’s Network Analysis Model (NAM), the resulting incurred delay (“network waiting time”) in the European core network of airports and airspace sectors (including Hamburg) is calculated. The incurred delay is compared with the cumulative delay in the baseline scenario, in which no trajectory planning updates are implemented (the do-nothing option). The incurred delay is a reliable criterion for the network throughput.

3. **Optimisation of the throughput**: This step consists of optimised Collaborative Air Traffic Flow & Capacity Management (ATFCM), balancing demand as part of DCB. By optimising the traffic flow in the network, a better throughput can be accomplished. Using NLR’s Optimised ATFCM tool, certain flights will be given a pre-departure proposed departure constraint to ensure a better flow through the network. To determine which flights should be given this delay, the tool offers a look-ahead feature that allows the user to determine future demand and capacity imbalances. Given these future imbalances, it is possible to trace back which flights are to be given a proposed pre-departure delay to ensure optimal throughput through the ATM network.

4. **Output** of (a) the incurred delay and (b) optimised ATFCM constraints to the gaming exercise:
a) The incurred delay resulting from step 2 is fed back to the gaming exercise. In case this delay is larger than the delay incurred when no decision is taken (the do-nothing option), the TOP planner delivers a warning to the stakeholder(s).

b) The optimised ATFCM constraints resulting from step 3 constitute a proposal to minimise network bottlenecks by giving certain flights a proposed pre-departure delay. This proposal will be presented by the TOP planner as an alternative solution. Especially in case the commonly reached decision leads to unacceptable delay, the stakeholders may decide to adopt this solution or to select another one.

The process above represents an isolated update process from agreed planning updates impacting the departure planning at the airport of Hamburg. This can be considered as a sufficient step to feed the gaming exercise. However, for a network representative process, the inputs at Hamburg have to be complemented by a similar feed-back process at all airports of the Kernel Network. It is optional to feed the Kernel Network with similar emulated trajectory planning updates for all other airports, and allowing the network to react with proposed departure constraints. Only in that case, it will be possible to get an indicative impression on how much the local collaborative planning process may impact and/or disrupt the Central Network Management process.

Representative emulation of agreed trajectory planning updates can be generated for example by running a DMAN process on RBTs at airport level for each airport of the Kernel Network. The DMAN process represents the optimal achievable results for each individual airport in this case, and regarding the airport of Hamburg, this result can be compared with results achieved by gaming. This is one option, nevertheless, also other ways can be considered to emulate the result of gaming at airport level.

6.4.2 Hypotheses

Network Management Analysis emulates the behaviour of Central Network Management on a Kernel Network of Europe. The hypothesis is:

- H4: The Kernel Network of Europe represents the behaviour of network constraining decision making in a sufficiently realistic way to provide a realistic context of network-wide operations for the APOC and its decision making at airport level.
- H5: The constraining conditions of the Kernel Network are providing appropriate guidance to the Gaming exercise, which can be used in an effective way to keep delays to an acceptable minimum throughout the Network.
- H6: The departure preferences, agreed at airport level, can be accommodated in an appropriate way by applying prioritisation within the Kernel Network.

6.4.3 Network Management Analysis

Two tools are required as equipment to perform the network management exercise. First, a Network Analysis Model (NAM) is used to model the Kernel Network, representing a network around the most significant airports in Europe. This network will represent the planning environment of Hamburg airport, and will include this airport. Second, an Optimised ATFCM tool is used to process optimal throughput through this network with minimal delays.

6.4.3.1 The Network Analysis Model

The Network Analysis Model (NAM) developed by NLR can be used to perform validation studies on use of airspace and on the regulation of traffic scheduling. This monitoring tool is implemented by means of a Petri-net, which is composed of nodes (either airports or airspace sectors) and transitions
between nodes. In the Petri-net model, flights move from node to node following their established 4-D flight planning – possibly revealing critical bottlenecks in the capacity of certain sectors or airports. The model allows the user to measure throughput performance of an airspace network.

The Network Analysis Model is used to visualize the flows of flights through the network and to get insight into potential bottlenecks, i.e., those nodes for which demand is greater than the declared capacity. The tool takes the RBTs of the network over 24 hours as the planned load of each node. The updated flight plans resulting from the gaming exercise are taken as updates on this input. Further, the declared capacities for each node in the network are input to network analysis, and this relates to declared capacities of sectors as well as airports. Output of the model is a list of delayed flights per node of the aggregated network, sectors as well as airport nodes. In addition, accumulated statistics are recorded, comprising information on throughput per node as well as delays per node.

6.4.3.2 Network Aggregation

For the exercise, a network model is built of the core area of Europe. This network, encompassing all sectors and main airports in the south-west and central region of airspace in Europe, is produced by aggregating flights per sector. The reason for aggregation is simple. The figure below illustrates what an average day of traffic over Europe (based on a 24-hours scenario from 2005) may look like (Figure 8).

![Figure 8: Overview of European traffic density in a 24-hours 2005 scenario](image)

This network is too detailed for the actual modest research purposes in the current experiment; therefore, an abstraction from the route network is mandatory. NLR has developed a methodology to abstract from the complexity of a real network situation by aggregating lowest loaded nodes. Lowest
loaded nodes are aggregated by applying objective geographic criteria to identify the most appropriate nearest neighbour as aggregation candidate, and aggregation is applied in an iterative way until the properties of the network show a satisfying level of aggregation. The criterion for an optimal level of aggregation can be identified by sufficient simplification to apply emulation, but also optimisation of throughput characteristics can be assessed. The following figure, Figure 9, gives the result of applying this methodology to a high level of aggregation, on the traffic sample presented in Figure 10.

Figure 9: Aggregated route network

Aggregation in this network takes place at three levels:

- Upper airspace sectors are aggregated above the somewhat arbitrary flightlevel 245. Each sector with a part above FL 245 is counted as upper airspace sector. Aggregation takes place when the lowest loaded sector node is added to its nearest neighbour.

- Lower airspace sectors are aggregated between FL 0 and FL 245 when sectors are fully allocated below FL 245. Again the lowest loaded sector is aggregated with its nearest neighbour.

- Primary airports of the network are not aggregated. These are pre-selected hub-airports and they are identified by name.

- Secondary airports are aggregated by land-code and applying nearest neighbour criteria. In this way, each country will end up with one or more aggregated ground airports. For example, Germany, end up with at least one ED** and one ET** ground node because military airbases have their own country-code identification.
All flights in this network keep their unmodified 4D flightplan, SBTs submitted by the users, following unmodified routes through a sectorised network. The flights are passing along the routes through sectors that may have reached a higher or lower level of aggregation. The aggregated sector is represented by its geographic weight point. The above network of sector nodes and airport nodes corresponds to the following figure, Figure 10, visualising the nodes in the network.

Figure 10: Main airports, aggregated airport nodes and out-nodes in the route network of Europe

In this network, the main hub-airports are marked by dark-green nodes. Furthermore, the boundaries of the selected part of the core area are marked by a purple polygon. All flights entering and leaving this area are lead through so-called out-nodes: these are the light-yellow nodes through which all air traffic entering and leaving the selected part of the core area are bundled in order to control the in- and out-going flows of the Kernel Network. The smaller airports in the selected part of the core area are modelled as aggregated-airport ground nodes of this network. All flights not entering or leaving the area via the out-nodes are departing or landing at an airport, and this might be either a pre-selected hub-airport or one of these aggregated ground nodes, gathering departures and arrivals for all remaining airports in the network. The ground nodes are represented by the light-green nodes in the figure.
6.4.3.3 Optimised ATFCM, balancing demand as part of DCB

To optimise the throughput in the network, optimised Collaborative Air Traffic Flow & Capacity Management (ATFCM) will be employed as part of the concept of DCB by balancing demand. This concept takes analysis one step further. Not only is the traffic throughput and saturation of the core area network aggregated and visualized (NAM), but using optimised ATFCM the effects of smoothing traffic flows to improve throughput can be studied. To this end, the concept offers the possibility to determine possible demand and capacity balances a few hours ahead.

The idea behind optimised ATFCM, performing part of the DCB process, is simple. Typically, traffic is unevenly distributed in the network. This variability leads to overloaded sectors and departure and arrival delays at airports. Variability can be reduced, however, by optimising the distribution of traffic flows through the network. Optimising ATFCM leads to a more balanced distribution of traffic demand and a smoother flow of flights through the network. The result of ATFCM is a time-table (scheduled demand, specified by SBTs) with adapted (delayed) planned departure times, leading to a decrease of queuing delays (departure and arrival queuing), a decrease of workload in overloaded sectors and a decrease of flight duration due to a more flight-efficient arrival management process.

Optimised ATFCM is done as follows. A Flow Management process on the full network proposes a pre-departure delay for every flight of a submitted flight trajectory planning, the SBT/RBT, that encounters a capacity overload in the airport of origin, any of the sectors along its route or the airport of destination. This calculation is possible since an algorithm has been implemented to offer the possibility to look ahead at future bottlenecks in the network. Only flights with sufficient time before departure to allow for trajectory updates are considered, i.e. taking into account the minimum time needed to accommodate a planned departure change under nominal operational conditions; flights that have gone off-blocks or are in-flight cannot be given pre-departure delay. RBTs are processed in the order of their scheduled departure times (off-blocks) and arrival times at a node of the network.

Network Management using optimised ATFCM is based on applying prioritisation, if applicable. The prioritisation rules used by optimised ATFCM are partly based on general network operational principles and partly on individual flight priority assignments. Flight with a high priority will have a small chance of receiving pre-departure delays, since lower prioritised flights will be chosen first to resolve overloaded sector conflicts. Network Management based on applying optimised ATFCM algorithms is specifically effective when the flight preferences resulting from collaborative decision making, are input to ATFCM, forcing this process to honour departure preferences as much as possible.

For this reason, apart from flight updates, also other output from the gaming exercise is required specifying its departure preference status. Given a scenario in which, due to sudden capacity limitations, not all flights can be executed according to plan, decisions will have to be made about which flights should have priority over others. These decisions can be fed to the emulated model of Central Network Management, guaranteeing that flights with high priority will be given small or no pre-departure delays when optimising the flows in the network. Optimisation is in this way most effective when a limited part of air traffic is prioritised.

To make the outcome of the optimising ATFCM algorithm more realistic, it is optimal to feed the network model with emulated trajectory planning updates (RBTs) for all other, non-Hamburg airports, and to allow the network to react to these updates as well with proposed departure constraints. In that case, it will be possible to get a more realistic impression on how the local collaborative planning process may be able to cope with constraints, fed by the Central Network Management process.

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6 Note that it cannot be simply assumed that the flight updates suggested by the gaming exercise should receive a high priority. After all, flights may be given a later departure slot (resulting in a flightplan update) to make room for flights having a higher priority.
These emulated flight plan updates can be generated by running a DMAN process for each airport of the Kernel Network, but other emulation alternatives might be considered.

After network analysis and applying optimised ATFCM, two results are returned to the actors in the APOC. The first result, stemming from network analysis, gives a first indication on the effects of commonly agreed flightplan updates on the network. An insight in the potential bottlenecks is provided by returning a list of delayed flights per node, i.e. per sector or airport, in the network. The second result, derived from the network management process and applying optimised ATFCM, will yield proposed departure constraints to guarantee an optimal flow through the network by minimizing the bottlenecks. This result constitutes a list of flightplans with proposed departure planning constraints.

Finally, this departure constraints list can be extended with less enforcing warnings to provide planning alert indicators for those flights going through bunchy conditions. The participants to the Gaming exercise are free to take notice and to use these weak planning constraints as input to collaborative agreements on planning problems.
Annex 2: Exercise Overview Table

The following table provides a summary and overview of the scope of the exercise.

<table>
<thead>
<tr>
<th>Validation Scenario</th>
<th>Summary/Purpose</th>
<th>Hypothesis</th>
<th>Metrics/Indicators</th>
<th>SESAR OI</th>
<th>SESAR KPA</th>
<th>DOD References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaming</td>
<td>Predicted severe capacity shortfall due to bad weather</td>
<td>To examine how SESAR collaborative airport planning can be applied to manage this situation. To examine the roles and responsibilities of processes and actors.</td>
<td>H1: Collaborative airport planning ensures a high level of situational awareness of the involved stakeholders (high level objective 1). H2: Collaborative airport planning allows stakeholders to agree on a set of performance parameters for the airport to deal with a forecast problem situation (high level objective 1). H3: Airport stakeholders are able to produce a solution that is better than a do-nothing solution by applying Collaborative CDM procedures (high level objective 2).</td>
<td>The main results for this exercise are qualitative in nature and will focus on situation awareness and the collaborative process itself. However, some preliminary and every limited performance indications based on the following metrics will be provided: CAP.LOCAL.APT.PI Total Throughput EFF.LOCAL.APT.PI Departure Delays PRED.LOCAL.APT.PI Arrival delays /punctuality</td>
<td>KPA Efficiency (punctuality): The collaborative planning process shall lead to an AOP that in critical situations defines an agreed compromise between achievable punctuality and throughput. This allows the stakeholders to define a level of predictability that shall be reached throughout the day and throughout critical phases. KPA Capacity (throughput): This KPA addresses the ability of the ATM system to cope with air traffic demand in number of flights and distribution through time and space. The focus in the gaming exercise is to make effective use of existing capacity. For given traffic demand, the delay can be minimised by collaborative decision making. KPA Predictability (enhanced quality of planning, i.e. 4D): The gaming exercise shall demonstrate that predictability is improved in adverse conditions by using collaborative decision making, as all stakeholders work together to achieve agreed new targets rather than each stakeholder trying to cope with the situation independently. KPA Access and Equity/Interoperability: The objective of the gaming exercise is to</td>
<td>M1 DOD – Collaborative Airport Planning OS-16: Turn-round management OS-18: Airport Operational Plan Lifecycle for Medium-Short-Execution Phases OS-19: Severe Capacity Shortfalls impacting Departures in the Short-Term</td>
</tr>
<tr>
<td>Validation Scenario</td>
<td>Summary/ Purpose</td>
<td>Hypothesis</td>
<td>Metrics/ Indicators</td>
<td>SESAR OI</td>
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<tr>
<td>Network Analysis</td>
<td>To examine how the planning decisions taken at the local airport level can be accommodated by the network.</td>
<td>H4: The Kernel Network of Europe represents the behaviour of network constraining decision making in a sufficiently realistic way to provide a realistic context of network-wide operations for the APOC and its decision making at airport level. H5: The constraining conditions of the Kernel Network are providing appropriate guidance to the Gaming exercise, which can be used in an effective way to keep delays to an acceptable minimum throughout the Network. H6: The departure preferences, agreed at airport level, can be accommodated in an appropriate way by applying prioritisation within the Kernel Network.</td>
<td>CAP.LOCAL.ER.PI daily/hourly throughput CAP.LOCAL.APT.PI Departure delays (imposed by network management)</td>
<td>DCB-0206 SDM-0101</td>
<td>KPA Efficiency (punctuality): The Network Management complementing the gaming exercise focuses on accommodating traffic as much as possible as planned. The DCB process used to accomplish this goal tries to make use of the network capacity as efficiently as possible. The collaborative planning process at airport level will result into preferences expressed as SBT prioritisation indicators. Again the aim for the network management process is to accommodate the extra planning prioritisation preferences as efficiently as possible: with minimised average delay and minimised spread in delays.</td>
<td>M2/3 DOD – Medium and Short Term Network Planning</td>
</tr>
</tbody>
</table>

table 8: Exercise overview
7 REFERENCES


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End of Document