STEP1 V3 Final Complexity Management OSED

Document information	
Project Title	Complexity Management in En Route
Project Number	04.07.01
Project Manager	ENAIRE
Deliverable Name	STEP1 V3 Final Complexity Management OSED
Deliverable ID	D68
Edition	00.02.01
Template Version	03.00.00
Task contributors	
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Abstract

This document describes in Step1 the Complexity Assessment and Resolution (CAR) concept in En Route environment. It covers SESAR Solution #19 'Automated Support for Traffic Complexity Detection and Resolution'.

It is based on an update of the interim version of the S1 V3 Complexity Management OSED taking into account the results from the EXE-04.07.01-VP-005 and EXE-05.03-VP-804 performed in Release 5 as well as the latest versions of the Step1 DODs from 04.02 and 07.02. Therefore, it is important to note that it details not only the CAR concept elements related to SESAR Solution #19, but also those concept elements that have not reached the end of V3 level yet.

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[redacted] EUROCONTROL	[redacted]	No comments
[redacted] NATS	[redacted]	Proposed for closure
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Rational for rejection
None.

Document History

Edition	Date	Status	Author	Justification
00.00.01	15/06/2016	Draft	ENAIRE / EUROCONTROL	Initial Draft
00.00.02	08/08/2016	Draft	ENAIRE / EUROCONTROL	Version for external and internal review
00.01.00	29/08/2016	Revised Draft	ENAIRE / EUROCONTROL / DFS	Update with comments from review process. Version for partners approval.
00.01.01	02/09/2016	Final	ENAIRE	Version delivered to SJU
00.02.00	27/09/2016	Final	ENAIRE / EUROCONTROL / DFS	Update with comments from SJU assessment
00.02.01	10/10/2016	Final	ENAIRE / EUROCONTROL / DFS	Additional updates to reflect properly the R5 SE#3 Review outputs. Version delivered to SJU.

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Table of Contents

List of tables

List of figures

Executive summary

This document describes the Complexity Assessment and Resolution (CAR) concept in En Route environment in Step1 which addresses the automated support for identifying, assessing and resolving local complexity situations based on complexity predictions covering the SESAR Solution #19 'Automated Support for Traffic Complexity Detection and Resolution'. The expected benefits and potential constraints of the concept are also provided. The previous and future operating methods are explained and their main differences highlighted. Operational Requirements (ORs) are listed. The document provides operational scenarios examples, list of Use Cases as well as the description of application services, information services and systems.

It is based on an update of the interim version of the S1 V3 Complexity Management OSED taking into account the results from the EXE-04.07.01-VP-005 and EXE-05.03-VP-804 performed in Release 5 as well as the latest versions of the Step1 DODs from 04.02 and 07.02. Therefore, it is important to note that it details not only the CAR concept elements related to SESAR Solution #19, but also those concept elements that have not reached the end of V3 level yet.

The SESAR Solution #19 has validated the use of automated tools to continuously monitor sector demand and evaluate traffic complexity (by applying predefined complexity metrics) according to a predetermined qualitative scale. Continuous monitoring enables to forecast demand and complexity over a specific airspace. These forecast of complexity and demand permit taking action to adjust capacity, or demand profiles through various means in collaboration with ATC and airspace users.

The use of what-if capabilities enables the identification of potential solutions that are either based on tailored pre-determined scenarios or on ad-hoc solutions. In both cases, the automated tools allow making evaluations of their impact on the local systems.

Complexity Assessment and Resolution (CAR)

Complexity Assessment and Resolution (CAR) is a service that is used by the Local Network Management Function and Extended ATC planning in order to manage, balance, individual ATCO (or sector ATCO team) workload at local level - ATSU environment and to achieve the goal of maximising the throughput of the ATM system by not wasting, or leaving unused, any latent capacity and reduces safety risks related to workload variations.

The key feature of the complexity management optimisation processes is the use of complexity metrics that encapsulate the relationship between workload and traffic.

CAR is supported by automated tools capable of assessing traffic complexity over the area of operation (ATSU). The automated function provides feedback on the characteristics of the predicted complexity figures identifying those components (airspace structures and trajectories) that are contributing the most to the sector complexity and controller workload.

Addressing Gap in the Layered ATM planning

The idea of covering this gap in SESAR was approached from two different sides one starting from Network perspective mainly covered by DoD07.02 and dDCB related to operational projects P13.02.03 (formerly P07.06.05)and the other one starting from ATC perspective covered by DoD04.02 and related to operational projects P04.07.01 and P04.07.08. Due to the fact that new functions, processes and roles have been addressed it was inevitable that certain level of duplication and non-harmonization in concept elements had to be avoided. Within OFA05.03.04 effort has been made to address this issue, with the general approach that the Project P13.02.03 is more focused on Network operational aspects such as the coordination and implementation of STAM measures including elaboration of TTA/TTO management and P04.07.01 deals more with the aspect of quality of complexity prediction and operational implications in the preparation and use of the STAM measures, effect of airspace /sector configuration on local ATC including staffing. Furthermore the scope of P04.07.01 includes local coordination between LTM and ATC as well as prototyping local tools for CAR.

Finally, it is important to note that this final OSED is built not only on the operational concept elements presented in the previous versions but also on the relevant and related validated concept elements from the P04.07.01 and the other projects mentioned above.

1 Introduction

1.1 Purpose of the document

This document details the Operational Concept for Complexity Management in En Route environment within the context of SESAR Concept Story Board STEP 1. Operational concept structure and its elements are based on SESAR Joint Undertaking (SESAR JU) template for Operational Service and Environment Description (OSED) documents.

OSED describes the operational concept defined in the Detailed Operational Description (DOD) in the scope of OFA05.03.04 'Enhanced ATFCM Processes'.

OSED defines the operational services, their environment, scenarios and use cases and requirements. It is used as the basis for assessing and establishing operational, safety, performance and interoperability requirements for the related systems further detailed in the Safety and Performance Requirements (SPR) document. OSED identifies the operational services supported by several entities within the ATM community and includes the operational expectations of the related systems.

The figure below presents the location of the OSED within the hierarchy of SESAR Concept documents, together with the SESAR WP or Project responsible for their maintenance.

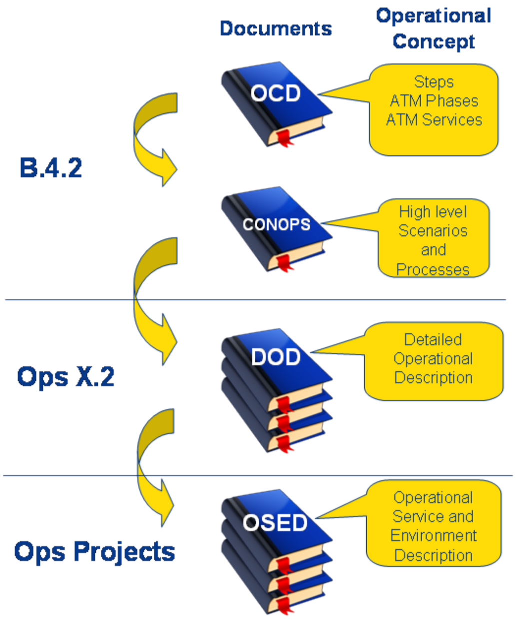

Figure 1: Four types of SESAR Operational Concept Documents

As depicted in the figure above, ideally, this operational concept is result of a process of detailing and refining an initial common SESAR Operational Concept into Scenarios and processes and into DOD.

This final version of this document is based on an update of the interim version of the S1 V3 Complexity Management OSED [21] taking into account the results from the EXE-04.07.01-VP-005 and EXE-05.03-VP-804 performed in Release 5 as well as the latest versions of the Step1 DODs from 04.02 and 07.02.

1.2 Scope

This document details the Operational Concept for Complexity Management in En Route environment within STEP 1 – V3. This concept is allocated to OFA 05.03.04 'Enhanced ATFCM Processes'.

1.3 Intended readership

Intended audience of this document are:

- P04.07.01 Members (ENAIRE, EUROCONTROL, DFS, DSNA and NATS);
- Project Members of the technical project P10.08.01 in charge of the prototype development needed to perform P04.07.01 validation activities (ENAIRE, INDRA and THALES);
- Projects performing validation activities that complete the validation path of the complexity management concept (P13.02.03, P04.07.08, SWP04.03 and SWP05.03);
- Projects within OFAs 05.03.03 'Dynamic Airspace Configuration' and OFA 05.03.04 'Enhanced ATFCM Processes';
- Project from WP08 for supporting the definition of information exchange requirements;
- Project in charge of consolidation activities (B.04.02, P10.01.07 and SWPs 04.02 and 07.02).

1.4 Structure of the document

The executive summary provides the information on the purpose and scope of the document as well as an explanation on the methods and approach used.

Section 1 provides the document introduction, its scope, purpose, intended audience, background information as well as the glossary of terms and acronyms.

Section 2 provides detailed description of operational concept elements, its processes and services including the mapping tables.

Section 3 provides the description of previous and future operating methods and highlights their main differences.

Section 4 provides an overview of operational environment including airspace characteristics and functional capabilities of the ground system.

Section 5 provides operational scenarios and use cases.

Section 6 provides the list of Operational Requirements.

Section 7 provides the list of applicable and reference documents.

Finally, Appendix A includes a detailed description of the Lyapunov-Convergence approach developed by DSNA to assess complexity.

1.5 Background

P04.07.01-D01 'STEP1 Consolidation of previous studies' [12] provides the results of previous initiatives related to complexity management in the domain of Air Traffic Management.

1.6 Glossary of terms

Term	Definition	Source
Airspace Management	Airspace Management is the process by which airspace options are selected and applied to meet the needs of the ATM community.	**ICAO 9854**
	Airspace Management is integrated with Demand and Capacity Balancing activities and aims to define, in an inclusive, synchronised and flexible way, an optimised airspace configuration that is relevant for local, sub-regional and regional level activity to meet users' requirements in line with relevant	**SWP07.02** **SWP04.02**

Term	Definition	Source
	performance metrics. Airspace Management primary objective is to optimise the use of available airspace, in response to the users demands, by dynamic time-sharing and, at times, by the segregation of airspace among various airspace users on the basis of short-term needs. It aims at defining and refining, in a synchronised and a flexible way, the most optimum airspace configuration at local, sub-regional and regional levels in a given airspace volume and within a particular timeframe, to meet users requirements while ensuring the most performance of the European Network and avoiding as much as possible any disruption. Airspace Management in conjunction with AFUA is an enabler to improve civil-military co-operation and to increase capacity for the benefit of all users.	
ATM Layered Planning	The intrinsic uncertainties within the traffic prediction process together with current ATM organisation leads us to regard air traffic control and air traffic flow management as a set of planning layers in which each layer addresses a particular future time frame of the traffic evolution. Each layer is characterised by the problems it addresses and the type of measures it takes to re-optimise the traffic plans. Layered planning should be seen as a continuous and seamless operation, which at times may be performed by one actor and at other times by several actors in unison.	**SWP04.02 (following EUROCONTROL ODT works)**
Business / Mission Trajectory	A trajectory, which expresses the business or mission intentions of the airspace user (respectively mainline, regional, business, general or military aviation). It includes both surface and airborne segments and is built from, and updated with the most timely and accurate data available in the Network Operations Plan (NOP), including turn-around elements.	**ATM lexicon**
Collaborative decision making	A set of applications aimed at improving flight operations through the increased involvement of airspace users, ATM service providers, airport operators and other stakeholders in the process of air traffic management. It induces an environment in which the consequences of decisions taken are visible to all partners. Note: Collaborative decision-making applies to all layers of decisions, from longer-term planning activities through to real-time operations, and is based on the sharing of information about events, preferences and constraints.	**ATM lexicon & ATM Masterplan glossary**
Complexity	In the ATM context, traffic complexity refers to the number of simultaneous or near- simultaneous interactions of trajectories in a given volume of airspace. <u>Note</u>: As there are additional factors that construct complexity on the top of the simultaneous and near simultaneous number of interactions (most simple ones being: weather, mixture of traffic, co-ordination conditions), which don't appear in this definition, for the content of this DOD, we'll prefer to define complexity as measure of the difficulty that a particular traffic situation will present to an air traffic controller.	**ATM lexicon** **Note from SWP04.02**

Term	Definition	Source
Complexity Management	Assessment and resolution of complexity problems within the given constraints is called Air Traffic Complexity Management. It is performed by the Network Management function in strong co-ordination with the Extended ATC planning function by managing and balancing controllers' workload to achieve the goal of maximising the throughput of the ATM system, by not wasting, or leaving unused, any latent capacity, and of reducing safety risks related to workload variations.	**SWP04.02**
Complexity Assessment and Resolution Service	Complexity Assessment and Resolution Service represents a dynamic, automated service, which applies a complexity function using metrics, within a defined airspace of operation in order to predict future controller workload within the appropriate look ahead time horizon. This horizon is directly dependant on trajectory prediction (TP) accuracy and the level of capability and interoperability of ATM systems and tools.	**SWP04.02**
Complexity metric	It determines workload for a prescribed sector and a prescribed air traffic situation. Complexity metric can be based on different methodologies, which are best suited for the local ATM environment. It is important that the outcome results are useable at network level and that the methodology is transparent.	**SWP04.02**
Decision making tool	A system-support tool, which helps the controller to evaluate situations and take, informed decisions.	**SWP04.02**
Dynamic sectorisation	The geographical and vertical limits of a control sector will be adapted to the traffic flow to optimise the capacity in real-time. Dynamic sectorisation does not imply that ATC will be faced with sector configurations that are not known either to them or to the supporting FDP and RDP systems. Sector configurations will be part of the pre-determined scenarios of the ACC and will be simulated and training will be provided prior to usage.	**SWP04.02**
En Route phase	That part of the flight from the end of the take-off and initial climb phase to the commencement of the approach and landing phase.	**ATM Lexicon**
Functional airspace block (FAB)	An airspace block, which is established regardless of State boundaries and is based on common operational requirements, where the provision of air navigation services and related functions are performance-driven. The services are also optimised with a view to promoting, enhanced cooperation among air navigation service providers or, where appropriate, an integrated provider. The FABs are put in place by the European Commission in the framework of the Single Sky.	**ATM lexicon**
4-Dimensional Trajectory	A set of consecutive segments linking waypoints and/or points computed by FMS (airborne) or by TP (ground) to build the vertical profile and the lateral transitions; each point defined by a longitude, a latitude, a level and a time.	**ATM Lexicon**
INAP	Integrated Network management and extended ATC Planning is a function assisted by automation that plans and organises air traffic within an area of operation (Sector Family) such that situations of excessive complexity and air traffic controller workload can be avoided. It also balances workload between the sector families if	**SWP04.02 / SWP07.02**

Term	Definition	Source
	required. (The INAP context is further described in section 2.3.6.1 below)	
Initial 4-Dimensional Trajectory (i4D) operations	Initial 4D operation is limited to the sharing of on board 4D trajectory data with the possibility for application of a single time constraint (only one constraint at a given time) at a specific point. This includes monitoring of the trajectory and its conformance with the assigned constraint.	**SWP04.02**
Network Management Function	Network Management Function is an integrated ATM activity with the aim of ensuring optimised Network Operations and ATM service provision meeting the Network performance targets, which encapsulates: • Collaborative layered planning and execution processes, including the facilitation of business/mission trajectories; • Airspace organisation and management processes; • Demand and Capacity Balancing processes through all planning and execution phases to ensure the most efficient use of airspace resources, to anticipate and solve workload/complexity issues and to minimize the effects of ATM constraints; • The enabling of UDPP process; • The provision and maintenance of Operation Plans covering the range of activity, i.e. Network to Local; • The provision of relevant complexity resolution advice to ATC operations. Based on CDM, the Network Management Function is executed at all levels (Regional, Sub-regional and Local) throughout all planning and execution phases, involving, as appropriate, the adequate actors (e.g. NM, FM, LTM…).	**SWP07.02/B.04.02**
Network Operations Plan (NOP)	A set of information and actions derived and reached collaboratively and both relevant to, and serving as a reference for, the management of the Pan-European network in different timeframes for all ATM stakeholders, which includes, but is not limited to, targets, objectives, how to achieve them and anticipated impact. The NOP has a dynamic and rolling lifecycle starting in the strategic phase and progressively updated up to and including the execution and post-operations phases. Note: It supports and reflects the result of the collaborative ATM planning process: at each phase, stakeholders collaborate in developing a common view of the planned network situation, allowing each of them to take informed decisions considering the network effect and the Network Manager to ensure the overall co-ordination of individual decisions needed to support network performance.	**ATM lexicon**
Queue Management	The tactical establishment and maintenance of a safe, orderly and efficient flow of traffic. Note: It includes the handling of queues, both in the air and on the ground. It operates on individual flights and is closely related to, and sometimes indistinguishable from, the Separation Provision	**ATM Lexicon**

Term	Definition	Source
	process. It aims at facilitating the highest achievable capacity of the ATM System and to manage delays in a fuel-efficient and environmentally acceptable manner.	
Sector Family	A Sector Family represents a group of adjoining airspace blocks (dynamically adjustable ATC sectors) that are treated as a single ATM airspace entity. The Sector Family is established to provide a contiguous volume of airspace, which is sufficiently large to enable coordinated NMF & Extended ATC Planning activities based on same procedures, working methods, data availability and granularity.	**SWP04.02**
Silent Transfer (of a flight)	Fully automated transfer of a flight across an AoR boundary between the two units concerned. The transfer is executed under the supervision of the respective Controllers, who are provided with situation awareness and monitor the flight's progress during the automated transfer process. The controller may, if necessary, override the process at any stage.	**SWP04.02**
Target Time of Arrival	An Arrival Time which is not a constraint but a progressively refined planning time that is used to coordinate between arrival and departure management applications. It is an ATM computed time.	**ATM lexicon**
Trajectory Adjustment through Constraint of Time (TRACT)	TRACT is a service used to reduce controllers' workload by reducing the number of potential conflicts by trajectory adjustment. The trajectory adjustment relies, among others, on FMS generated trajectory that will facilitate more reliable information and potentially better decision aid performance. The computed speed adjustments are translated into Controlled Time Over (CTO) which are operated via Data link between ground system and airborne system. Note: The flight crew will play a key role in the process, as the CTO will be submitted to them for validation.	**SWP04.02**
Traffic synchronization	Traffic synchronizations is about fine-tuning the position of an individual aircraft into a stream that optimises the utilisation of a constrained resource, hence improving the overall outcome of the process	**Extract from the WP B04.02 Step 1 CONOPS section 3.2.1**

1.7 Acronyms and Terminology

Term	Definition
2D, 3D, 4D	2 Dimensional, 3 Dimensional, 4 Dimensional (Trajectory)
ACC	Area Control Centre
ADS-B/-C	Automatic Dependent Surveillance – Broadcast / Contract
AFUA	Advanced Flexible Use of Airspace

Term	Definition
AIS	Aeronautical Information Service
AMAN	Arrival Management/Arrival Manager
ANSP	Air Navigation Service Provider
AoR, AOR	Area Of Responsibility
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATFCM	Air Traffic Flow and Capacity Management
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATS	Air Traffic Service
ATSU	Air Traffic Service Unit
AU	Airspace User
B2B	Business to Business
CAR	Complexity Assessment and Resolution
CDM	Collaborative Decision Making
CDT	Conflict Detection Tool
ConOps / CONOPS	SESAR Concept of Operations
CORA	Conflict Resolution Assistant (controller tool)
CPDLC	Controller Pilot Datalink Communication
CTA	Controlled Time of Arrival
CTO	Controlled Time of Over- fly
DCB	Demand and Capacity Balancing
DCT	Direct route
DOD / DoD	Detailed Operational Description
EAP	Extended ATC Planner / Planning
EATMA	European Air Traffic Management Architecture

Term	Definition
EC	Executive Controller
EN	ENabler
ETFMS	Enhanced Tactical Flow Management System
FAB	Functional Airspace Blocks
FDP	Flight Data Processing
FDPS	Flight Data Processing System
FL	Flight Level
FM	Flow Manager
FMP	Flow Management Position
FMS	Flight Management System
FOC	Flight Operations Centre/control
FPL	Flight Plan
FUA	Flexible Use of Airspace
HMI	Human Machine Interface
i4D	initial 4D Trajectory
ICAO	International Civil Aviation Organisation
INTEROP	Interoperability Requirements
IOP	Interoperability
IR	Implementing Rule
KPA	Key Performance Area
LTM	Local Traffic Manager
MONA	MONitoring Aids
MSP	Multi-Sector Planner
MTCD	Medium Term Conflict Detection
NM	Network Manager
NMF	Network Management Function
NMOC	Network Management - Operation Centre

Term	Definition
NOP	Network Operation Plan
OI	Operational Improvement
OR	Operational Requirement
OSED	Operational Service and Environment Definition
P&S	Process & Service
PC	Planning Controller
RBT	Reference Business / Mission Trajectory
R&D	Research & Development
SBT	Shared Business / Mission Trajectory
SESAR	Single European Sky ATM Research Programme
SESAR JU/SJU	SESAR Joint Undertaking
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
SPR	Safety and Performance Requirements
STAM	Short Term ATFCM Measures
SWIM	System Wide Information Management
SYSCO	SYstem Supported Co-ordination
TCM	Traffic Complexity Management
TMA	Terminal Manoeuvre Area
TP	Trajectory Predictor / Trajectory Prediction (as a function)
TRACT	TRajectory Adjustment through Constraint of Time
TS	Technical Specification
TSA	Temporary Segregated Area
TTA	Target Time of Arrival
TTO	Target Time Over
UC	Use Case

Term	Definition
UDPP	User Driven Prioritisation Process
WOC	Wing Operations Centre
WP	Work Package

2 Summary of Operational Concept from DOD

Up to now, capacity issues were monitored by ATC systems equipped with automated support tools, thus enabling traffic load and complexity management in accordance with declared sector capacities.

In Step 1, **Complexity Assessment and Resolution (CAR)** in ATM is performed within several different time horizons. It is supported by **new automated tools in order to continuously monitor sector demand and evaluate traffic complexity** (by applying predefined complexity metrics) according to a predetermined qualitative scale. Forecast complexity coupled with demand enables Network Management Function (NMF)/Extended ATC Planner (EAP) to take timely action to adjust capacity, or demand profiles through various means, in collaboration with ATC and airspace users.

The following OI steps described in the Integrated Roadmap Data Set 15 [15] have been identified as part of the complexity management concept in Step1:

- Automated Support for Traffic Complexity Assessment:

  Automated tools continuously monitor sector demand and evaluate traffic complexity (by applying predefined complexity metrics) according to a predetermined qualitative scale. Forecast complexity coupled with demand enables ATFCM to take timely action to adjust capacity, or demand profiles through various means, in collaboration with ATC and airspace users **(CM-0103-A)**;

- Automated Controller Support for Trajectory Management:

  Trajectory prediction & de-confliction for: the Extended ATC Planning and ATC planning role to manage the ATC team's workload by minimising traffic situations with the potential for unforeseen high complexity, through strategic de-confliction and reduction of number of potential conflicts. Providing support to the control team level of operation will improve situational awareness and provide solutions harmonised with the previous LTM level of planning to better manage traffic, e.g. interaction with trajectories in terms of level/ speed etc. The tools will operate, up to circa 30 mins before sector entry. The tools that assist in resolving complexity issues may include a 'What-if' capability where resolution strategies can be trialled before implementation and may provide assistance in identifying the trajectory or trajectories that are causing the most complexity, through interactions or application of sequencing measures or other constraints **(CM-0104-A)**.

It is important to note, that, in addition to these two OI steps, the **CM-0102-A** 'Automated Support for Dynamic Sectorisation and Dynamic Constraint Management' is part of the context of the CAR concept given that Complexity Assessment (CM-0103-A) is an enabler to support the dynamic sectorisation based on predefined sector configuration (CM-0102-A) with new complexity indicators at a time closer to the execution (for more information see Table 3).

2.1 Concept Maturity Assessment

The following table shows the maturity level of the Operational Improvements Step CM-0103-A and CM-0104-A.

Operational Package	Operational Focus Area	OIs or Operational Services	Initial Maturity Level	Target Maturity Level	Maturity Level after the exercise
PAC05 Integrated and Collaborative Network Management	**Enhanced ATFCM Processes.**	CM-0103-A — Automated Support for Traffic Complexity Assessment	V2	V3	V3
	Enhanced ATFCM Processes.	CM-0104-A — Automated Controller Support for Trajectory Management	V2	V3	Intermediate V3

Table 1: Maturity Level Assessment

Taking into account the results from all the validation activities performed, it can be stated that the **complexity assessment** to detect potential overloads from 3 hours up to 20 minutes before sector entry is at the end of V3 maturity level, although not all the approaches adopted to predict complexity have reached the same maturity level:

- Algorithmic Approach is ready to be deployed as demonstrated in the performed validation activities;
- Cognitive Approach is mature enough to be deployed although some improvements are needed before implementation [18];
- Lyapunov-Convergence Approach requires further work to reach the same level of maturity as described in exercise validation report [17].

However the **complexity resolution aspects** by means of trajectory management have achieved different maturity levels:

- Trajectory management measures analysis and preparation, including what-if functionality is at the end of V3 level (ready for Large Scale Demonstration and subsequent deployment, no more V3 validation required);
- Trajectory management measures coordination is at early V3 level (not ready for Large Scale Demonstration and major additional V3 validation is required);
- Trajectory management measures implementation is at mid V3 level (ready for Large Scale Demonstration but some remaining V3 validation is required).

Moreover, the complexity assessment has been probed to support the resolution of overloads by means of capacity management (i.e. refinement of sectorisation).

2.2 Mapping tables

This section contains the link with the relevant DOD, scenarios and use cases, environment, processes and services relevant for this particular operational concept.

Table 1 lists the Operational Improvement Steps (OIs from the Integrated Roadmap), within the associated Operational Focus Area addressed by this document.

Relevant OI Steps ref. (coming from the Integrated Roadmap)	Definition	Operational Focus Area name / identifier	Story Board Step	Master or Contributing (M or C)	Contribution to the OIs short description
CM-0103-A Automated Support for Traffic Complexity Assessment	Automated tools continuously monitor sector demand and evaluate traffic complexity (by applying predefined complexity metrics) according to a predetermined qualitative scale. Forecast complexity coupled with demand enables ATFCM to take timely action to adjust capacity, or demand profiles through various means, in collaboration with ATC and airspace users.	OFA05.03.04 Enhanced ATFCM Processes	Concept Storyboard Step1	M	Taking into account dynamic information as 4D trajectories, it will be possible to predict and detect, at any time, potential overloads and under loads, using indicators generated in an automated way.

Relevant OI Steps ref. (coming from the Integrated Roadmap)	Definition	Operational Focus Area name / identifier	Story Board Step	Master or Contributing (M or C)	Contribution to the OIs short description
CM-0104-A Automated Controller Support for Trajectory Management	Automated tools support the ATC team in identifying, assessing and resolving local complexity situations through assessment of evolving traffic patterns and evaluation of opportunities to de-conflict or to synchronise trajectories.	OFA05.03.04 Enhanced ATFCM Processes	Concept Storyboard Step1	M	Taking into account dynamic information as 4D trajectories, it will be possible to decide which trajectories should be updated to solve unforeseen complexity imbalances at the tactical phase, by taking into account the traffic complexity.

Table 2: List of relevant OIs within the OFAs 05.03.03 and 05.03.04

The following table has been added to provide relation of the OIs addressed by P13.02.03 and P04.07.01 and explanation of specific approaches in concept and validation terms taken by the respective projects. This table is not part of the standard format and it is included in order to provide additional clarification on the differences in focus between both projects during validation.

P 13.02.03	P 04.07.01	Explanation
DCB-0308 Contribution to SESAR Solution #17 – Advanced Short ATFCM Measures (STAM) • Imbalance alerting based on Occupancy Count/Complexity in the Network View • Hotspot notification in the Network View • CDM coordinated promulgation and implementation of STAM measures • DCB Step1 Generic Network Position (GNWP) • Network Supervision (Step1) • Local DCB tools connected via B2B services to NM	CM-0103-A Contribution to SESAR Solution #19 – Automated Support for Traffic Complexity detection and resolution Taking into account dynamic information as 4D trajectories, it will be possible to predict and detect, at any time, potential overloads and under loads, using indicators generated in an automated way.	The related P 13.02.03 operational improvement covers the P 04.07.01 to an extent. The need of specific Complexity Management OIs is based on the highest sensitivity of all the related elements (Operational Environment, Automation Needs, and Procedures) since these processes are located in the execution phase very closely related to separation management and for all this having higher safety impact. This could be explained in a way that during the ATM layered planning process the STAM measures are taking places iteratively. As their implementation is closer to the actual problem time requirements on all process elements become heavier, this is why they are treated separately when they take part of the INAP function.

Table 3: P04.07.01 and P13.02.03 OI steps

Moreover, P04.07.07 addressed some aspects of the CM-0102-A OI step (part of the CAR concept context) within the SESAR Programme. The table below show the interrelations of this project with P04.07.01.

P04.07.07	P 04.07.01	Explanation
CM-0102-A Contribution to SESAR Solution #66 –	CM-0102-A Contribution to SESAR Solution	Complexity indicators must be adapted to the planning time horizon due to the

P04.07.07	P 04.07.01	Explanation
Automated Support for Dynamic Sectorisation This SESAR automated solution considers the traffic needs, and groups or ungroups airspace sectors to match capacity with evolving demand. The support tool is used by the supervisor to determine sector planning on the day of operations and to manage staff resources accordingly.	#19 – Automated Support for Traffic Complexity detection and resolution Based on advanced tools to assess complexity (what-if and optimizer functionalities), LTM/EAP could evaluate the most appropriate sector configuration in order to solve potential complexity imbalances.	available accuracy of the traffic demand. From 8 to 2 hours in advance, the accuracy of traffic demand doesn't seem to be enough to provide exhaustive complexity indicators, but as a first attempt, the complexity could be assessed though the entries at the sector (P04.07.07 framework). From 3 hours before the operations, this initial indicator can be refined with more information and new complexity indicators could be used (P04.07.01 framework).

Table 4: P04.07.01 and P04.07.07 OI steps

Table 4 identifies the link with the applicable scenarios and use cases of the DOD04.02.

Scenario	Sub-Scenario identification	Use Case Identification	Reference to 04.02 DOD section
Operational scenario 1 – Complexity Management in En Route	Sub scenario 1 – Sector configuration change	• Evaluate (Update) Traffic Complexity. • Mark a Situation as Critical or not. • Identify (Update) a Non-critical Complexity Situation. • Initiate De-complexing Solutions Circulation. • Select a Solution for Implementation • Update the Constraints • Update the Sectorisation. • Create a New De-complexing Solution • Edit a Sectorisation Solution • Display De-complexing Solutions • Manage Co-ordination Requests.	4.2 DoD section 4.2.2.4.2.1.
	Sub scenario 2 - level capping and re-direction of traffic flows	• Display Complexity Details on Request. • Initiate De-complexing Solutions Circulation • Select a Solution for Edition. • Calculate impact of a Solution on Complexity (What-if). • Display Complexity Impact of an Edited Solution (What –if). • Manage Co-ordination Requests. • Manage a Co-ordination Receipt. • Edit an iRBT/iRMT Solution. • Update the Sectorisation.	4.2 DoD section 4.2.2.4.2.2.

Scenario	Sub-Scenario identification	Use Case Identification	Reference to 04.02 DOD section
		• Modify an Existing De-complexing Solution. • Create a New De-complexing Solution. • Monitor De-complexing Solution Implementation.	
	CAR Alternative Scenario – coordination of STAM measures	• Display Monitored Complexity. • Display Complexity Problem • Alert a Critical Complexity Problem • Initiate De-complexing Solutions Circulation. • Select a Solution for Implementation • Manage Co-ordination Requests • Manage a Co-ordination Receipt • Update the iRBTs/iRMTs • Update the Flows • Generate new constraints • Update the Constraints • Update the Sectorisation • Monitor De-complexing Solution Implementation. • Adjust Implemented De-complexing Solution. • Edit a Sectorisation Solution. • Edit a Constraint Solution. • Edit a Flow Solution. • Calculate impact of a Solution on Complexity (What-if). • Display Complexity Impact of an Edited Solution (What –if).	4.2 DoD section 4.2.2.4.2.4
	Sub scenario 3– Management of individual trajectories	• Display Monitored Complexity. • Display Complexity Problem • Alert a Critical Complexity Problem • Calculate impact of a Solution on Complexity (What-if). • Display Complexity Impact of an Edited Solution (What –if). • Update the Constraints • Initiate De-complexing Solutions Circulation.	Created by P04.07.01 to feed VP-005 exercise (P04.07.01)

Scenario	Sub-Scenario identification	Use Case Identification	Reference to 04.02 DOD section
		• Select a Solution for Implementation • Manage Co-ordination Requests • Manage a Co-ordination Receipt • Update the iRBTs/iRMTs • Evaluate (Update) Traffic Complexity	
	Sub scenario 4 Management of individual trajectories in extended AMAN environment.	• Display Monitored Complexity. • Display Complexity Problem • Alert a Critical Complexity Problem • Calculate impact of a Solution on Complexity (What-if). • Display Complexity Impact of an Edited Solution (What –if). • Update the Constraints • Initiate De-complexing Solutions Circulation. • Select a Solution for Implementation • Manage Co-ordination Requests • Manage a Co-ordination Receipt • Update the iRBTs/iRMTs Evaluate (Update) Traffic Complexity	Created by P04.07.01 to feed VP-804 exercise (P05.03)
Operational Scenario 2 – Non severe capacity shortfalls resolved by STAM Measures with support of local tools	N/A	• Identify (Update) a Critical Complexity Situation. • Display Monitored Complexity • Display Complexity Problem. • Alert a Critical Complexity Problem • Update the Flows • Display Complexity Impact of an Edited Solution (What –if) • Manage Co-ordination Requests • Manage a Co-ordination Receipt. • Display Complexity Details on Request. • Update the iRBTs	Created by P04.07.01 to feed VP-700 (P13.02.03)

Table 5: List of relevant 04.02 DOD Scenarios and Use Cases

Table 5 identifies the link with the applicable scenarios and use cases of the DOD07.02.

Scenario identification	Use Case Identification	Reference to 07.02 DOD section
Operational Scenario Medium/Short Term	• UC-NP-13 Assess Complexity and Sector Workload • UC-NP-16 Identify the Optimum Sector Configuration	Section 4.2.2

Scenario identification	Use Case Identification	Reference to 07.02 DOD section
	• UC-NP-17 Monitor Declared Capacity Values	
Operational Scenario Execution Phase	• UC-NP-13 Assess Complexity and Sector Workload • UC-NP-17 Monitor Declared Capacity Values • UC-NE-07 Detection of Demand Capacity Imbalances (Hot Spots) • UC-NE-14 Adapt Airspace Configurations • UC-NE-17 Facilitate and Optimise local complexity resolution	Section 4.2.3

Table 6: List of relevant 07.02 DOD Scenarios and Use Cases

The following table has been added to clarify the difference between P13.02.03 and P04.07.01 indicating the relations between associated Use Cases treated by both projects.

P 13.02.03	P 04.07.01	Explanation
UC-NP-13 Assess Complexity and Sector Workload UC-NP-17 Monitor Declared Capacity Values UC-NE-07 Detection of Demand Capacity Imbalances (Hot Spots) UC-NE-17 Facilitate and Optimise Local Complexity Resolution.	UC-NP-13 Assess Complexity and Sector Workload UC-NP-17 Monitor Declared Capacity Values UC-NE-07 Detection of Demand Capacity Imbalances (Hot Spots) UC-NE-17 Facilitate and Optimise Local Complexity Resolution.	Use Cases already addressed by both projects.
UC-NE-01 Monitor the Application of DCB/dDCB Measures	CM-UC-05-01 Monitoring De-complexing Solution Implementation	The Use Case is addressing the same actions normally in the CAR context they are related to more refined short-term measures.
UC-NE-10 Coordination of STAM Solution	CM-UC-03-01 Manage Coordination Request CM-UC-03-02 Manage Coordination Receipt	This Use Case and related requirements are very extensively addressed in P 13.02.03, the related Complexity Management Use Case addresses the same process normally related only to the actors in the short-term execution case. It is to be noted that the coordination in the short-term phase should be reduced to minimum and based on the predefined agreed procedures and scenarios and supported by automation, which takes into account local ATC working methods.
UC-NE-11 Implement STAM Solution	CM-UC-02-07 Select a Solution for Implementation CM-UC-04-01 Update the iRBT/iRMTs CM-UC-04-02 Update the Flows	Since that for P 04.07.01 concentrates on prediction accuracy, the actual operational implementation of the short-term STAM measures related to the CAR concept are validated mainly in the scope of P 13.02.03 and related

P 13.02.03	P 04.07.01	Explanation
	CM-UC-04-03 Generate New Constraints CM-UC-04-05 Update the Sectorisation	validation activities.
UC-NP-22 Analyse and Prepare DCB/dDCB Measures		Post-analysis of short-term measured and very refined scenarios application is subject S2 developments in project P 04.07.01 due its complexity. The first indications are that this kind of analysis requires collection and processing of very huge amounts of data and on the top very specialized ATC knowledge, which make them difficult to perform and maintain as cost-effective element.

Table 7: P13.02.03 and P04.07.01 Use Cases

Table 7 identifies the link with the applicable environments of the DOD04.02.

Operational Environment	Class of environment	Sub-Class of environment	Reference to DOD04.02 section where it is described
OPERATIONAL CHARACTERITICS	Airspace characteristics		Section 3.1.1
	Ground technical capabilities	ATC Support TOOLS: CAR tool	Section 3.1.5.2.6.
		ATC Support TOOLS: Conflict detection tools for planning purpose	Section 3.1.5.2.2.
		ATC Support TOOLS: Conflict detection tools for tactical purpose.	Section 3.1.5.2.2.
		ATC Support TOOLS: Arrival management extended to En Route	-----
		ATC Support TOOLS: Conformance monitoring	Section 3.1.5.2.3.
		Automated support for ATC coordination	------
		Air / ground data link	Section 3.1.3.1.2.
		Human Machine Interface (HMI)	-----

Table 8: List of relevant 04.02 DOD Environments

Table 8 identifies the link with the applicable Operational Processes and Services defined in the DOD04.02.

DOD Process / Service Title	Process/ Service identification	Process/ Service short description	Reference to 04.02 DOD section
Perform Extended ATC Planning	Assess traffic complexity	To assess the complexity of the future traffic situation at the ACC level based on	Section 5.1.2

DOD Process / Service Title	Process/ Service identification	Process/ Service short description	Reference to 04.02 DOD section
		forecasts within a 120 min look-ahead time.	
	Determine de-complexing solution	To identify a potential solution to reduce the imbalance of complexity (using "What-if" facilities). The applicable measures are based on either Dynamic re-sectorisation or trajectory management solutions.	Section 5.1.2
	Coordinate de-complexing solution	Co-ordination may involve different actors depending on the de-complexing solution including network management function.	Section 5.1.2
	Prepare de-complexing solution implementation	Among the potential de-complexing measures, EAP will make a full evaluation of the solution for positive network performance impact, and will update the necessary information to actually trigger the implementation of the chosen de-complexing solution.	Section 5.1.2
	Implement de-complexing dynamic re-sectorisation	At the appointed time the new Sector Configuration is implemented to re-distribute traffic flows. Executive Controllers instruct the Concerned flights to contact the appropriate sector via voice or data link.	Section 5.1.2
	Implement trajectory management solutions	This includes the management of individual trajectories (re-routeing, change of FL, allocation of a TRACT issued CTO).	Section 5.1.2
	Monitor de-complexing solution implementation	Activity related to the monitoring of the de-complexing solution's implementation and impact.	Section 5.1.2
	Manage Complexity Management co-ordination receipt	Co-ordination requests are sent to the relevant actors, including if necessary the network manager.	Section 5.1.2

Table 9: List of the relevant 04.02 DOD Processes and Services

Table 10 and Table 11 summarize the Requirements from DOD04.02 including Performance (Key Performance Area - KPA related) requirements relevant for the OSED.

DOD Requirement Identification	DOD requirement title	Reference to 04.02 DOD section
REQ-04.02-DOD-0005.0001	ATM actors shall be provided with automated support for decision making based on pre-defined sector configurations and traffic constraints for the dynamic management of airspace.	section 6.1
REQ-04.02-DOD-0005.0002	Local Traffic Manager shall be provided with automated support tools which continuously monitor	section 6.1

DOD Requirement Identification	DOD requirement title	Reference to 04.02 DOD section
	sector demand and evaluate traffic workload and complexity, in a certain airspace volume and timeframe, according to a predetermined qualitative scale.	
REQ-04.02-DOD-0005.0005	EAP and ATC Planning roles shall be supported by automated tools to resolve local complex situations by strategic de-confliction or synchronization of the trajectories.	section 6.1

Table 10: List of the relevant 04.02 DOD Requirements

DOD Requirement Identification	DOD requirement title	Reference to 04.02 DOD section
REQ-04.02-DOD-ENV1.1022	OFA "Enhanced ATFCM processes" shall deliver a 0.0075% reduction in fuel burn per flight by reducing "En Route Horizontal Deviation"	section 6.2
REQ-04.02-DOD-ENV1.1023	OFA "Enhanced ATFCM processes" shall deliver a 0.0025% reduction in fuel burn per flight by reducing "En Route Vertical Deviation"	section 6.2
REQ-04.02-DOD-SAF1.0045	The safety of En Route related operations shall be maintained at or above the current level.	section 6.2.1
REQ-04.02-DOD-CAP1.0024	OFA "Enhanced ATFCM processes" shall deliver a 6.5% increase in airspace capacity by ATFCM for En Route.	section 6.2.5
REQ-04.02-DOD-CEF1.0011	OFA "Enhanced ATFCM processes" shall deliver a 1.66% increase in Cost Effectiveness per ATCO productivity En Route phase	section 6.2.4
REQ-04.02-DOD-HMI.0001	The HMI shall support capabilities that humans deploy to achieve their task goals including perception, decision making, planning, memory and task execution	section 6.3
REQ-04.02-DOD-HMI.0003	The HMI shall provide users with means to gain and retain the appropriate level of Situation Awareness.	section 6.3
REQ-04.02-DOD-HMI.0006	The HMI shall support to prevent and manage system errors efficiently and effectively. This includes the detection of system errors, their management and recovery.	section 6.3

Table 11: Performance Requirements from 04.02 DOD

Table 12 summarizes the requirements from DOD07.02 including Performance (Key Performance Area - KPA related) requirements relevant for the OSED.

DOD Requirement Identification	DOD requirement title	Reference to 07.02 DOD section
REQ-07.02-DOD-0001.0006	Enabled by improved Traffic and workload predictions, ANSPs shall define and share sector capacities in a	section 6.1

DOD Requirement Identification	DOD requirement title	Reference to 07.02 DOD section
	more proactive and reliable manner improving the predictability of capacity and network planning and the effectiveness of short term ATFCM measures.	
REQ-07.02-DOD-EAPP.1030	Safety (based on number of fatal accident per year to be prevented) shall be increased by 1,89% thanks to an improved traffic and workload prediction and more efficient management of capacity.	section 6.2.1
REQ-07.02-DOD-EAPP.1020	Controller productivity shall be increased by 2,50% thanks to an improved traffic and workload prediction and more efficient management of capacity.	section 6.2.3
REQ-07.02-DOD-EAPP.1000	En Route busy hour throughput shall be increased by 6,50% thanks to an improved predictability on traffic and workload predictions as well as thanks to more efficient capacity and demand management.	section 6.2.4
REQ-07.02-DOD-0001.0022	Technical systems shall support the human actors in performing their tasks.	Section 6.2.12

Table 12: Operational and Performance requirements from 07.02 DOD

2.3 Operational Concept Description

2.3.1 CAR Overview

Complexity Assessment and Resolution (CAR) is a service that allows traffic and airspace structure to be dynamically adjusted to optimise the efficiency of the Air Traffic Control (ATC) / Air Traffic Management (ATM) services concerned with its airspace of application called - ATC Centre.

CAR is mainly used in high traffic density airspace regions (ATC Centres) in which an environment (in terms of system capabilities) exists that enables the refinement of airspace sectorisation and traffic planning to be fully dynamic and used to adjust the controller workload balance. In the ATC Centre individual flight optimisation in terms of complexity is performed. This addresses a future time interval for which traffic complexity prediction is practical. Key to the success of CAR is the development of a traffic pattern based complexity metric that serves to predict future controller workload.

The key feature of the Complexity Management optimisation process is the use of complexity metrics that encapsulate the relationship between workload and traffic.

2.3.2 CAR Concept

Complexity Assessment and Resolution (CAR) in ATM is performed within several different time horizons. In short term planning to execution phase, Complexity Management for ATC sectors is firstly handled by the Network Management Function through the DCB and the dDCB processes. The result is published in the NOP which includes updates on iSBTs/iSMTs and iRBTs/iRMTs as well as on airspace configurations, along with other information relevant to all stakeholders. The rolling NOP is continuously updated through the DCB/dDCB processes.

With the progression of iSBTs/iSMTs and iRBTs/iRMTs, the traffic situation may evolve due to (among others) reasons such as lack of accuracy of the NOP inputs, poor weather information and accuracy, too coarse control of flights allocated with a departure slot, local traffic plan deviations caused by preceding tactical ATCO interventions, especially open loop clearances.

As a consequence of evolving traffic ATC sectors can experience micro peaks and troughs of demand that cannot be eliminated by the DCB medium to short term planning process due to remaining uncertainty of data. The Local Network Management function in co-ordination with the Extended ATC planning is handling such dynamic, unexpected situations by re-optimising airspace and air traffic and re-coordinating iSBTs/iSMTs/iRBTs/iRMTs as required.

Complexity Assessment and Resolution (CAR) is a service that is used by the Local Network Management Function and Extended ATC planning in order to manage, balance, individual ATCO (or sector ATCO team) workload at local level - ATSU environment and to achieve the goal of maximising the throughput of the ATM system by not wasting, or leaving unused, any latent capacity and reduces safety risks related to workload variations.

CAR is supported by automated tools capable of assessing traffic complexity over the area of operation (ATSU). The automated function provides feedback on the characteristics of the predicted complexity figures identifying those components (airspace structures and trajectories) that are contributing the most to the sector complexity and controller workload (CM-0103-A).

CAR will be performed when complexity metrics need to be applied to predict future controllers workload in a specific part of the airspace -sector family (i.e. an airspace corresponding to an ATSU), which are established to provide a large enough contiguous airspace, within which meaningful complexity management can be performed.

The resolutions to air traffic complexity problems are constrained by:

- availability of airspace (e.g. due to weather, airspace reservation);
- availability of ATC sector capacity;
- Airspace users preferences;

- air traffic queue management targets (e.g. target times, levels and speeds as results of AMAN, DMAN and Extended AMAN processes);
- the Network stability requirements, and;
- iRBT/iRMT update rules.

Resolution of complexity problems within the given constraints is performed through harmonised application of Local Network Management function related measures (e.g.: STAM) and extended ATC planning at the ATSU level.

The processes related to Complexity Management need to consider the goals for an individual trajectory, i.e. a need to be strategically de-conflicted and to comply with the time constraints and targets (such as CTO/CTA and TTO/TTA) agreed in the iRBT/iRMT while balancing individual ATC sector controllers' workload.

Workload management is performed for an ATSU and within the Complexity Management related processes operational horizons which could be down to the 20 minutes or up to several hours from real time; this time may vary depending on the environment, and operational working methods being used in each specific ATSU. In Step 1, Complexity Management is performed firstly through the Local Network Management function application of dDCB and it is ACC based, with appropriate co-ordination with adjacent ACCs, The Local Network Management Function will use CAR based predictions where the local tools provide this kind of information. The local tools based on Complexity prediction will also provide some decision making support for implementation of the dDCB/STAM measures (what- if sector configurations, dynamic constraints or individual iRBT/iRMT revisions).

Where these tools are not available, dDCB process , application of STAM and the Extended ATC planning are supported by other Network based tools or conventional methods.

Interaction between the Local Network Management function and ATC in the application of the dDCB/STAM measures is considered as a part of the overall CDM process for dDCB. Co-ordination procedures between Local network management function and Extended ATC planning are locally introduced in that respect. It is to be pointed out that ATCOs still maintain full autonomy and responsibility in the provision of ATC service in the execution phase, respecting to the maximum possible extend the network goals.

The balancing methods, corresponding to the STAM measures used in execution phase within the ATSU, are applicable to a number of ATC sectors along with their sector control teams (executive and planning controllers). They are aimed first at utilising all of the available ATC resources, and only in exceptional cases, at adjusting the air traffic. They include:

- flexible re-deployment of human resources;
- Dynamic sectorisation based on predefined sector configurations;
- re-direction of air traffic flows to ensure that high levels of efficiency are sustained; (CM-0104-A)
- redistribution of individual iRBTs/iRMTs within the sector family (ATSU); (CM-0104-A)
- adjustments to iRBT/iRMT parameters (e.g. target times and/or levels, parallel Off-set). (CM-0104-A)

The objective of complexity management is to make sure that the planned ATSU and sector resource arrangements are able to meet the demands of the actual traffic load and complexity.

The primary intention of complexity management is to simplify the ATM situation through the application of dDCB/STAM so that Separation Provision can be efficiently applied by human intervention. This is achieved by ensuring that the complexity of future air traffic situations in any sector within the ATSU is reduced just enough to allow resolutions of conflicts to be found at an acceptable level of controller workload and within acceptable limits of individual iRBT/iRMT modifications.

There are two levels of CAR.

1. Complexity prediction for Local Network Management Function (CM-0103-A)

Analysing aircraft trajectories using SBT/RBT and other demand information, coupled with the use of validated complexity metrics, allows prediction of changes in traffic complexity and potential overload situations, allowing mitigation strategies to be applied. Such ability will support decision making processes such as:

- Determine the optimum organization of ATC sectors (including adjustment of sector AOR);
- Apply dynamic ATM constrains (on traffic flows (e.g. Level Cap);
- Modify individual trajectories by route, level or timing
- Local Traffic Management based on Complexity assessment is seen as a tool supported process to simplify/optimize the ATM situation through application of STAM so that separation provision can be efficiently applied by human intervention in a productive manner.

This level has been validated and agreed within the SESAR Solution #19.

2. Automated Controller Support for Trajectory Management (CM-0104-A)

Trajectory prediction and de-confliction for: the Extended ATC Planning and ATC planning role to manage the ATC team's workload by minimising traffic situations with the potential for unforeseen high complexity, through strategic de-confliction and reduction of number of potential conflicts. Providing support to the control team level of operation will improve situational awareness and provide solutions harmonised with the previous LTM level of planning to better manage traffic, e.g. interaction with trajectories in terms of level/ speed etc. The tools will operate, up to circa 30 mins before sector entry. The tools that assist in resolving complexity issues may include a 'What-if' capability where resolution strategies can be trialled before implementation and may provide assistance in identifying the trajectory or trajectories that are causing the most complexity, through interactions or application of sequencing measures or other constraints.

This concept element was not fully validated at V3 maturity level, since it is addressing completely new roles and functions which are supposed to bridge the gap between the ATFCM and ATC planning at local level through integrated INAP function. Anyhow the need of performing CAR to achieve this target was demonstrated and the requirements have been defined. Additional work has to be performed in the area of further definition of the roles and provision of guidelines for distribution of these roles to the appropriate actors (human and automation) in respect of the local environment and working methods as well as definition of operating procedures training and regulatory requirements for the human actors involved.

2.3.2.1 CAR Service

CAR is a service, required applied mainly in high traffic complexity airspace regions where traffic pattern based complexity metrics will serve to predict future controller workload. In these regions it is proposed that ATC Centre is established to structure the airspace within which complexity management will be applied. Sector configurations suitable for the expected traffic demand will have been determined in previous processes. These will be taken into account by the complexity management which will apply a fully dynamic process to adjust and balance controller workload.

The other process aims to balance the goals for a trajectories that need to be as conflict free as possible, comply with the RBT goals agreed during previous processes (e.g. the Controlled Time of Arrival - CTA) whilst incurring a minimum of control workload.

Traffic Complexity Management seeks to address both of these processes within a domain of application airspace corresponding to ATC Centre and for a planning interval that will address the future traffic evolution from the present to a time up to three hours ahead.

2.3.2.2 The need for CAR

The first step in the process of de-complexion traffic in a sectorised environment is taken by the Network Management Function (NMF) on flights prior to their take-off. At present it uses a simple method to evaluate traffic complexity which is called dynamic density and looks only at the number of a/c simultaneously present into a sector for a given time interval.

If this number exceeds a given threshold, the slot allocation system allocates a slot to one or more flights as it is the only parameter the system can play with. There is however a move now to use complexity based predictions even in this phase of the planning for Dynamic Capacity Balancing.

However when aircraft become airborne, the traffic situation evolves in a quite different way from the one planned by the NMOC and there are several reasons for this, among others:

1. Lack of accuracy of the NM traffic demand prediction process;
2. Poor weather information and accuracy;
3. Too coarse control of flights allocated with a departure slot;
4. At local level – trajectory revisions due to ATC tactical open loop interventions.

The consequence of this deviation from the NM plan is that sectors experience peaks and troughs of demand that are not eliminated by the DCB process. The less immediate consequence is that to prevent these demand peaks from overloading the sector, the Target Sector Flow (TSF) is set at a level that provides some 'headroom'. Essentially, the TSF is set below the level that the sector can safely handle to allow for the inefficiencies inherent to the Network Management process and the vagaries of the subsequent control process. This means that for much of the time capacity is available but remains unused because the sectors must be protected from overloads.

This situation shows the need for the development and implementation of a real time processes which will, at a local level, manage the complexity of the traffic to avoid that sectors are overloaded and as a result capacity restriction measures have to be activated, thus complicating the situation for upstream sectors. The goal is that by predicting and managing complexity locally, the TSFs can be set at a level that approaches maximum acceptable workload thus closing the gap between theoretical capacity and available capacity.

Such processes must operate on a wide area, at ATC Centre level or at the level of ATC sector families, as the management of the traffic complexity aims at reducing the peaks of complexity by distributing it over a wider number of sectors through early actions supported by a traffic complexity prediction process.

Measures taken to de-complex traffic will serve to balance controller workload, however, it will be necessary to strike a reasonable balance between complexity reduction and other important ATC goals (e.g. Operator Costs and CTA adherence).

Consequently there is a need to embrace traffic optimisation within the de-complexion processes. The service supporting these processes is CAR.

Is there a need for a new ATC team member? Perhaps, it is tempting to identify a human actor role within TCM, perhaps a Traffic Complexity Manager or a Local Traffic Manager but to do so suggests the introduction of an additional kind of planner controller whereas it is more likely that existing roles will be revised through the introduction of TCM tools that will support the expansion of a planning controller's remit to multi-sector planning and enable the local traffic manager to initiate Short-Term ATFCM Measures (STAM) at local level.

2.3.3 Concept Benefits

The CAR concept envisages the following safety benefits:

- reduction of Tactical Controller workload through better work distribution within the ATC Centre;
- minimising the need for tactical intervention through traffic optimization and better workload distribution (avoiding of bottlenecks), thus reducing possibility of human error.

2.3.4 Complexity Engineering

2.3.4.1 Complexity Definition

For CAR purposes the term complexity, or traffic complexity, relates to the notion that for a given disposition of traffic in a sector it is possible to derive a metric, the complexity that is equivalent to the sector workload. Sector workload has a threshold, usually 80%, which should, ideally, not be exceeded. Lower values such as 60% are open to definition, though they should support workload balancing. An additional threshold (e.g. around 20%) could be defined to detect underload situations that could lead to safety issues.

2.3.4.2 Traffic complexity forecast

To support CAR, there is a need for a tool capable of predicting traffic complexity over the area of operations (ATC Centre). The tool needs to provide some feedback on what are the characteristics of the complexity figures computed in the sense that this additional information allows the identification at high level of what components are contributing the most to the sector complexity. Additionally it may be an advantage for the tool to have a sense of sector traffic patterns specificity.

2.3.4.3 Traffic de-complexion

There are several options to concerning how to perform the complexity management processes, from a complete manual human driven approach to an automated one where the TCM tool provides solutions for complexity management in the form of local STAM or even advisories on how to implement them.

2.3.4.4 Workload / Complexity Metrics

By considering the probable disposition of traffic at future times it is possible to determine the workload that controllers will experience. Algorithms developed for this purpose measure controller workload in terms of a complexity metric which needs to have the following properties:

1. Indicate work overload (e.g. formula allows a threshold to be specified);
2. Be monotonic i.e. increasing complexity results in increasing workload;
3. Facilitate load balancing and equivalence to other ATC costs.

Several potentially complementary approaches allow the assessment of complexity from either a microscopic or a macroscopic point of view. The following three approaches were adopted by the members of Project 04.07.01 during the studies they led prior to SESAR launch:

1. Algorithmic approach;
2. Cognitive approach;
3. Statistical approach.

Chapter 3 of "STEP 1 Consolidation of previous studies" deliverable (DEL04.07.01-D01-STEP 1 Consolidation of previous studies-00.01.00 [12]) describes synthetically the different studies, engineering methods and subsequent realizations and results.

It is important to note that, after several internal studies, the approach initially proposed by DSNA to manage complexity (i.e. 'Statistical Approach') has been substituted by 'Lyapunov-Convergence Approach'. This approach is based on two different algorithms:

- **Convergence algorithm**:

  The principle of the convergence algorithm is to measure the reduction of relative distance between nearby aircraft. The value of this reduction is weighted by the distance between those aircrafts (distant aircrafts will have less impact than close aircrafts, for the same convergence value). The convergence indicator is calculated on a 3D map, and then is summed for the different sectors.

  This algorithm is not as thorough as the Lyapunov algorithm but is faster to compute.

- **Lyapunov algorithm:**

  The principle of the Lyapunov algorithm is to measure the sensibility to initial conditions in a field of speed vectors including all the aircrafts.

  First, a non-linear field of vectors V=f(x,y,z) is calculated from the present aircraft, using a method developed by ENAC. This field attributes a speed to each point of the airspace, this speed matching the speed of the aircraft in the points where there is an aircraft.

  In a second step, the algorithm measures the sensibility to initial conditions, assessing the change of proximity of two aircrafts in close locations. The idea is that the more they converge (the distance between them is reducing), the more complicated is the situation in that point.

A detailed description of both algorithms can be found in Appendix A.

The optimising approach also needs expression in order that TCM can be usefully embraced. As a starting point it seems reasonable to have control strategies which will reflect the kind of methods employed to date.

These control strategies may well be layered in terms of scope such as:

1. Coarse (re-sectorisation);
2. Medium (level capping, re-routing);
3. Fine (flight trajectory change).

Use is likely to be made of pre-defined control scenarios – particularly, in above example, for coarse and medium layers. The validations showed that the use of the third strategy is not fully applicable in the Step 1 environment due to the required levels of system integration and data sharing in order to achieve enhanced CDM processes.

2.3.4.5 What-if support to traffic complexity management

Two what if approaches are considered, as follows:

- A permanent what if where alternate strategies like different airspace configurations or sectorisations are continuously evaluated for complexity and the human actor will decide based on that information to which alternate strategy to switch and when. It is clear that this is only possible for a limited number of well-defined strategies and applies mainly to airspace sectorisations. This strategy has been fully validated and it is considered as concept element ready for implementation. The validation has shown that combination of this strategy with advance ATCO resources planning tools (rostering tools) could provide significant benefit in terms of ATCO's productivity;

- On request what if where the human actor needs to generate and alternative strategy and request the CAR tool to get complexity figures ensuring that the strategy solves the identified problems. Although a more flexible approach, the definition of the alternate strategy may be a heavy job. An identified possibility is to provide a "generic strategies" toolbox where strategies can be picked and customised for the specific traffic complexity situation identified. The application of this strategy show to be impracticable especially in environments with of high complexity.

2.3.4.6 Automated support to traffic complexity management

The power of automated traffic complexity management relies on the huge number of variables which need attention when developing a strategy for traffic complexity management. Assuming that the complexity prediction process will be able to provide traffic complexity characteristic with a level of detail, an automated process can investigate strategies which may be extremely complex for the human to capture. These strategies will have a temporal distribution in function of the specific complexity situations.

2.3.5 CAR Context

2.3.5.1 CAR in SESAR Concept

SESAR Target Concept aims at optimising task distribution between actors, improving decision making through Collaborative Decision Making (CDM) principles and the development of an information network, reducing uncertainty, increasing safety and creating additional capacity.

SESAR Target Concept foresees the deployment of System Wide Information Management (SWIM) and a Network Operations Plan (NOP) which together will assure that controllers are provided with appropriate information to enable them to work collaboratively towards the greater efficiency of the system as a whole.

Trajectory Management (TM) is a central SESAR theme in which the trajectory determined just before flight execution, named - Reference Business Trajectory (RBT). The Airspace User agrees to fly the RBT and Air Navigation Service Provider (ANSP) and Airport agree to facilitate the RBT.

RBT is the goal to be achieved and will be progressively authorised. The authorisation takes the form of a clearance by the ANSP or is a function of aircraft (crew/systems) depending on who is the designated separator. Most times indicated in the RBT are estimates, however some may be target times to facilitate planning and some of them may be constraints to assist in particular in queue management when appropriate.

The network effect of planned ATC interventions will need to be taken into account when determining traffic de-complexion measures affecting RBT's.

It is likely that complexity reduction measures may be beneficially applied at both MSP level (within the smaller area of two or more ATC sectors called Multi Sector Area) and at a higher - COMPLEXITY MANAGEMENT level (applied within larger area – ATC Centre). It should be noted that Complexity Management Operational Concept for STEP 1 concentrates on higher level of application – Complexity Manager level – mainly addressing the area of improvement of workload distribution and better utilization of the resources.

There is a belief that measures such as traffic complexity management and traffic optimisation accompanied by data linked capabilities and advanced separation management tools will allow for a control regime to be established that will meet the future capacity demands. To prove this is somewhat difficult – in general it is a straightforward matter to simulate the ATC regime, the difficulty arises when dealing with controller workload. If the controller were an automaton responding to advisories faithfully then workload could easily be determined through time budget analysis. However, controller workload comprises many intangibles, not the least of which is trust in support tools, and finding a sensible way of determining useable controller metrics is perhaps the biggest challenge faced.

In the absence of such a validated metric, assumptions are made about its formulation. It is assumed that it will depend on a few factors (complexity metrics) such as number of aircraft, mix of aircraft, interactions of aircraft boundary proximities and it is further assumed that an algorithm can be specified in such a way (e.g. using fuzzy logic as a non-linear dependency is likely) as to permit system optimisation. This metric formulation will have a number of intrinsic tuning parameters the optimal setting for which will need to be determined via trials. However, by demonstrating at an early stage that effective optimisation can be attained for a variety of tuning parameter settings (applied to various typical traffic scenarios) confidence is achieved in the optimising approach. This is important as in fact the ultimate complexity metric is never really exactly determined as it depends not only on traffic but also on the tools and protocols that support the ATC process. The influence of these tools and protocols could be included through a new set of metrics (e.g. taking into account the use or not of Controller-Pilot Data-link Communications - CPDLC in the task associated to communication workload).

A phased implementation will need to be expressed to follow advancements in the technical environment.

2.3.5.2 Implications of context/scope

Before presenting a more focused concept description this chapter looks at TCM and ATM optimisation in a general way.

2.3.5.2.1 ATM as an optimisation problem

ATM is charged with safe, efficient and expeditious and conduct of traffic and the main processes are those of traffic synchronisation, traffic complexity management and traffic optimisation and separation assurance.

These processes could be regarded as a single optimisation problem in which constraints are imposed that serve to keep aircraft apart and reduce controller workload and minimise the extent to which aircraft trajectories deviate from those desired by the aircraft operators.

An automated system that could perform this optimisation would need to model the relevant features of the control domain e.g. the airspace structure, traffic plans, the way aircraft fly, ground/air and ground/ground protocols etc. Such an optimiser would need to be able to measure and predict controller workload, safety risk, and aircraft costs for given control scenarios and would then optimise by seeking out alternative scenarios that improve matters.

There are of course difficulties in going down the path to full automation and so TCM development will seek to find a pragmatic mix of men and machines that will demonstrably improve matters in a short timescale and in a cost effective manner.

2.3.5.2.2 Local / global targets

Where safety and workload issues are concerned the focus is on sector level arrangements, however, there is a need to address other goals such as arrival time targets or ensuring that aircraft operators wishes are well respected.

When solving conflicts weight is usually given to disturbances that may be made to these targets and in this is easy to introduce where tool advisors are present. The presence of tools / their output could be part of complexity calculation and the solutions should be taking into the account overall goal of adherence to the RBT. Even in STEP 1 sector configurations should be defend in such a way to serve this goal.

Another question arises as to whether the system should pro-actively intervene to support such activities. The answer is yes provided the advantages that RBT adherence brings outweigh the cost of the extra workload. The need to be able to make such judgements imposes a constraint on workload metrication.

2.3.5.2.3 CAR in ATC Centre

In the airspace where an ATC Centre is responsible for provision of ATC service, a process related to CAR should be applied that enables the airspace capacity to be optimised according to changing demand and available resources.

These processes are only applicable in regions of high traffic loads in which classical sectorisation and flow control measures are insufficient to support the capacity demand.

The internal working methods in the ATC Centre allow for flexible re-deployment of human resources and re-direction of traffic to ensure that high levels of efficiency are sustained.

The airspace within the Area of Responsibility of the ATC Centre maybe be either fixed route or free-route.

A key feature of CAR in the ATC Centre is the use of a complexity metric that encapsulates the relationship between workload and traffic.

Within the ATC Centre the controllers (MSP / Planning / Tactical) will be assisted with various support tools designed to maximise their individual efficiency. At the ATC Centre level the primary concern is that of ensuring that the internal arrangements match the expected traffic – this process is precisely TCM.

CAR represents a milestone in operation within ATC Centre in which a flexible sectorisation regime is supported by traffic complexity management tools.

It is clear that even with higher level of prediction accuracy CAR will never provide full one to one workload prediction due to the non-linear elements contributing to the workload, but validations have shown that the CAR outcome provided by the automated tools based on validated assessment approaches in combination with human knowledge and appropriate presentation (HMI) it is valuable and necessary element for the decision making.

2.3.6 INAP – Integrated Network and ATC planning

ATM Planning Layers are characterised by the time intervals planned for, the problems addressed and the kind of resolution measures taken. Naturally matters are never clear cut as the account needs to be taken of the sectorisation and disposition of planning and executive roles. Consequently, the time characterisation of layered planning is regarded as simply indicative with its notions being subsumed within a more comprehensive scheme that addresses roles/tools and methods. This concept is an attempt to develop an area of airspace in which an effective control regime can be established utilising models that account for controller workload, predictive uncertainty, aircraft operator goals, and global control aims. Although, such an approach is considered to be of general applicability, early developments will centre on environments where there is an immediate need to increase capacity in terms of area of application and on effective use of dynamic sector configuration in terms of mode of operation.

The scope of the INAP function (“Integrated Network management and extended ATC Planning”) is to address the overlapping period where the Network Management function runs DCB and dynamic DCB processes at all geographical levels, while extended ATC planning starts preparing early strategic de-confliction and conflict detection within the appropriate look ahead time horizon and within its defined local area of responsibility.

2.3.6.1 INAP Function

INAP – Integrated Network management and extended ATC Planning is a function assisted by automation that plans and organises air traffic within an area of operation (Sector Family) such that situations of excessive complexity and air traffic controller workload can be avoided. It also balances workload between the sector families if required. In S1 this integration is initial and it is limited since the assessment of workload still involves human knowledge and the local actions are predominantly independent, since there is no possibility to assess and monitor impact of high granularity local actions on the network, NM is part of the CDM but enhanced CDM where all the actors share the same information , procedures and interact with automation support in the application of different levels of pre – agreed resolution scenarios is not possible.

INAP seeks to enable an increase in controller productivity by taking measures in advance that serve to de-complex the traffic. Complexity is seen as traffic airspace and environment derived metric that can be equated to controller workload.

This INAP function is part of a layered planning process encompassing all ATM activities. It is important that this work is aligned to contemporary ATM development work and in this regard it is the SESAR Programme where this work is performed.

Ensuring that all these planning and control processes interoperate in a beneficial manner is one of the SESAR objectives.

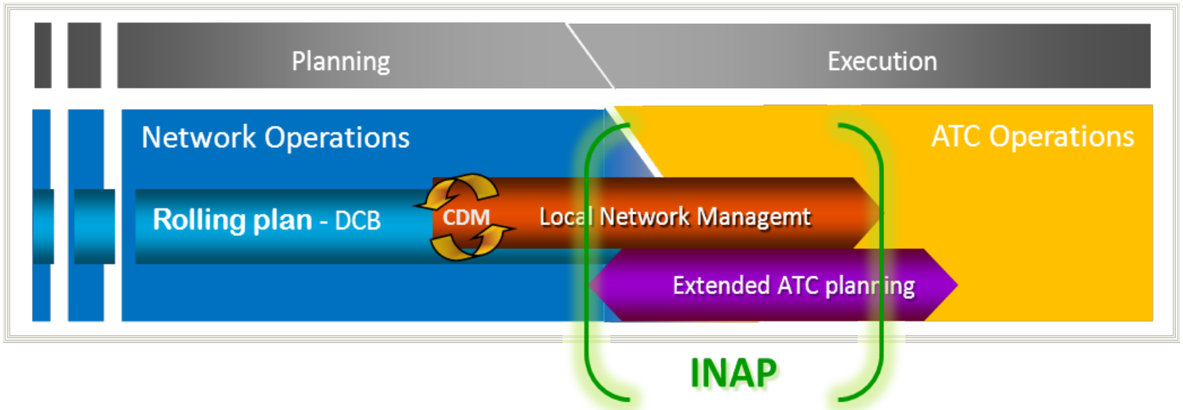

Figure 2: INAP horizon

The objective is to enable a seamless ATM layered planning process, taking into account both targets:

- Provide optimum solutions (airspace configuration and trajectory/flow management) to solve workload imbalances with resolution assessment from local level to the network level;
- Ensure that those solutions are compatible and efficient with traffic synchronization activities and strategic conflict management under the responsibility of the extended ATC planning function.

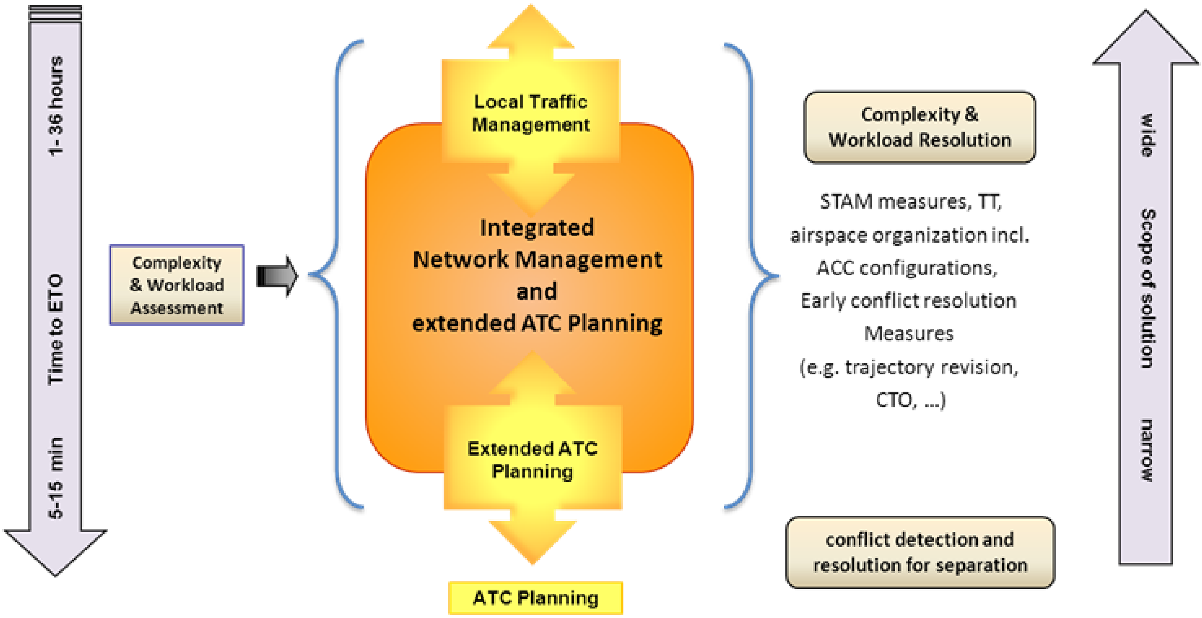

Figure 3: INAP function

The main responsibilities of the INAP function are the following:

- Monitor and manage workload distribution within the area of responsibility;
  - Implement agreed (d)DCB measures taken within its area of responsibility, including airspace re-configuration;
  - Monitor the execution of the measures and the situation within its area of responsibility;
- Perform early conflict detection and resolution (the implementation of the resolution might be shared with the control sector);

- Integrate Network Management measures, traffic synchronization and strategic conflict management measures within its area of responsibility to allow a seamless, efficient and consistent ATM process.

The area of responsibility of INAP is established to provide a volume of airspace which is sufficiently large to enable INAP function activities (Network Management Function and extended ATC planning) to be performed.

In SESAR Step1, a first stage of the INAP function is introduced, the full implementation being expected to be reached in step 2, through the development of an integrated toolset.

In Step1, co-ordination procedures between the involved actors are locally developed to support the first stage of implementation, each activity being facilitated by adequate support tools.

The INAP function can be handled by several roles from Network Operations and ATC Operations. It includes the LTM role from the Network Management function and extended ATC planner role from ATC operations. It has been demonstrated that additional Extended Planning Role is necessary to close the gap and cover the processes between the present ATFCM and ATC planning. The distribution of the tasks related to this role to the human and automation actors is highly dependent on the local ATM environment, mainly on the complexity level and on the ATC working methods. The performance gain is related to implementation of CAR related OI steps.

Performing this function requires actors to have local expertise and the way it will be implemented (procedures, detailed activities, actors involved …) will vary dependent upon local drivers.

2.3.6.2 Manual INAP

This is the simplest approach to INAP where a human decides on what strategy to apply for solving traffic complexity overloads detected by the CAR service. No tool support is provided and the efficiency of the resolution strategy to be applied completely relies on human expertise.

The feedback of the manual actions implemented to solve the complexity overloads situation will become visible with time as new complexity forecasts include the changes in traffic and/or airspace implemented.

2.4 Processes and Services (P&S)

The diagram in Figure 4 is the process representing a cycle of traffic complexity management from the identification of the problem to the implementation and monitoring of the determined solution.

Please note the small round circles in the model identify the events that can be triggered, including the non-nominal ones described in the alternative scenario such as "Negative coordination" or "De-complexing solution obsolete".

Each phase of the complexity management cycle has a dedicated sub-process described in the next sub-sections.

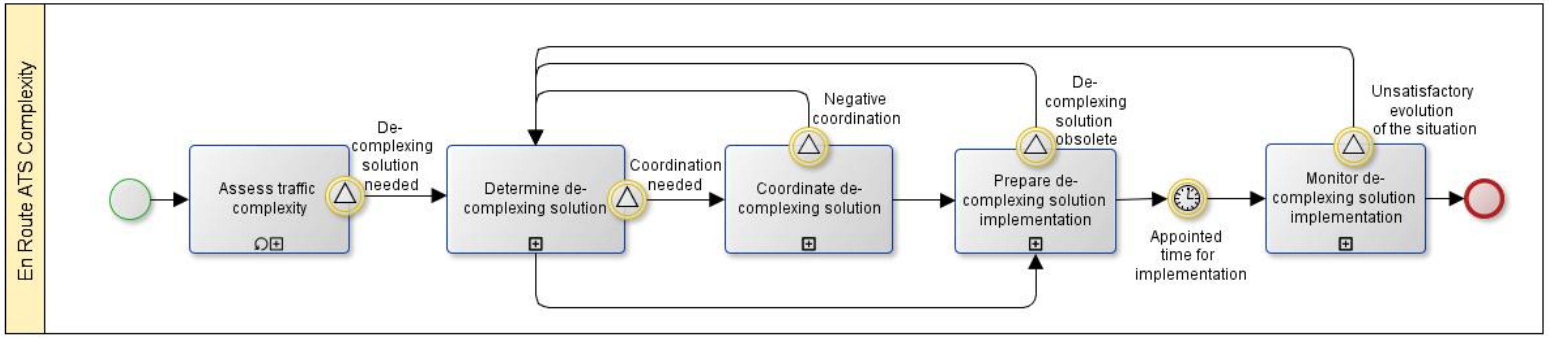

Figure 4: "Manage Traffic Complexity" process

2.4.1.1 Assess traffic complexity

The diagram in Figure 5 shows the detail of the sub-process dealing with the assessment of the complexity for the current traffic situation. Even though the model uses a higher level of abstraction, it implicitly covers use case activities ranging from CM UC 01 to CM UC 09.

If a complexity problem is detected, the event "De-complexing solution needed" is triggered, the sub-process ends and the following sub-process in the cycle, "Determine de-complexing solution", is called (see Figure 4). Otherwise, the sub-process ends and waits for the event "New data received" to be triggered again.

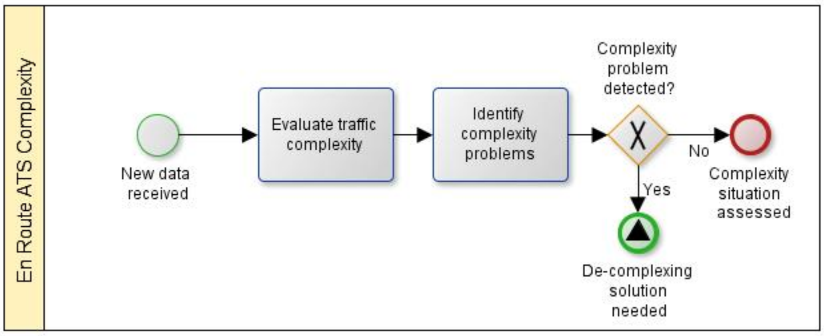

Figure 5: "Assess traffic complexity" sub-process

2.4.1.2 Determine de-complexing solution

Next diagram in Figure 6 represents the activities concerning the identification of a potential solution and its assessment through "What-if" facilities. The four basic de-complexing techniques are represented. Use cases CM UC 10 to CM UC 14, CM UC 24 to CM UC 29 plus the "What-if" ones (CM UC 30 and CM UC 31) can be considered as being modelled here in a high level way.

If coordination is needed, the sub-process ends by triggering the event "Coordination needed" and the following sub-process in the cycle, "Coordinate de-complexing solution", is called. Otherwise, the sub-process ends and "Prepare de-complexing solution implementation" is called next (see Figure 4).

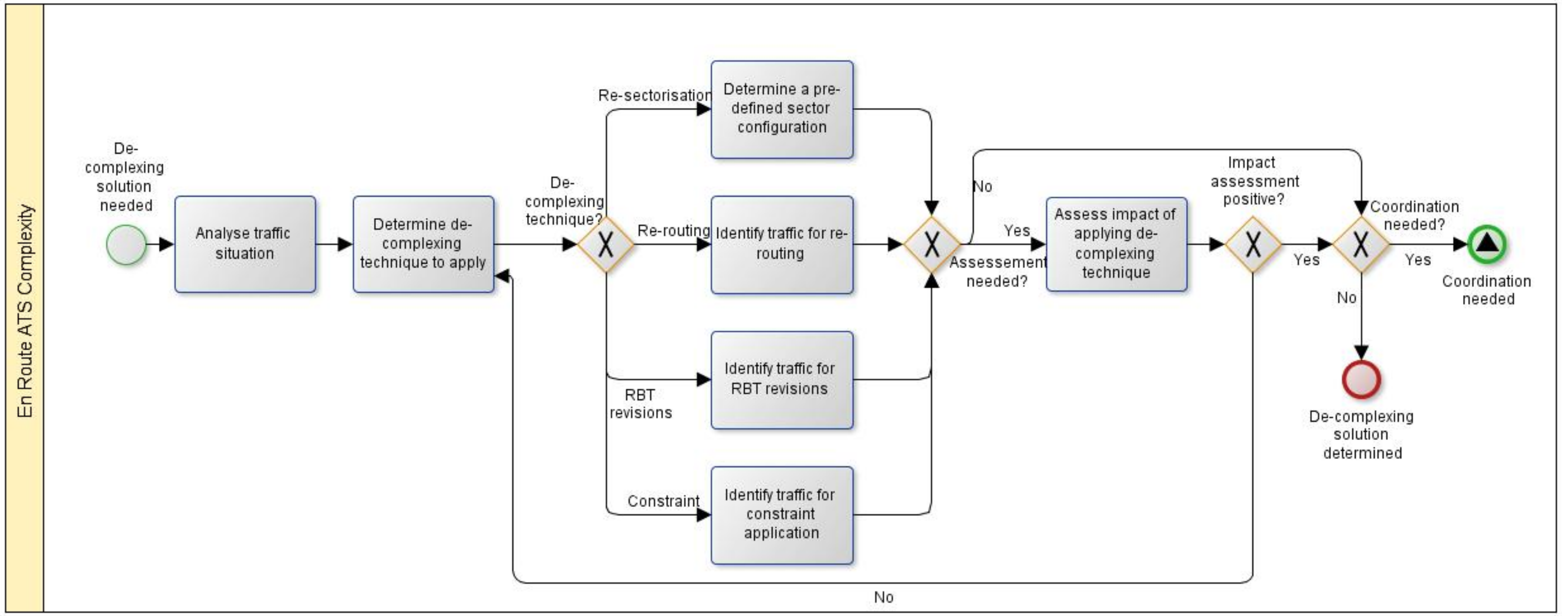

Figure 6: "Determine de-complexing solution" sub-process

2.4.1.3 Coordinate de-complexing solution

Coordination sub-processes may be different depending on the de-complexing solution adopted. The modelling reflects the two situations described in the Complexity Management sub-scenario 1 and sub-scenario 2.

Figure 7 diagram models the coordination sub-process for a re-sectorisation de-complexing solution. It includes several additional sub-processes which will not be further detailed,

In the nominal case, the sub-process ends with a positive coordination and "Prepare de-complexing solution implementation" sub-process is called next. However, the Complexity Management alternative scenario refers to another situation where the coordination cannot be achieved. In that case, the sub-process ends by triggering the signal "Negative coordination" and "Determine de-complexing solution" is called again to initiate a new cycle of the complexity problem resolution (see Figure 4).

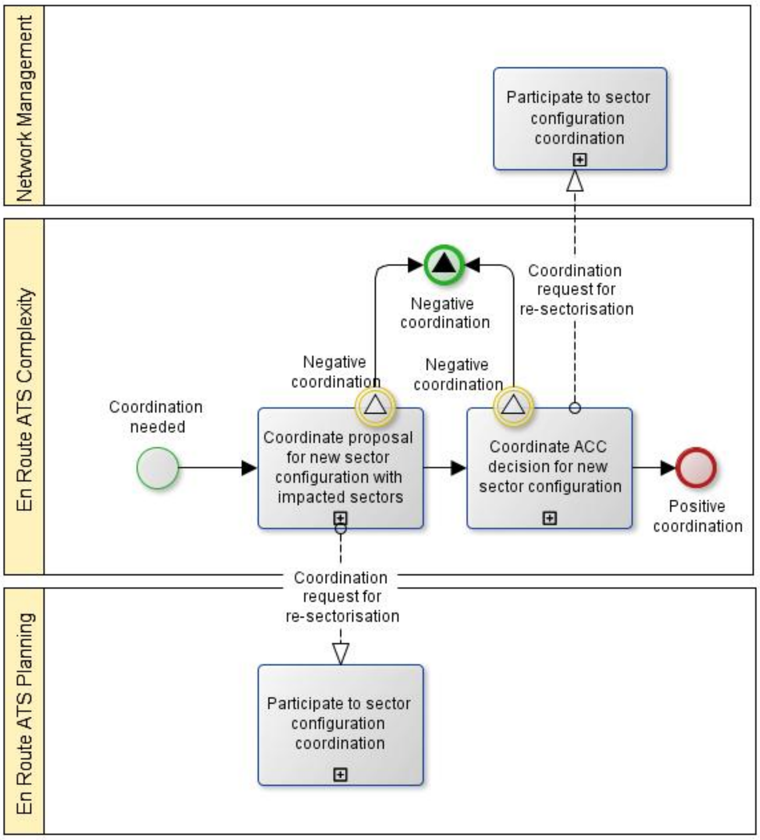

Figure 7: "Coordinate de-complexing solution" sub-process (sub-scenario 1)

Figure 8 represents the situation where the de-complexing solution implies re-routing of traffic flows or revisions of iRBT impacting the adjacent sectors. In the same way, the modelling includes both the case of a positive or negative coordination.

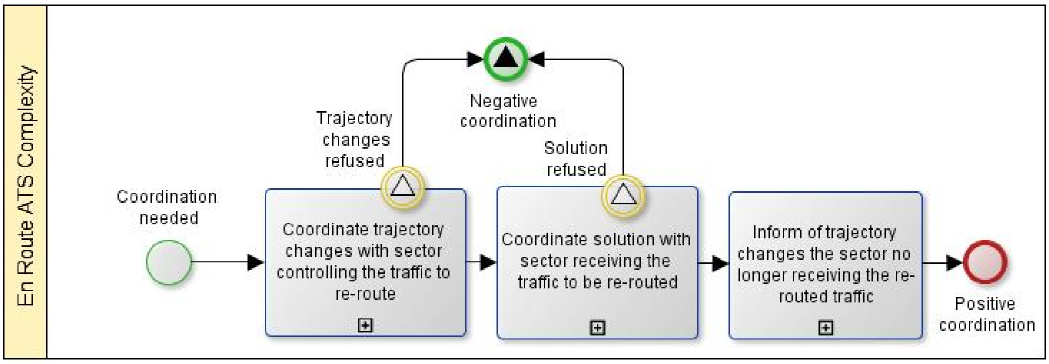

Figure 8: "Coordinate de-complexing solution (sub-scenario 2)" sub-process

2.4.1.4 Prepare de-complexing solution implementation

The sub-process in Figure 9 models the activities described in use cases CM UC 18 to CM UC 21, when coordination have been achieved and the system needs to be updated with the necessary information to actually trigger the implementation of the chosen de-complexing solution.

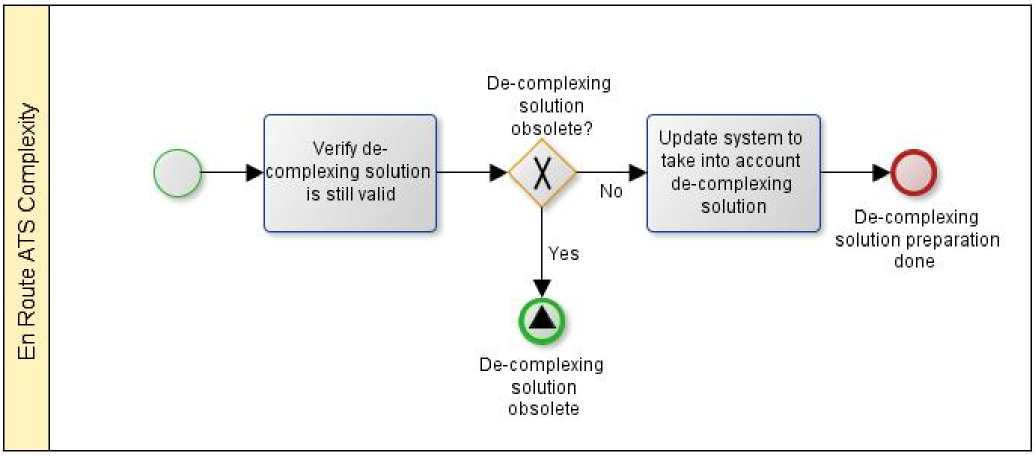

Figure 9: Prepare de-complexing solution implementation

As indicated in the alternative scenario, the sub-process takes into account the fact that the selected solution may become obsolete. If this is the case, the sub-process ends by triggering the "De-complexing solution obsolete" signal which initiates a new cycle of the complexity problem resolution. Otherwise, the sub-process ends and the actual implementation can start at the appointed time (see Figure 6).

2.4.1.5 Monitor de-complexing solution implementation

Figure 10 and Figure 11 show the sub-processes where the de-complexing solution is implemented, as described in the two sub-scenarios, and the complexity manager monitors the evolution of the implementation process. The monitoring activity is not explicitly mentioned in the scenarios, but it is covered by the CM UC 22.

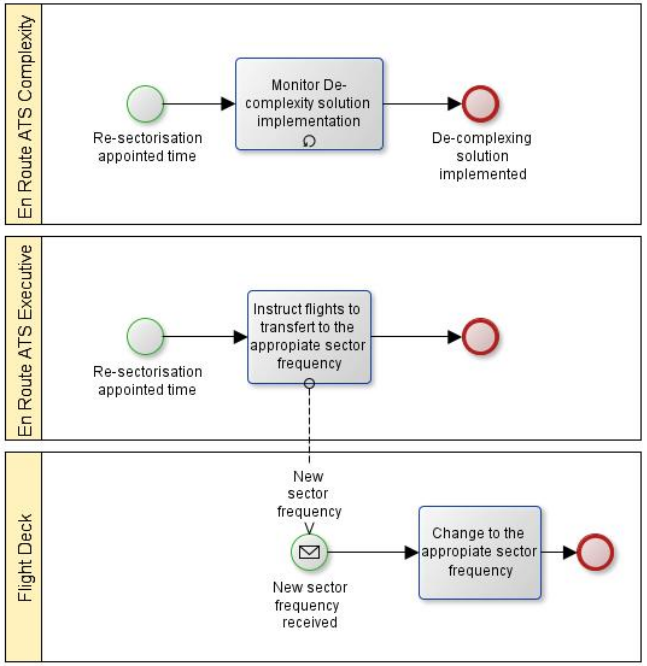

Figure 10: "Monitor de-complexing solution (sub-scenario 1)" sub-process

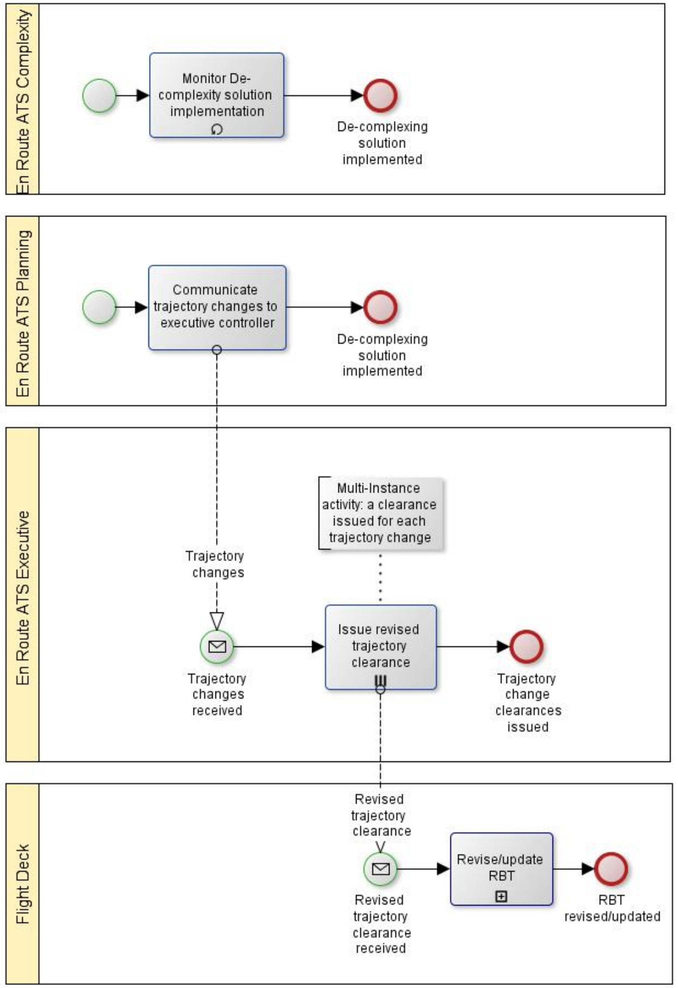

Figure 11: "Monitor de-complexing solution (sub-scenario 2)" sub-process

2.4.2 Perform Extended ATC Planning

The above detailed processes and sub processes are contributing to the performance of the EAP role in the wider context of INAP. This higher level process description describes the main activities related to the management of the traffic complexity in En Route ACCs: complexity assessment, determination of de-complexing measures and their application and monitoring. The applied measures can consist on the deployment of pre-determined ATC Sector Configurations and the modification of individual trajectories or traffic flows.

This process is part of the OFA Enhanced ATFCM processes (see diagram below). All the other OFA processes are described in the 7.2 DOD Step1.

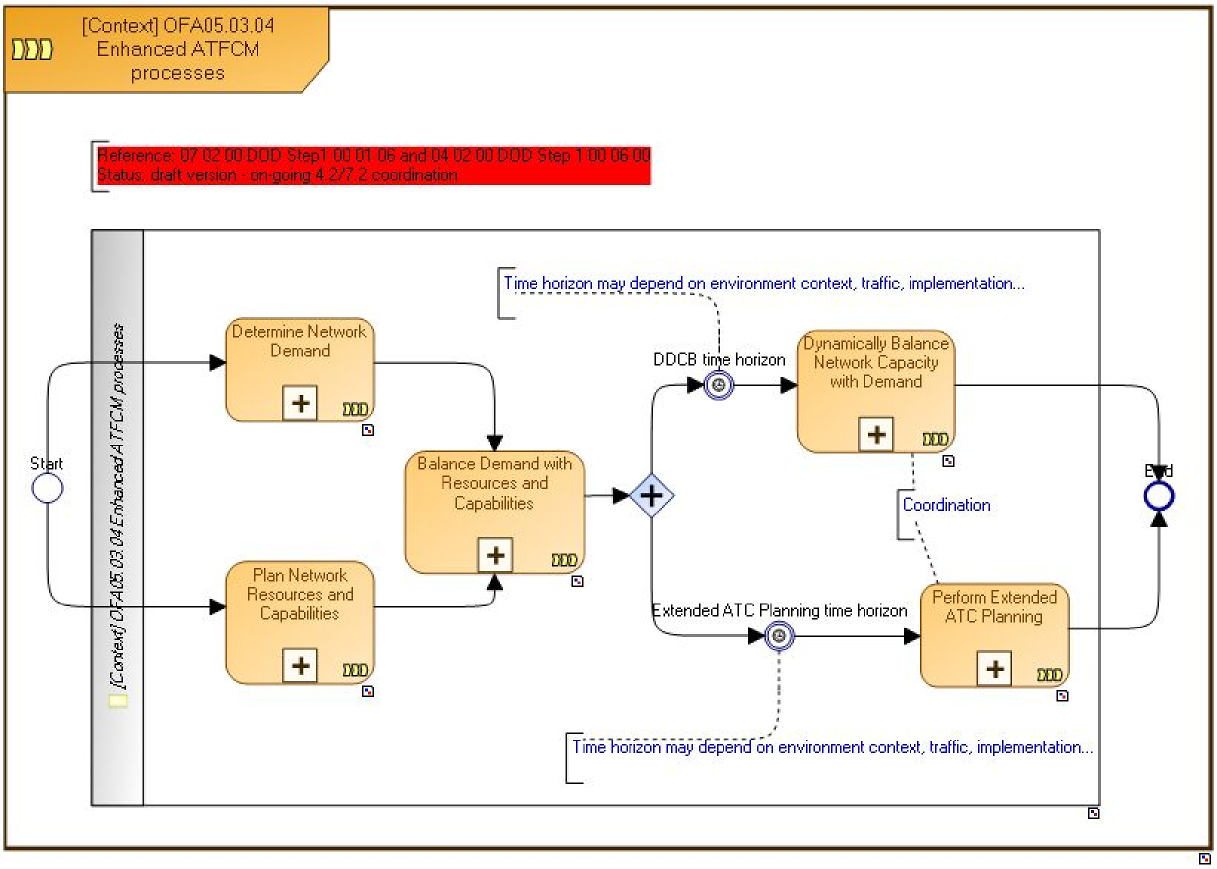

Figure 12: OFA 05.03.04 processes

Node	Activity	Description
En Route ATSU	Assess traffic complexity	This activity is run periodically to assess the complexity of the current and future traffic situation at the ACC level based on forecasts within a 120 min look-ahead time. Complexity metrics and thresholds are defined to calculate and evaluate when a situation is acceptable or not in terms of complexity within a sector.
	Determine de-complexing solutions	When the traffic situation involves an unacceptable level of complexity, it is necessary to identify a potential solution to reduce it. This can be done by using "What-if" facilities to assess several pre-determine scenarios for complexity resolution before their actual implementation. The applicable measures are based on either Dynamic re-sectorisation or trajectory management solutions (2D/3D trajectory modifications, CTO). EAP will make a full evaluation of the solution for positive network performance impact, with an emphasis on A/C performance and AU needs.
	Coordinate de-complexing solution	Co-ordination may involve different actors depending on the de-complexing solution including network management function (see Complexity Management sub-scenarios). At the end of that process, the implemented Solution (according to its type) shall become the new contract for Complexity Management by all of the involved actors (update of the NOP with the implemented De-complexing solution).
	Manage Complexity Management co-ordination requests	Co-ordination requests are sent to the relevant actors, including if necessary the network manager.
	Prepare and select de-complexing solution implementation	Among the potential de-complexing measures, EAP will make a full evaluation of the solution for positive network performance impact, with an emphasis on A/C performance and AU needs. After checking that the solution is still valid, he/she updates the necessary information to actually trigger the implementation of the chosen de-complexing solution.
	Implement de-complexing dynamic re-sectorisation	At the appointed time the new Sector Configuration is implemented to re-distribute traffic flows. Executive Controllers instruct the Concerned flights to contact the appropriate sector via voice or data link.
	Implement trajectory management solutions	This includes the management of individual trajectories (re-routeing, change of FL, allocation of a TRACT issued CTO).
	Monitor de-complexing solution implementation	Activity related to the monitoring of the de-complexing solution's implementation and impact. If the evolution of the situation is not satisfactory, another cycle of complexity assessment and resolution is launched.
Local/Sub-regional Network Management	Manage Complexity Management co-ordination receipt	Network management Function receives the request for co-ordination, assesses the ACC's decision and provides an answer.

Table 13: OFA 05.03.04 processes description

The “Perform Extended ATC Planning” process is detailed in the following diagram:

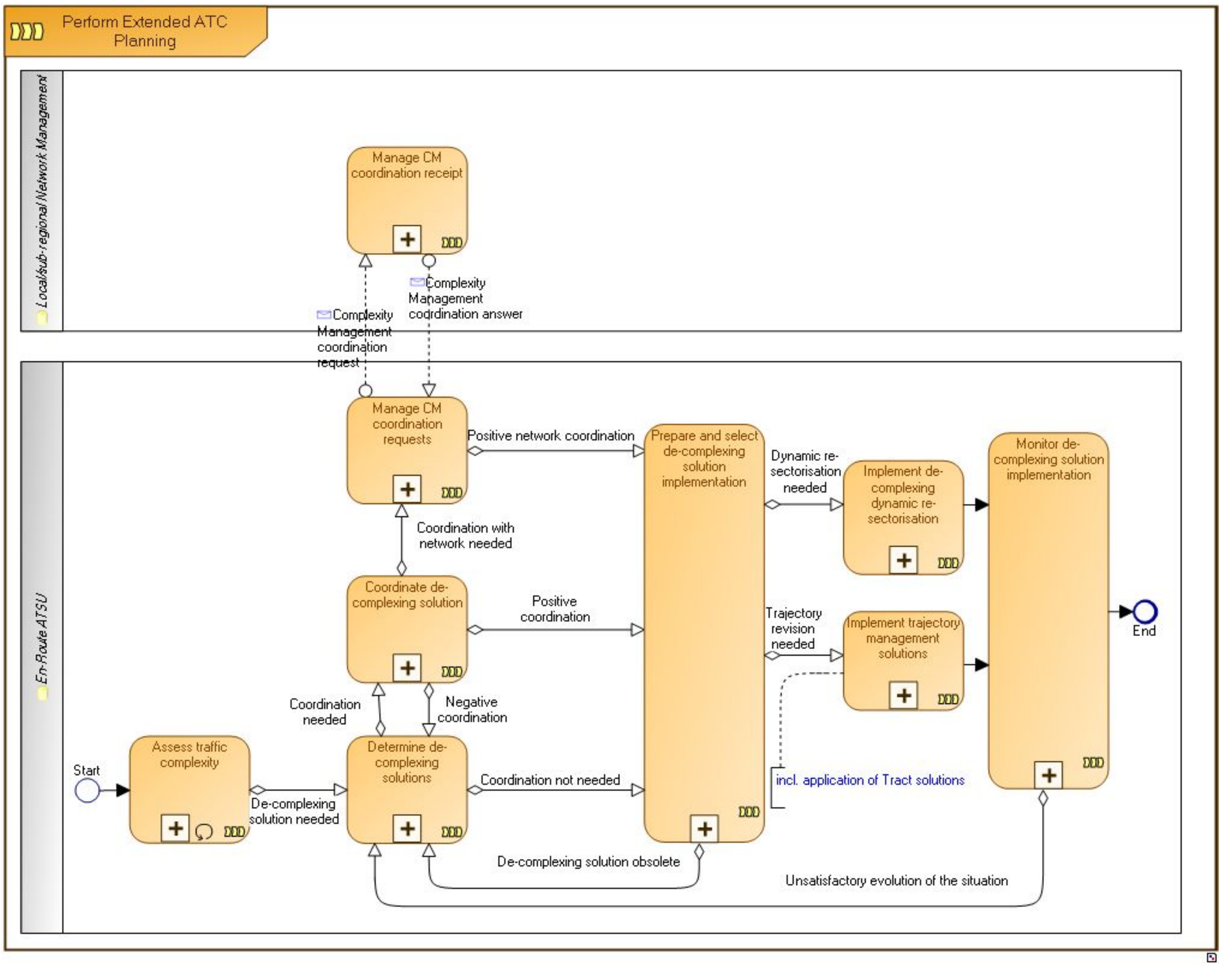

Figure 13: “Perform Extended ATC Planning” processes

2.4.2.1 Service 1

Service Group: A.3 ATM Network Management Service Group

The ATM network management service group assures stability of the whole ATM network in the face of the traffic demand and also threats such as weather phenomena and loss of significant assets such as airports or runways for whatever reason.

Service Family: A.3.6 Demand and Capacity Balancing Service Family

The Demand and Capacity Balancing Service Family ensures the most efficient balance between capacity and demand. It concerns looking for optimisation of available resources in readiness to introduce mitigation measures to maintain the ATM network stability.

Operational CAR Service represents a dynamic, real time, automated service which applies a complexity function / metrics within a defined airspace of operation (ATC Centre), in order to predict future controller workload within up to approximately 90 - 30 min. look-ahead time horizon. It is directly dependant on trajectory prediction (TP) accuracy and level of capability and interoperability of ATM systems and tools.

Within CAR there are three layers of planning:

- Complexity management (complexity detection and resolution, operational horizon up to 90 minutes)

- Queue management (sequencing and metering, operational horizon up to 45 minutes)
- Conflict management (operational horizon up to 30 minutes).

These planning layers are defined by their areas of application, which are overlapping and should be seen as a continuous and seamless operation.

TCM deals with air traffic complexity problems within ATM Execution phase, filling the gap between Demand / Capacity Balancing and Tactical ATC. In essence, the planning and executive ATM actions deal with similar problems, the only difference is their scope in time and methods of action. The Tactical Controller will still inherit all the tasks from earlier planning layers that are to be implemented and is therefore involved in complexity, queue and conflict management, in addition to their own task, prevention of losses of separation.

2.4.3 Mapping to Service portfolio and Systems (optional for V1 and V2)

Section 5.2.5 of 07.02 Step1 DOD [14] refers to the European ATM Architecture portal, which is updated twice a year, after each EATMA iteration cycle. The OFA 05.03.04 activity views can be found on: OFA05.03.04 Enhanced ATFCM Processes.

3 Detailed Operating Method

3.1 Previous Operating Method

In the method used today the most advanced elements of this method are:

- Collaborative Decision Making between TCM, Flow Management Position (FMP) and Sector Supervisory staff, as well as with external ATM partners (NMOC, Airspace Users - AOs, Military Units, ANSPs);
- A philosophy of traffic management versus traffic regulation;
- Better understanding of the available tools/procedures.

At the moment, the main tool is remote client software NM Human Machine Interface (CHMI) from the NMOC for tactical decision makers. This data provision includes predicted sector occupancy, and sector entries, over the subsequent few hours from 'now' time. However, experience has shown this information to be inaccurate to such an extent that it is used as a guide only. Supervisors/LTM Operators rely upon a mixture of unreliable data and experience to make and adapt short-term tactical plans.

Furthermore, the CHMI:

- does not show workload;
- does not have a sector configuration optimization;
- is based on Flight Plan - FPL; it does not take into account:
  - prevailing or planned tactical flight/flow constraints, decided by TCM
  - typical routing through ATC Centre airspace;
- is subject to NM change management.

Otherwise, various other non-integrated tools and information and above all operational experience are used, primarily to interpret/enrich/correct the traffic predictions but also to test the feasibility of sector configuration schemes, allowing for a better tactical decision making.

Today, predictions are based on sector entries (Hourly Entry Rate) or on occupancy. Occupancy is often a better indicator than Hourly Entry Rate, as the number of aircraft entering a sector per hour is no indication for the distribution of these entries over time (how many aircraft are entering at the same time).

However, occupancy does not take into account complexity. Workload does take this into account, recognizing the fact that it is not simply the number of aircraft in a sector that determines controller workload, and is therefore the preferred indicator.

3.2 New SESAR Operating Method

Complexity Assessment and Resolution (CAR) concept addresses the automated support in identifying, assessing and resolving local complexity situations based on complexity prediction. It relies on a real time integrated process for managing the complexity of the traffic with capability to reduce traffic peaks through early implementation of measure for workload balancing.

3.2.1 Concepts elements related to SESAR Solution #19

From the concept maturity assessment stated in §2.1, it can be concluded that the SESAR Solution #19 covers the following aspects of the CAR concept:

Scope of complexity assessment:

Automated tools continuously monitor sector demand and evaluate traffic complexity (by applying predefined complexity metrics) according to a predetermined qualitative scale. Forecast complexity coupled with demand **enables** ATFCM to take timely action to adjust capacity, or demand profiles through various means, in collaboration with ATC and airspace users.

Complexity prediction is used by Local Network Manager and/or ACC Supervisor roles. Analysing aircraft trajectories using SBT/RBT and other demand information, coupled with the use of validated complexity metrics, allows prediction of changes in traffic complexity and potential overload situations, allowing mitigation strategies to be applied.

Scope of complexity resolution:

Complexity prediction will **support decision making processes** such as:

- Determine the optimum organization of ATC sectors;
- Apply dynamic ATM constrains (on traffic flows (e.g. Level Cap));
- Modify individual trajectories by route or level;

The tools that assist in resolving complexity issues includes a 'What-if' capability where resolution strategies can be trialled before implementation and may provide assistance in identifying the trajectory or trajectories that are causing the most complexity, through interactions or application of sequencing measures or other constraints.

3.3 Differences between new and previous Operating Methods

The differences between new and previous operating methods addressed by SESAR Solution #19 are highlighted in bold text.

Operational method element used	Current	SESAR 1
ATFM Planning	**Based on Sector hourly entry rates or in best case on sector occupancy**	**Based on real workload** **Increased awareness and reliability of traffic and workload predictions**
Sector Configuration Management	**Static, linked to demanding procedures and static coordination arrangements**	**Dynamic based on seamless implementation of pre-defined schedules taking into account workload predictions of CAR tool.**
Coordination of the ATC Centre with the NM	Manuel based on procedures	Supported by automation and proactive
Roles	**Ops Supervisor ; FMP**	**Ops Supervisor, Local Network Manager** Extended ATC Planning
Accuracy of prediction	**Based on standard FPL information**	**Based on ATC Centre System information and Enhanced Tactical Flow Management System (EFTMS) data**
Prediction of workload and ATC Centre resource management	**Manual**	**Supported by automated CAR and resource distribution tools**

Table 14: Differences between new and previous operating methods

3.3.1 CAR Procedures

FCM

Hotspot detection is based on accurate and reliable prediction of imbalances between capacity and demand. The imbalance prediction will be based on supporting tools displaying hourly entry counts and occupancy counts and on complexity assessment analysis. The use of complexity algorithms is the main enabler and advanced monitoring techniques are required for the application of complexity resolution.

The LTM starts the analysis of the traffic for traffic volumes for which there is a confirmed hotspot. The key parameters analysed by the LTM to support decision-making are predictability and complexity.

After the analysis of the complexity, the LTM shall consider an option for a capacity or demand measure. If capacity measure is not possible, the LTM may choose between cherry-picking measures or flow measures. The proposed measures are assessed with a basic complexity what-if on the current and predicted traffic.

Once measures are proposed by the LTM, the coordination phase starts with involved actors (ACC LTMs, Airport LTMs, AUs and NM) who evaluate and approve the measure.

Once the STAM measure is implemented, the LTM requester (initiator) continues the monitoring of the hotspot including evolving complexity.

ATC

The ATC Supervisors analysis traffic flows and sector load in collaboration with the LTM and the Flow Manager. Decision is taken on split or combining of control sectors according to expected complexity. In collaboration with the Local Traffic Manager and ATC sector team re-routeing of traffic is planned in case of overload.

4 Detailed Operational Environment

This section describes the expected operational environment defined in SESAR STEP 1 En Route DoD WP04.02 Step1 [13], in this document the operational environment is limited to the airspace of a single ATC Centre.

4.1 Operational Characteristics

The main characteristic brought by CAR is the optimal workload distribution and use of resources through dynamic application of optimal sector configurations corresponding to predicted complexity.

4.1.1 Airspace characteristics

Airspace organisation planning and management based on current Implementing Rule (IR).

Military aspects based on current IR related to Flexible Use of Airspace (FUA).

INAP is mainly applicable in regions of high traffic loads in which classical sectorisation and flow control measures are insufficient to support the capacity demand. Such airspaces could be regarded as those in which the capacity, in terms of aircraft occupancy, of its sectors can exceed a certain percentage (e.g. 80%) of the nominal maximum. Local circumstances will dictate whether INAP application is performance beneficial in medium complexity areas.

4.1.2 Ground technical capabilities

Ground technical capabilities are expressed in terms of their ATM Capability Level. Note that these descriptions do not fully detail all the capabilities, but instead provide those characteristics which are relevant to this document.

This section summarizes the capabilities of the ground system that are expected to be available to support En Route operations within the timeframe of SESAR Step 1.

4.1.2.1 ATC support tools

4.1.2.1.1 CAR tool

Basic CAR tool will continuously predict and monitor traffic complexity within 3 hours look-ahead time horizon. Only the basic indication of predicted complexity will be displayed (unacceptable, excessive, critical, acceptable or manageable), without advisories related to the resolution of the complexity problems.

The tool that assist in resolving complexity issues includes a 'What-if' capability where resolution strategies can be trialled before implementation and provides assistance in identifying the trajectory or trajectories that are causing the most complexity, through interactions or application of sequencing measures or other constraints.CAR process is performed with awareness of adjacent sectors' air traffic situations; typically LTM/EAP would have a responsibility to maintain the controller workload at an acceptable level and optimise trajectories within the area of operation (with the objective to be as conflict free as possible and at the same time taking into consideration any constraints imposed to aircraft by other tools such as TTL/TTG imposed by AMAN).

4.1.2.1.2 Conflict detection tools for planning purpose

Conflict detection tools for planning purpose will support the controller within planning look-ahead time horizon (e.g. 20-30 min). One of the examples of such tool would be Medium-term Conflict Detection, indicating conflicts, risks, exit problems and context traffic to the controller. The conflict detection tool for planning purposes (MTCD) outputs are used as one of the parameters for assessing and predicting complexity when the algorithmic approach is used. It is also used by the human actors to further analyse complex traffic situations and the workload.

4.1.2.1.3 Conflict detection tools for tactical purpose

Conflict detection tools for tactical separation purpose will support the controller within the tactical look-ahead time horizon (e.g. 8-10 min). These tools will detect similar types of problems as specified for planning purpose, but with higher detection accuracy, as required for the tactical separation and taking into consideration any issued clearances .Availability of tactical ATC tools could have huge direct impact on the ATCO's workload, especially the information of possible tactical solutions, in Step 1 mainly, given that the uncertainty of the trajectory prediction element in the development of the conflict detection tool was still not at the level to be effective and useful input for the CAR service.

4.1.2.1.4 Arrival management extended to En Route

AMAN into En Route concept enables the modification of the trajectories of flights (based on arrival management constraints) while still in the Area of Responsibility of En Route sectors. At Step 1 level, basic input from the Arrival manager into the CAR tools was considered.

4.1.2.1.5 Conformance monitoring

Conformance monitoring tools continuously monitor the actual aircraft progress in relation to the system trajectory and will either display non-conformances to the controller or trigger automatic trajectory re-calculation.

4.1.2.2 Automated support for ATC coordination

Automatic support for ATC coordination enabling more effective coordination procedures based on IOP.

4.1.2.3 Air / ground data link

European Commission Regulations No 29/2009 laying down requirements on data-link services for the Single European Sky (SES).

4.1.2.4 Human Machine Interface (HMI)

En Route controller interface will need to integrate all functionalities of the ground system (e.g. CAR, conflict detection, arrival management in En Route, air ground data link, ground-ground messages, safety nets) presenting the required information, at the right time in an intuitive way. It has to enable to the controller to easily build accurate situation awareness.

4.2 Roles and Responsibilities

This section is dedicated to the new roles in ATM layered planning and scoped for the short term and execution phase of this process. Indeed in Step 1, one of the main improvements is that a new ATM layered planning is made possible with the introduction of new roles (i.e. Local Traffic Manager, Extended ATC Planning). New working methods and optimized tasks sharing are defined; the main objectives are to improve safety, improve capacity, reduce controller workload per flight, reduce tactical intervention on flights, and allow trajectory facilitation.

In Step 1 ATC Planning will be organised in a way that is suited to the traffic density and technical environment as illustrated in the following table.

Table 15, Table 16 and Table 17 below describe roles, environment and systems associated with the ATM layered planning roles in an En Route control centre:

- "ATC Planning" refers to a planning role working on one or group of ATC sector and for which tasks would be approximately what the corresponding controller is doing in today's environment enriched by enhanced sector team task sharing resulting, in Executive Controller workload smoothing;
- "Extended ATC Planning" refers to an ATC planning role, involved in organising air traffic by managing individual iRBTs/iRMTs or traffic flows in a Sector Family within ATSU airspace. Depending on the ATSU environment and operational working methods the actor performing the Extended ATC planning would serve several operational sectors in order to insure

execution of iRBTs/iRMTs with minimum deviation while maintaining Sector Team workload at optimum level and facilitating network generated tasks at the same time;

- Local Traffic Management is performed at ATSU airspace consisting of a large number of ATC sectors and a number of sector families that fall within the Local Traffic Management's area of responsibility.

The Roles in the ATM Layered Planning could overlap. Actors endorsing these roles would depend on local ATSU or ANSP procedures, operating methods and traffic environment. A given actor could assume a given role, part of the tasks of a given role, several roles or part of the tasks of several roles.

For example the Multi-sector Planner (as an actor) could perform the tasks of the Extended ATC Planning role.

Similarly, a Complexity Manager (actor) could endorse the tasks of the Local Traffic Management role and the Extended ATC Planning role.

Description of Planning Roles and associated tasks in the ATM Layered Planning environment

ATC Planning role	Extended ATC planning role	Local Traffic Management role
Primarily concerned with entry and exit co-ordination. Boundary problems are resolved by re-coordinating. Planning horizon about 10 to 15 minutes.	Has planning responsibilities for a Sector Family. Monitors complexity and workload for the next 15 to 40 minutes (approximately). If necessary to balance workload, individually optimises entering flights within given dynamic constraints (target times, target levels, target speeds, CTO), or coordinated for a new route. Workload optimisation implies different kinds of solutions, e.g. level capping, top of descent advisories, levels or speeds, miles in trail procedures. The Extended ATC planning role is active in achieving Network generated targets contained in the iRBT/iRMT and in avoiding actions that could compromise their compliance (e.g. to achieve a CTA). Moreover, the Extended ATC planner could provide early conflict detection and resolution (depending on the Conflict Detection and Resolution tools horizon) if this early resolution brings operational benefit (either on the ground side or the airborne side).	Leading role in DCB/dDCB process in short term to execution Includes complexity related multi-sector planning responsibilities. Responsible for balancing the workload of sectors within the ATSU or assigned Sector Family using CDM process with appropriate actors. Sensitive to the internal and external complexities expected for the future 30-180 mins (approximately). Will re-organise internal ATC sectors or families of sectors and implement complexity problem resolutions with straightforward rules. May adjust internal air traffic flows or constraints according to forecast traffic and priority rules. Will act on single trajectories, if they have a high complexity signature. Will be aware of any Network issues related to forecast traffic and possible actions

Table 15: Planning roles

Environment and Procedures: Procedures which are directly related to SESAR Solution #19 and validated are highlighted in bold text.

ATC Planning role	Extended ATC Planning role	Local Traffic Management role
Provide conventional ATC planning for one or more ATC sectors with one Executive controller. Perform conflict detection and resolution and assist the Executive controller	Extended ATC planning is Performed at the level of sector family. **It is the core role for application of the procedures related to the coordinated NMF and ATC planning processes.** **The priority for actions tends towards trajectory management, especially optimisation and workload balancing.** Trajectory management is effected through data link messages or on voice transmitted by the tactical controllers who controls the flight at the time of the message.	**Performed at the level of a sector, a sector family, and up to an ATSU.** **Manages workload rather than capacity. Through the display system and system advisories awareness of both situational complexity and its effects on the individual workloads.** **Situation awareness beyond the ATSU boundaries to facilitate co-ordination.** Aware of the Network performance impact **LoA's need to accommodate workload balancing measures across ATSU boundaries.** **Interacts with ATC planning, and Extended ATC planning, as well as with the airport capacity planning.**

Table 16: Environment and procedures

System Functionality (system environment): System functionalities related directly to SESAR Solution#19 which have been validated are highlighted in bold text.

ATC Planning role	Extended ATC Planning role	Local Traffic management role
CDT/MONA/SYSCO/Queue management tools and What-if tools Output of workload prediction and current workload measure	**Complexity Management Tools in addition to conventional ATC planning tools.** Trajectory management infrastructure (IOP +I4D). CORA including TRACT and What if tools. Infrastructure to allow effects on adjacent planning areas to be assessed.	**Workload/Complexity monitoring and workload/complexity reduction tool with what If capability. Tools to support CDM process and co-ordination / sharing within Network Management function.** Trajectory management infrastructure (IOP +I4D) **Ability to spot individual flight with high associated workloads** **Infrastructure to allow effects on adjacent sector families to be assessed.**

Table 17: System functionality

4.2.1 Network Related Roles

The Network Operation roles described below are those involved in short term planning and the execution phase and relevant for the application of the CAR concept. Further details can be found in the Appendix A 'Actors, Roles and Responsibilities' of the B.04.02 D106 Transition CONOPS [26].

4.2.1.1 Local Traffic Manager Role

As described in Transition ConOps SESAR 2020 [26], the Local Traffic Manager (LTM) is a role exercised at local level that contributes to the Network Management Function:

- The Local Traffic Manager functionally lies in between the Flow Manager and ATC planning actors, taking a view over a sector family or group of sectors (potentially a complete ACC) and any Airfield Towers that fall within the Local Traffic Manager's area of responsibility. He acts as the coordinating link between the ANSP, sub-regional and regional flow and airspace management;
- He develops and coordinates locally and adequately within the FAB area and appropriate partners, catalogues of dDCB measures to solve hotspots at local/FAB level during execution phase;
- The Local Traffic Manager has the leading role in the DCB/dDCB processes in execution phase (and appropriately in the short term planning phase close to execution);
- He monitors the situation at local level and anticipates hotspots and workload issues. In case of an imbalance, he is responsible for:
  - Declaring the hotspot;
  - Identifying the adequate solutions (Airspace Configuration and flow / trajectory management if necessary);
  - Assessing their impact, looking for optimisation, coordinating and refining them with concerned partners (other LTMs, AUs, Airports, Flow Manager, Network Manager, ATC actors…);
  - using CDM process, except if time doesn't permit, implementing them (or delegating the implementation to the adequate actors), requiring a sub-regional or regional action where necessary.
- The output of this DCB/dDCB process is decision on the ATM Network Management which is integrated into the rolling NOP;
- The Local Traffic Manager provides a bridge in understanding between operational perceptions of complexity, workload & demand and how that translates into DCB requirements as deliverable occupancy & workload values;
- In execution and as appropriate within the short term planning phases, the Local Traffic Manager works closely with Supervisors and ATC Planners (through INAP (Integrated Network Management and extended ATC planning) function). The LTM is also likely to either be a Supervisor, or report to one, and as such will retain local safety accountability. As such any proposed DCB initiatives will have to be approved by him;
- The LTM is one of the roles related to the function: he brings the expertise of Workload Assessment and Resolution with Network Management dimension awareness to facilitate a continuous and coherent activity with extended ATC planning process.

For further details on the LTM responsibilities in the long and medium term planning, refer to Transition ConOps SESAR 2020 [26].

4.2.2 Extended ATC Planning Role

Within the ATM layered planning, the Extended ATC Planning Role stands between the Local Traffic Management Role and the Planning Controller Role.

The Extended ATC Planning Role:

- Has planning responsibilities for a Sector Family;
- Is in charge of monitoring of the internal and external complexity and workload for about the next 15 to 40 minutes;
- If necessary to balance workload, individually optimises entering flights within given dynamic constraints (target times, target levels, target speeds, CTO), or coordinated for a new route. Workload optimisation implies different kinds of solutions, e.g. level capping, top of descent advisories, levels or speeds, miles in trail procedures;

- Is active in achieving Network generated targets contained in the iRBT/iRMT and in avoiding actions that could compromise their compliance (e.g. to achieve a CTA);
- Works closely with the LTM, through INAP (Integrated Network Management and Extended ATC planning) function.

Moreover, the human actor performing Extended ATC planning could provide early conflict detection and resolution (depending on the Conflict Detection and Resolution tools horizon) if this early resolution brings operational benefit (either on the ground side or the airborne side). This concept element related to OI CM-0104A was not fully addressed by P 04.07.01 and it was subject validation of other related projects, such as P04.07.08 [20]. However although the necessity of the role was demonstrated additional validation work is required in respect of application since it is highly dependent on local complexity levels and ATFCM and ATC working methods.

4.2.3 Air Traffic Services Operations roles

4.2.3.1 ACC Supervisory role

As stated in Transition ConOps SESAR 2020 [26], the ACC Supervisor is responsible for the general management of all activities in the Operations Room. He decides on staffing and manning of Controller Working Positions in accordance with expected traffic demand. Supported by simulations of traffic load and of traffic complexity, and assisted by the NMF (Network Management Function), he takes decisions concerning the dynamic adaptation of sector configurations to balance capacity to forecast demand. Based on the results of simulations the required flow control measures may be implemented by ATFCM through a CDM process.

The ACC Supervisors main responsibilities are:

- Analysis of traffic flows and sector load in collaboration with the LTM and the Flow Manager;
- Split or combining of control sectors according to expected traffic load after co-ordination with the Local Traffic Manager;
- Allocation of sector configuration and declared capacity;
- Decide on staffing and manning of Controller Working Positions according to their training and sector validations;
- The planning, activation and de-activation of flow control measures on the day of operations;
- Coordinating with the other concerned Supervisors on the activation and de-activation of special use airspace;
- Collaboration with the Local Traffic/Flow Manager regarding re-routeing of traffic in case of overload;
- Initiates implementation/removal of ACC flow measures based on runway acceptance rates;
- Collaboration with adjacent ACC Supervisors.

For further details on the additional ACC Supervisor responsibilities, refer to the Appendix A ‘Actors, Roles and Responsibilities’ of the B.04.02 D106 Transition CONOPS [26].

4.2.4 Remark on actor, role and responsibilities terms

According to the Transition ConOps SESAR 2020 [26], following are the terms actor, roles and responsibilities described to get a better understanding and distinction between actor and roles.

- ATM **actor** is a person, organisation or technical system authorised/licensed to act within the ATM System.
- A **role** is a collection of responsibilities that an ATM actor can take.

  Note: A role can be performed by several ATM actors. One ATM actor can perform several roles.

- **Responsibility** is the obligation to conduct assigned tasks to a successful conclusion.

The actual deployment of ATM actors varies throughout Europe and is dependent upon a number of local factors including: company policy; local procedures; method of operations; and traffic environment. In some cases a particular actor may be responsible for: all of a given role; part of the tasks of a given role; several roles; or part of the tasks of several roles. Likewise some actors may be named differently and implemented at different organizational levels.

In the context of the **SESAR Solution #19**, the roles related to CAR are LTM and ACC Supervisor defined at concept level. However the final decision on which specific actor should be assigned to those roles will be made at local level taking into account the local procedures and operational environment.

4.3 Constraints

The main constrains for the CAR and INAP in Step1 are:

- Accuracy of the input Flight Data Processing (FDP) data to be used for complexity prediction, due to the required time horizon and quality characteristics of that data;
- Human Factors (HF) constrains related to frequent sector configuration changes;
- Additional co-ordination procedures required by introducing of additional layer of planning without adequate automated support in Step1.

5 Use Cases

5.1 Operational scenario 1- Complexity Management in En Route

5.1.1 Scenario Summary

This scenario describes actions taken within an ACC to manage complexity through the deployment of pre-determined ATC Sector Configurations and specific measures to modify trajectories. It takes place in a busy ATC environment during a period of high traffic demand. The Complexity is assessed through a complexity management tool up to 20 minutes ahead. Depending upon the prevailing circumstances (e.g. ACC specific or local requirements, staffing, traffic situation, time) the individual or team managing the complexity could differ. The Scenario indicates, in broad terms, a sequence of actions taken to reduce a predicted period of high complexity within a sector.

5.1.2 Additional Information and Assumptions

5.1.2.1 Information

A complexity management process will be required in ACCs with medium to high levels of traffic. This will be particularly the case where a significant number of flights are in the climb or descent phase of flight.

The role of the individual and or team tasked with the Complexity Management process is to manage the complexity at the ACC or Sector Family (ATSU) level to ensure protection from overload and an equitable workload balance amongst sectors. With tools providing an indication of predicted complexity (within a 90 min look-ahead time) he/she uses specific means to reduce periods of high complexity (e.g. Sector configuration, rerouting, level capping). This role could be conducted by different individuals depending upon the specific requirements within each ACC. There may be a dedicated Complexity Manager/Local Traffic Manager or the task can be taken up by the Supervisor in the Ops room, Flow Management Position, the Multi Sector Planner or a locally appointed equivalent.

For the purposes of this Scenario the term Complexity Manager is used to describe the person or persons fulfilling the role.

5.1.2.2 Assumptions

It is assumed that the following tools will be available to the Executive Controller (EC) and Planning Controller (PC):

- Conflict Detection Tools (CDT);
- Data link (limited data link services e.g Single CTA uplink for AMAN) to a proportion of the aircraft;
- System supported coordination tools (ATSU/ATSU and sector/sector).

Additional tools will be available for the Complexity Management process including:

- A catalogue of pre-defined Sector Configurations coordinated with the NOP;
- Basic automated support for Complexity Assessment and Resolution tool (Basic Traffic Complexity Management Tool – Basic CAR). This tool continuously predicts and monitors traffic complexity with a 3 hours look-ahead time horizon. An indication of predicted complexity, for the current Sector Configuration and updated, at least, every 5 minutes is displayed (In Step 1 a complexity value on a scale of 0-100 will be shown for each sector with 60-80 regarded as optimal. Over and under-loads will be specifically highlighted) via a Complexity monitoring window. The CAR tool:

1. proposes the optimal Sector Configuration to reduce overall complexity;
2. indicates, via a list, the flight or flights that is/are responsible for causing the greatest complexity (using an algorithm that takes into account the Traffic Volume, Vertical State, Proximity to sector boundary, Data Link Equipage, Potentially Interacting Pairs, Aircraft Type Diversity, Time Adjustment Constraints, Sector Normalization Parameter and a Temporary Restriction Parameter) The tool does not provide a solution to mitigate against the flight or flights creating the complexity.

5.1.3 List of Actors

This scenario primarily concerns the:

- Planning Controller (PC);
- Executive Controller (EC);
- Multi Sector Planner (MSP);
- ACC Supervisor;
- Local Traffic Manager;
- Network Manager;
- Flight Crew.

5.1.4 Scenario Text

5.1.4.1 Operations prior to Complexity Management

In terms of chronology, among the SWP4.2 operational scenarios, the Complexity Management scenario stands before 0S-4-03-Separation Management in En Route, as it describes actions undertaken within the first layer of conflict management (as described by ICAO doc. 9854). Indeed, effective complexity management ensures the Controllers do not encounter excessive peaks of complexity and reduces the need for conflict management by resolving potential separation and conflict management issues prior to the arrival of a flight within a sector or group of sectors. Before this scenario stand scenarios related to Network Management Function which are described within the P07.02 DoD and more precisely the scenario related to Dynamic DCB in the execution phase.

5.1.4.2 Scenario text

The scenarios take place in the Execution Phase or Short Term Planning Phase, in En Route airspace, during a busy traffic period. Based on the traffic prediction, a Sector Configuration which will be a part of the wider ranging Airspace Configuration[1] has been coordinated and agreed with the Network Manager. This Sector Configuration is one of a pre-defined set available to the ACC and is used to balance predicted demand with available capacity and airspace. The agreed Sector Configuration is reflected in the NOP (in Step 1 this will be a record of the agreed Sector Configuration for a given time period and updated whenever a change is introduced).

Within the airspace designated to the ACC a military TSA with a vertical limit of 245+ is active. The TSA activation timeframe is not modifiable in this scenario. This impacts the civil traffic flows by reducing the availability of CDRs and airspace available for radar vectoring or tactical parallel offsets.

Events beyond the control of the ACC have resulted in a slight shift in the traffic pattern. The arrival stream into the Terminal airspace has been delayed and there are more overflights than anticipated during the pre-tactical phase. It is expected that the traffic situation will prevail for a reasonable time period.

[1] Airspace Configurations refer to the pre-defined and coordinated organisation of ATS routes and/or Terminal routes and their associated structures (this includes temporary airspace reservations if appropriate)

The scenarios take place within a group of sectors (Sector Family) within a single ACC. For the purposes of this scenario only activities in four of the sectors (Sectors 1, 2 and 3 and 4) are described though there may be more sectors within the complexity management area of responsibility. The sectors are assumed to have a base division Flight Level of FL 245. Below the Sector Family sits terminal airspace and associated sectors.

The basic structure and traffic flow orientation is illustrated in Figure 17 below.

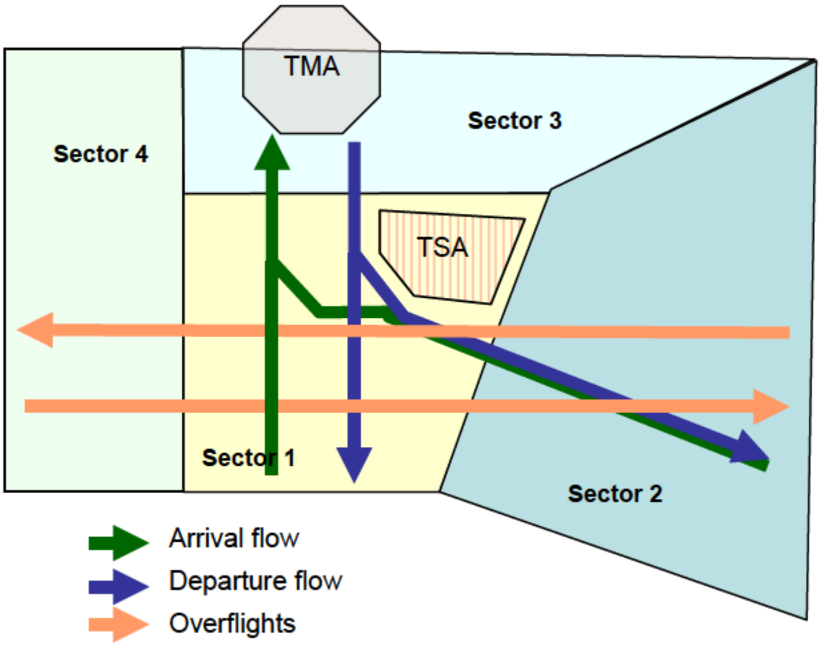

Figure 14: airspace structure and traffic flows

In the scenario, the flows/flights illustrated in the Figures and described in the text are only a sample of those planned to enter the ACC. In a busy ACC many other flights would be transiting the sectors. The flows used in this scenario are shown as they are the ones contributing to the rise in the complexity value.

This scenario describes the process followed after the detection of a period of high complexity in one ATC sector (Sector 1). The resolution is illustrated through two separate sub scenarios:

- Sub scenario1: Designation of a new Sector configuration to re-distribute traffic flows
- Sub scenario2: Using management of individual trajectories (re-routeing, change of FL)

5.1.4.2.1 Sub scenario 1 – Sector configuration change

The CAR tool [CM-0103-A] indicates that 90 minutes ahead the complexity within ATC Sector 1 is predicted to become excessive whilst it will remain at an acceptable level within the surrounding sectors. /CM-UC-01→07/

The Complexity Manager performs a closer analysis of the predicted air traffic situation within ATC Sector 1, using the tools and information available (including CDT, Sector Inbound Lists, activation of military zones, constraints) and his own experience and knowledge of the area./CM-UC-08/.

Within Sector 1 a number of departures from the north are planned to enter the sector in evolution. An arrival flow into the TMA is expected from the South East. These flights enter the sector at FL300, expecting to begin descent (to an Exit Flight Level (XFL) of 250) All arrivals into the Terminal airspace have an allocated CTA and are expecting a continuous descent (CDA).

Overflights at various FLs are routeing on an east/west axis. These overflights potentially block the climb/descent profiles of the Terminal Airspace departures and arrivals.

The crossing of the various flows creates the excessive peak in complexity within Sector 1 (a value that exceeds predefined threshold) identified by the CAR tool [CM-0103-A] /CM-UC-03/.

The Complexity Manager determines that given the limited airspace available it is not feasible to reroute the arrival and departure flows and levelling off the descent or climb will penalise the Aircraft Operators and make it difficult for arrivals to respect the agreed CTA. The Complexity Manager uses the CAR tool to identify which of the pre-defined Sector Configurations will allow all the Sectors to achieve a manageable level of complexity) /CM-UC-10→14/.

The CAR tool proposes a new Sector Configuration (one of the pre-defined catalogue on Configurations) that reduces the size of Sector 1 by 'offloading' the merging of the arrival streams to Sector 4. This option is illustrated in Figure 15 below. /CM-UC-15;25;26/.

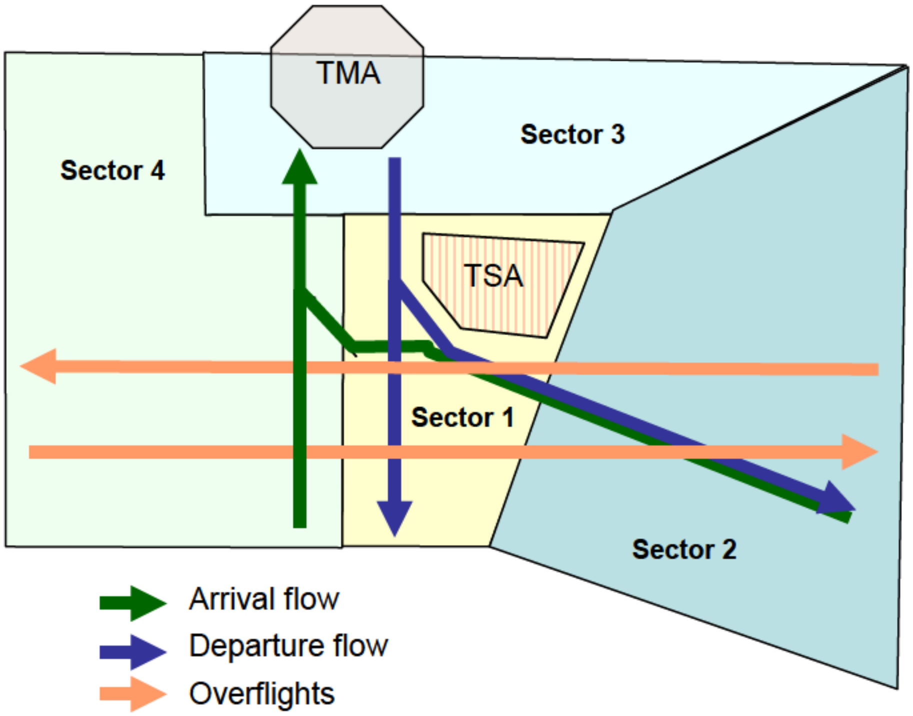

Figure 15: New sector configuration

The Complexity Monitoring Window indicates that the complexity will be reduced to a manageable level within all ATC Sectors and will remain so for an acceptable period of time. /CM-UC-12/.

The Complexity Manager coordinates the proposal with MSP/Planning controllers on Sectors 1 and 4. In the new configuration both sectors 1 and 4 will be of a revised shape and may be given different names or numbers to easily identify their role in the Configuration. For the purposes of this Scenario the identifiers Sector 1 and Sector 4 continue to be used. /CM-UC-16/.

If required the complexity Manager/Local Traffic Manager co-ordinates the ACC's decision with the Network Manager and agrees the time at which the Configuration will change. This is sufficiently far ahead for the sector teams to prepare and the FDPS to adapt to the change and redistribute the flight notification to the correct sectors./CM-UC-16/.

At the appointed time the new Sector Configuration is implemented. Concerned flights are instructed to transfer to the appropriate sector frequency via voice or data link by the Executive Controllers./CM-UC-15;20;21/.

5.1.4.2.2 Sub scenario 2 - level capping and re-direction of traffic flows

This sub-scenario provides an alternative course of action and could be more appropriate for short peaks in traffic or when a change to the Sector Configuration is not possible / suitable.

When alerted by the CAR tool [CM-0103-A] that complexity within ATC Sector 1 is predicted to become excessive 30 minutes ahead, the Complexity manager performs a closer analysis of the predicted air traffic situation. The traffic picture is illustrated in Figure 16 below.

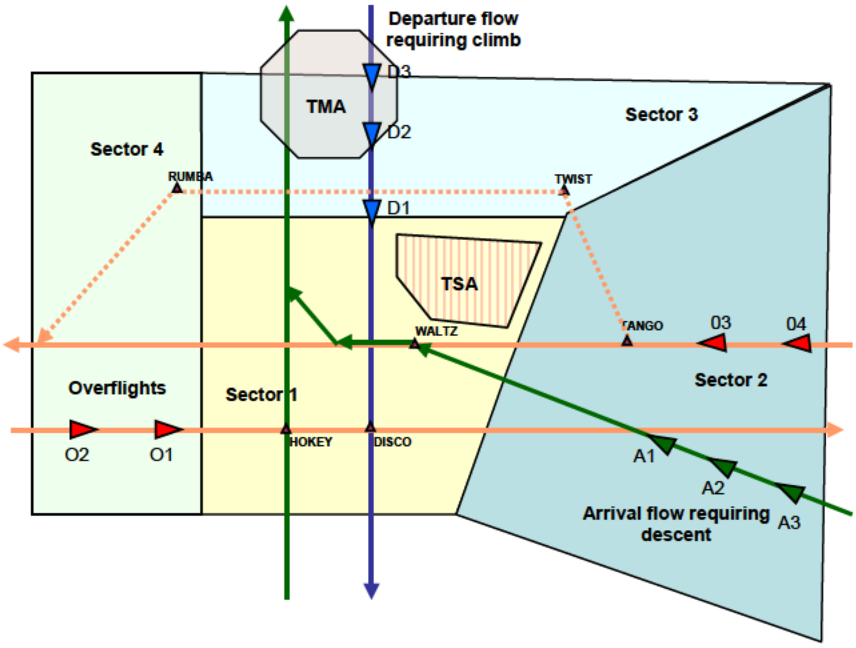

Figure 16: Traffic picture

The CAR tool displays a list of flights contributing to the rise in complexity. The flight list indicates that two separate issues cause the complexity peak. The first involves a number of departures from the north (Flights D1, D2 and D3) planned to enter ATC Sector 1, from below, in the climb. Flight D3 is faster than the two aircraft ahead and will subsequently have to overtake D1 and D2. Under normal circumstances the controller would place D3 on a parallel heading or use a tactical offset to perform an overtaking manoeuvre. /CM-UC-09/.

However, a TSA with vertical limits of FL245+ is active within the predicted high complexity period and this will restrict the airspace available for the vectoring of traffic within ATC Sector 1. Overflight O2 (at FL 270) will conflict over point DISCO with the departures D2 and D3. The workload involved in solving the overtaking flights and the potential conflict at point DISCO increases the complexity in the sector.

The second issue highlighted by the flight list involves the overflights from the East. At point WALTZ the arrival stream from the South East (Flights A1, A2 and A3) will be in the early stages of descent from FL300. The arrivals have a CTA allocated by AMAN and are expecting a continuous descent. The two overflights O3 and O4 at FL 260 and FL 280 will block the descent profiles of the TMA arrivals.

Using the 'what if' function the Complexity manager analyses the impact of re-routeing the westbound overflights (O3 and O4) via an alternative route [CM-0104-A]. This will re-route the flights north of the TSA via points TWIST and RUMBA and into Sector 3/CM-UC 10; 14; 30; 31/.

The CAR tool [CM-0103-A] indicates complexity will be reduced in Sector 1 with no significant increase on the complexity within Sector 3 and Sector 4. This will also allow the arrival stream to descend without restrictions. The Complexity Manager initiates coordination with the MSP/Planning Controller in Sector 2 (to change the trajectory for flights O3 and O4) and then coordinate the solution with the MSP/Planning Controller responsible for Sector 3.

The MSP/Planning Controller in Sector 2 acknowledges the trajectory change and requests the executive controller to relay the revised trajectory via voice communication or data link when operationally suitable [AUO-0303-A]. In some cases this action could be performed by other actors in line with local operational procedures. The flight crew acknowledges the revised trajectory and inputs the detail into the FMS (iRBT revision/update process). The iRBT is also revised (or updated) within ground systems.

When flights O3 and O4 reach point TANGO they turn towards TWIST. /CM-UC-16; 17; 29/

However, the CAR tool [CM-0103-A] indicates that there will still be an excessive traffic complexity situation in Sector 1. Flight O2 is highlighted as the prime contributor to the overload. Using the 'what if' function the Complexity Manager assesses the effect of descending flight O2 to a FL below Sector 1's AoR. This will force the flight into the airspace of the sector below. /CM-UC-10; 21; 24; 25/

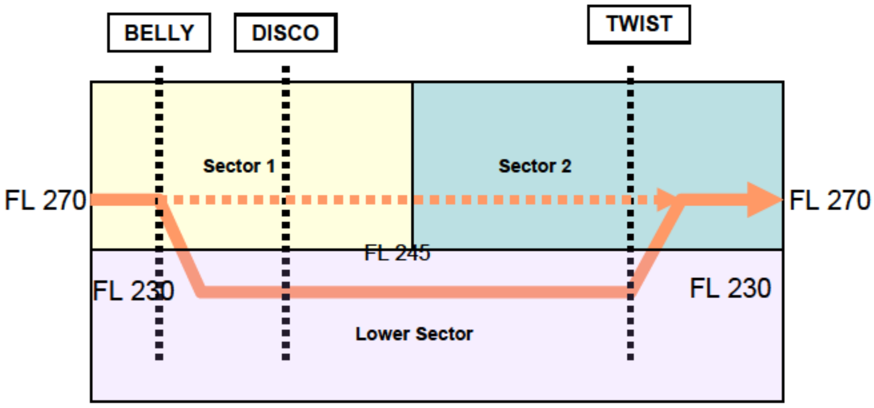

Figure 17: Vertical representation

The 'what if' function indicates that the FL change will solve the potential complexity peak within Sector 1 without a significant increase in complexity in Sector 2 and the Lower sector. /CM-UC-30; 31/

The Complexity Manager coordinates with the Planning Controllers or MSP responsible for Sector 1 and the Lower Sector. After agreeing the course of action the Complexity Manager then informs the MSP/Planner in Sector 2. The MSP or Planner in Sector 1 communicates the trajectory change to the Executive controller who, when traffic conditions permit, issues via voice or data link [AUO-0303-A] the revised trajectory to the pilot and updates the system accordingly. The flight crew of O2 acknowledges the revision and updates the FMS. At point BELLY the aircraft begins descent to FL 230. The Executive Controller in Sector 1 initiates the transfer of frequency to the sector below via voice communication or data link./CM-UC16; 17; 29/.

The Complexity Monitoring window [CM-0103-A] indicates that traffic complexity is reduced to a manageable level within all the ATC sectors within the ACC. Any remaining conflicts are left to the Sector team (Executive and Planning controller or just Executive controller) to resolve. /CM-UC-22/

5.1.4.2.3 CAR Alternative Scenario – coordination of STAM measures

Complexity Management is based on number of predefined scenarios for resolution of complexity problems and workload smoothing within an ATSU.

As described in the basic scenario to implement them four basic techniques are being used

- Dynamic re-sectorisation /CM-UC-21; 26/;
- Change of Traffic flows /CM-UC-19; 28/;
- Dynamic constraint Management /CM-UC-20; 27/;
- Individual iRBT revisions./CM-UC-21; 26/.

These scenarios are designed in coordination with the NM and adjacent ATSUs as a logical extension of the NM scenarios used in the pre-tactical and tactical phase and so that they require minimum or no coordination for their implementation.

However for application of some scenarios coordination will be required. Since this is application of new services in the ATM layered planning, the coordination procedures have yet to be designed. The coordination process is supported by automation. /CM-UC-16; 17/.

These techniques and the resolution scenarios have different time envelops for implementation, so they are implemented a Δ time before the event. /CM-UC-15; 18; 19; 20; 21/.

Due to the various factors affecting the evolution of the traffic, prediction on complexity problems can be affected in which case an already chosen and coordinated resolution may become obsolete. /CM-UC-10; 22; 23/.

This event is indicate by the CAR support tools, and the new resolution has to be implemented corresponding to the relevant complexity prediction. /CM-UC-05; 06; 07/.

Since re-sectorisation resolutions have to be planned well in advance, if the resolution is no longer valid and the Δ time to the event doesn't allow for a resolution of same type, application of a set of constrains is proposed. /CM-UC-27; 30; 31/ For this resolution coordination is required and the ATSU Complexity Manager/Local Traffic Manager coordinates the resolution with the Complexity Managers/Local Traffic Managers of the adjacent ATSU and/or with the Regional Traffic manager. /CM-UC-15; 16; 17/.

In order to facilitate coordination the complexity measurement and resolution impact information is available to all the actors (shared vision).

Positive coordination results in implementation of the chosen resolution, negative coordination initiates a new cycle of the complexity problem resolution. /CM-UC-10; 15; 19; 22/.

This scenario has been developed for the initial version of this OSED. It served as a base and it was further elaborated by the P04.07.02 and P04.07.08 related to the EAP role and the coordination of LTM and ATC at ACC level.

5.1.4.2.4 Sub scenario 3 – Management of individual trajectories

This sub-scenario takes into account the possibility of action *(by an EAP/MSP)* on individual trajectories to solve an imbalance when this imbalance has not been fully solved by the previous sub-scenario actions.

It represents the fine-tuning of the workload by acting on the individual trajectories from 40 to 20 minutes before entering the affected sector. This action would be performed by the Multi-Sector Planner (MSP) or Extended ATC Planner (EAP) that would have information on the latest complexity indicators and a what-if tool that assesses the impact of individual trajectory changes on the workload of the sector affected and the adjacent ones. /CM-UC05; 06; 07; 30; 31/

The measures taken will need to be coordinated with the Local Traffic Manager (LTM), if needed, and the adjacent sectors./CM-UC16; 17/

As an outcome of sub-scenario 2 actions, it has been foreseen that the traffic complexity is going to be reduced to a manageable level in Sector 1. However, due to deviations from the planning, the EAP/MSP of Sector 1 detects an unexpected overload monitoring the workload tool. /CM-UC-01/

In particular, there is an overflight, O5, from the east at FL280 that arrives earlier than expected due to a DCT that it received by an upstream sector from an adjacent ACC (and therefore was not possibly taken into account in the previous analyses by the LTM). Similarly to O3 and O4, O5 is also in conflict with the continuous descent of arrivals A1, A2 and A3.

There is also a new arrival from the south (A4), diverted from a neighboring airport due to weather conditions. A4 adds to the workload as Sector 1 needs to integrate it in the arrival sequence together with the rest of the expected incoming traffic from the south and the southeast.

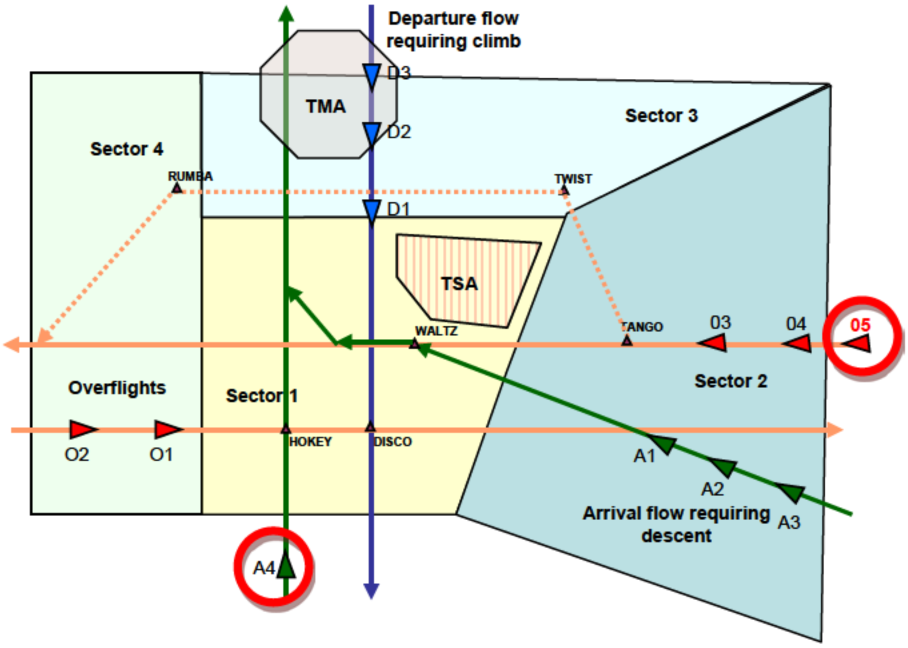

Figure 18: Traffic picture with O5 new overflight

The EAP/MSP checks in the complexity tool the individual contribution to workload of each flight in the Sector 1 during the overload period, identifying the O5 and D3 are the main contributors to the local complexity imbalance. Based on his/her experience, the EAP/MSP identified the following potential measures to solve it:

a) To re-route O5 through TWIST and RUMBA, as it was done with O3 and O4. This seems to be the logical course of action, as it has helped before.

b) To apply MDI between D2 (slow) and D3 (fast) in order to avoid the need to allow D3 to overtake D2 within Sector 1, and let downstream sectors handle the overtake at probably different FL when flights will be already established.

CM-UC 01; 30; 31/

The EAP/MSP uses then the trajectory what-if functionality of complexity tool, in order to assess if workload will be reduced to an acceptable level by applying:

- Measure a) on O5 ➔ the reduction of the workload is not enough, the overload remains;
- Measure b) on D2-D3 ➔ the overload is solved → The executive controller will not need to handle the overtake of D2-D3 although s/he has to give a heading to 05 overflight to allow continuous descent of A1, A2 and A3.
- Both measures ➔ the overload is solved;

As result, EAP/MSP decides to apply measure b) in order to minimise the number of the affected flights. CM-UC 25/

With this action the overload is solved and workload remains acceptable within Sector 1 and the surrounding Sectors.

The solution is coordinated; it is coordinated as described in Sub-scenario 2: CM-UC 16; 17/

The EAP/MSP initiates coordination with the LTM, as there are several sectors affected and TMA/Airport need to be contacted.

The TWR controller acknowledges the MDI requested and relay the revised departure time via voice communication or data link when operationally suitable. The flight crew acknowledges the revised departure time and inputs the details into the FMS. The iRBT is also revised within ground system.

CM-UC 20; 25/

5.1.4.2.5 Sub scenario 4 – Management of individual trajectories in extended AMAN environment.

As in Sub-Scenario 3, this one takes into account the possibility of action (by an EAP/MSP) on individual trajectories to solve an imbalance when this imbalance has not been fully solved by the Sub-Scenario 2 actions. The main difference with Sub-Scenario 3 is that some of the potentially impacted trajectories belong to aircraft in the sequence of an E-AMAN. The most suitable action to solve the imbalance in the En Route sectors could jeopardize the stability of the sequence downstream.

As in Sub-Scenario 3, the action will be performed by the MSP or EAP that will have information on the latest complexity indicators from 40 to 20 minutes before entering the sector/s under his responsibility, and a what-if tool that will assess the impact of individual trajectory changes on the workload of the sector/s under his responsibility[2]. These workload calculations could be impacted by the new tasks delegated to the Executive Controller to facilitate building the arrival sequence in the En Route phase.

As an outcome of Sub-Scenario 2 actions, it has been foreseen that the traffic complexity is going to be reduced to a manageable level in Sector 1. However, due to deviations from the planning, the EAP/MSP of Sector 1 detects an unexpected overload monitoring the workload tool.

In particular, there is an arrival to TMA2 (B1) from the east at FL280 that arrives earlier than expected due to a DCT that it received by an upstream sector from an adjacent ACC (and therefore was not possibly taken into account in the previous analyses by the LTM). Similarly to O3 and O4, B1 is also in conflict with the continuous descent of arrivals A1, A2 and A3 to TMA1. B1 is pre-sequenced by the TMA2 E-AMAN which gives a Time-To-Loose (TTL) to this aircraft.

There is also a new arrival from the south (A4), diverted from a neighbouring airport due to weather conditions. A4 adds to the workload as Sector 1 needs to integrate it in the arrival sequence together with the rest of the expected incoming traffic from the south and the southeast. There is no supporting tool to build the arrival sequence to TMA1.

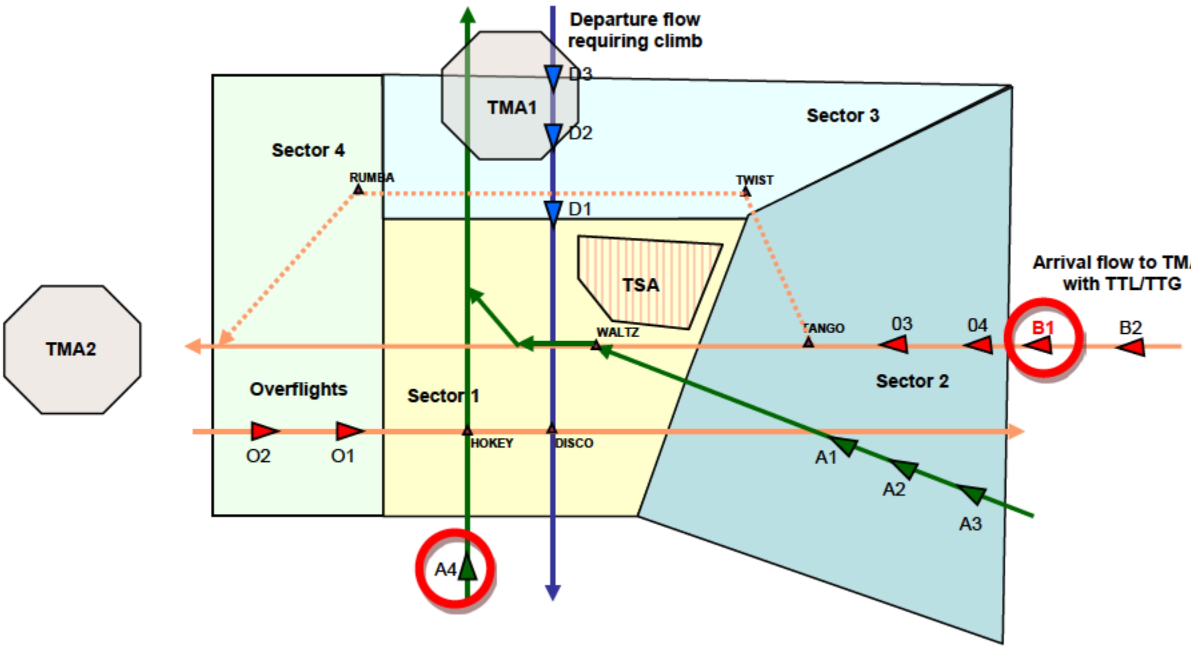

Figure 19: Traffic picture with B1 arrival to TMA2

The EAP/MSP checks in the complexity tool the individual contribution to the workload of each flight in the Sector 1 during the overload period, identifying that B1 and D3 are the main contributors to the

[2] EAP/MSP will only have information related to his own sectors and an alarm will be displayed only if the trajectory changes will overload the adjacent sectors.

local complexity imbalance. Based on his/her experience, the EAP/MSP identifies the following potential measures to solve it:

c) To apply MDI between D2 (slow) and D3 (fast) in order to avoid the need to allow D3 to overtake D2 within Sector 1, and let downstream sectors handle the overtake at probably different FL when flights will be already established.

d) To re-route B1 through TWIST and RUMBA, as it was done with O3 and O4 in the previous operational scenario. However this is an arrival to TMA2 with a target TTL[3] to be managed by the executive controller in Sector 1.

The EAP/MSP uses then the trajectory what-if functionality of the complexity tool in order to assess if workload will be reduced to an acceptable level by applying:

- Measure a) on D2-D3 ➔ Although the executive controller will not need to handle the overtake of D2-D3, the reduction of the workload is not enough and the overload remains;
- Measure b) on B1 ➔ the overload is solved and no overload is registered in the adjacent sectors ➔ The executive controller will not need to handle B1 instructions such as speed reduction to lose the time proposed by the TMA2 AMAN;
- Both measures ➔ the overload is solved.

As result, EAP/MSP decides to apply measure b). With this action the overload is solved and workload remains acceptable within Sector 1 and the surrounding Sectors.

The E-AMAN receives the new B1 arrival time. TMA2 Sequence Manager[4] refines the sequence with this new arrival time. The consolidated sequence results in a TTG for B1 in Sector 3, which is acknowledged by the Sector 3 Executive Controller prior to the B1 entry into the sector.

The solution is coordinated as described in Sub-scenario 2: The EAP/MSP initiates coordination with the LTM, if there are sectors affected outside his/her area of responsibility, and the TMA2 Sequence Manager need to be contacted.

5.1.5 Use cases

CM-UC-01 Evaluate (Update) Traffic Complexity.

Goal: According to data received from adjacent systems (FDPS, IOP, Conflict Detection tools, Sequencing Tools), evaluate (or update) the complexity of the current and future traffic situations. That evaluation is made according to the current Complexity Management configuration (e.g. CAR Area of responsibility) and based for the future complexity evaluation on forecasts from the Traffic Manager/Complexity Manager actor.

CM-UC-02 Compare Traffic Complexity with Thresholds.

Goal: When the Complexity is evaluated, it is compared to thresholds in order to detect if the Situation is acceptable or not: Non-critical Situation versus Critical Situation.

CM-UC-03 Identify (Update) a Non-critical Complexity Situation.

Goal: When the evaluated Complexity is detected as being outside the thresholds, the related Complexity situation is marked as Non-critical (acceptable situation). The resulting actions (displays) shall be performed.

CM-UC-04 Identify (Update) a Critical Complexity Situation.

Goal: When the evaluated Complexity is detected as inside the thresholds, the related Complexity situation is marked as Critical (Non-acceptable situation). The resulting actions shall be performed.

CM-UC-05 Display Monitored Complexity.

[3] The total B1 Time-To-Loose (TTL) could be divided among the sectors that B1 goes through. This depends on the delay sharing strategy which is applied at the local level by the E-AMAN of TMA2.
[4] Sequence Manager cannot reject the changes in the trajectory.

Goal: When the Complexity is evaluated and classified as Non-critical (with an associated value corresponding to its levels of severity), it is provided for display.

At that point, the Complexity Manager can request details on the displayed Complexity, mark a Situation as Critical if not performed by the system, request De-complexing Solutions (manual request for Solutions calculation) or change some of the CAR Settings and Configuration. From that display, the Complexity Manager can decide that the evaluated complexity is in fact at a Critical level even if it has not been detected by the system. Then the Complexity Manager marks the situation as Critical.

CM-UC-06 Display Complexity Problem.

Goal: When the Complexity is evaluated and classified as Critical (with an associated value corresponding to its levels of gravity), this Complexity is provided for display.

At that point, the Complexity Manager can request details on the displayed Complexity, request Solutions calculation or change some of the CAR Settings and Configuration.

CM-UC-07 Alert a Critical Complexity Problem.

Goal: When a Complexity Problem has been detected (or updated), then depending on the severity, the CAR system alerts the Complexity Manager about it.

At that point, the Complexity Manager can request details about the warned Complexity Problem or change some of the CAR Settings and Configuration.

CM-UC-08 Mark a Situation as Critical or not.

Goal: When a Complexity situation is provided for display, the Complexity Manager can decide whether the CAR system should treat it as a Complexity Problem or not.

CM-UC-09 Display Complexity Details on Request.

Goal: When requested by the Complexity Manager, details on a selected Complexity situation are displayed.

That display is updated according to any change occurring in the associated situation.

At that point, the Complexity Manager can change some of the CAR Settings and Configuration, request or mark a Situation as Critical (or not) if that has not been performed by the system.

CM-UC-10 Initiate De-complexing Solutions Circulation.

Goal: The CAR system initiates calculation of Solutions by taking into account the data provided by FDPS, IOP (i.e. the NOP with the iRBTs, Airspace Configuration, Weather information, available resources and so on) and by respecting Sequencing constraints and the CAR configuration and settings.

That calculation is initiated when a new Complexity Problem has to be solved, when updates occur in the information related to Complexity problems for which Solutions have been already calculated or when there is a change in the CAR Configuration and settings which has an impact on the calculation process.

CM-UC-11 Select De-complexing Sector Configurations within the Catalogue (predefined sectorisations).

Goal: When the CAR system has triggered the De-complexing Solutions calculation from a Complexity Problem (or situation), potential solutions patterns will be selected based on complexity calculations using alternative sectorisation configurations in order to solve the problem.

CM-UC-12 Display De-complexing Solutions.

Goal: When the set of De-complexing solutions are prepared, the CAR system displays the Solutions on request by the Complexity Manager and according to the type of requested Solutions.

At that point, the Complexity Manager can select a De-complexing Solution for implementation or edition, or change some of the CAR Settings and Configuration.

CM-UC-13 Display De-complexing Solutions Details on Request.

Goal: When requested by the Complexity Manager, details on a selected De-complexing Solution are displayed. That display is updated according to any change affecting the displayed De-complexing Solution.

At that point, the Complexity Manager can select the related De-complexing Solution for implementation or edition, or change some of the CAR Settings and Configuration.

CM-UC-14 Select a Solution for Edition.

Goal: When the De-complexing Solutions are displayed, the CAR system allows the Complexity Manager to select a provided solution for editing. The CAR system detects that selection and triggers the edition process.

CM-UC-15 Select a Solution for Implementation.

Goal: When the De-complexing Solutions are displayed, the CAR system allows the Complexity Manager to select a solution for implementation. The CAR system detects that selection and triggers the implementation process.

CM-UC-16 Manage Co-ordination Requests.

Goal: When Co-ordinations are needed, the CAR system manages the required Co-ordinations through the Systems Co-ordinator. In SESAR Step 1 System coordination is mainly based on procedures with limited automated support. At the end of that process, the implemented Solution (according to its type) shall become the new contract for Complexity Management by all of the involved actors (update of the NOP with the implemented De-complexing solution).

CM-UC-17 Manage a Co-ordination Receipt.

Goal: When a Co-ordination process is required for agreement of a De-complexing Solution implementation, the CAR system manages the required Reception of a Co-ordination Request. The Co-ordination is displayed in the CAR system receiving the Co-ordination Request, in order to allow the involved actors to answer to the Request.

CM-UC-18 Update the iRBTs.

Goal: Once an iRBT De-complexing Solution has been chosen for implementation and the required Co-ordinations are achieved, the CAR system updates all of the relevant Systems with the iRBT(s) contained in the implemented Solution.

CM-UC-19 Update the Flows

Goal: Once a Flow De-complexing Solution has been chosen for implementation and the required Co-ordinations are achieved, the CAR system updates all of of the relevant Systems with the modified Flow(s) of traffic contained in the implemented Solution.

CM-UC-20 Update the Constraints.

Goal: Once a Constraints De-complexing Solution has been chosen for implementation and the required Co-ordinations are achieved, the CAR system updates all of the relevant Systems with the modified Constraint(s) contained in the implemented Solution.

CM-UC-21 Update the Sectorisation.

Goal: Once a Sectorisation De-complexing Solution has been chosen for implementation and the required Co-ordinations are achieved, the CAR system updates all of the relevant Systems with the modified Sectorisation contained in the implemented Solution.

CM-UC-22 Monitor De-complexing Solution Implementation.

Goal: When a De-complexing Solution is implemented, the CAR system ensures the correct implementation in terms of actions to be performed by the actors involved to execute the Solution. In SESAR Step 1 the monitoring process is mainly performed by the human and is supported by adequate procedures. The CAR system also maintains the Solution implemented in order to adapt it to the evolution of the situation. In the worst case, it is possible to go back to the original Situation.

CM-UC-23 Adjust Implemented De-complexing Solution.

Goal: When an implemented De-complexing Solution is required to be adjusted (automatically or manually maintained by the involved actors), the CAR system calculates the necessary adjustments to cope with the evolution of the Complexity Situation. In SESAR Step 1 the adjustment process is mainly performed by the human and supported by adequate procedures.

CM-UC-24 Modify an Existing De-complexing Solution.

Goal: The Complexity Manager can edit the base of an existing De-complexing Solution displayed by CAR to solve a specific Situation. Alternatively the base of a generic De-complexing solution (a pattern) may be used. The Complexity Manager will adapt it to his (her) own purpose.

CM-UC-25 Create a New De-complexing Solution.

Goal: The Complexity Manager can start the edition of a new De-complexing Solution on the base of De-complexing Solution pattern. The Complexity Manager will create it to fit his (her) own purpose.

CM-UC-26 Edit a Sectorisation Solution.

Goal: When manual edits are needed for a Sectorisation Solution, the related Editor is provided to the Complexity Manager. The Editor opens with the Complexity Situation/Problem to be solved, as the initial context, along with the related Sectorisation De-complexing Solution to be edited.

Then, the Complexity Manager can perform any desired editing action to build his (her) own Sectorisation based on the available sector configurations.

Naturally, during editing, any update of the Situation/Problem that the Sectorisation Solution is intended to solve will trigger an update of the editing tool and related relevant elements in order to be sure that the editing is based on the most up-to-date information.

CM-UC-27 Edit a Constraint Solution.

Goal: When manual Edits are needed for a Constraint Solution, the related Editor is provided to the Complexity Manager. The Editor opens with the Complexity Situation/Problem to be solved, as the initial context, along with the related Constraint De-complexing Solution or Pattern to be edited.

Then, the Complexity Manager can perform any desired editing action to build his (her) own Constraint De-complexing Solution.

Naturally, during editing, any update of the Situation/Problem that the Constraint Solution is intended to solve will trigger an update of the editing tool and related relevant elements in order to be sure that the editing is based on the most up-to-date information.

CM-UC-28 Edit a Flow Solution.

Goal: When manual Edits are needed for a Flow Solution, the related Editor is provided to the Complexity Manager. The Editor opens with the Complex Situation/Problem to be solved, as the initial context, along with the related Flow De-complexing Solution or Pattern to be edited.

Then, the Complexity Manager can perform any desired editing action to build his (her) own Flow De-complexing Solution.

Naturally, during editing, any update of the Situation/Problem that the Flow Solution is intended to solve will trigger an update of the edition tool and related relevant elements in order to be sure that the editing is based on the most up-to-date information.

CM-UC-29 Edit an iRBT Solution.

Goal: When manual Edits are needed for an iRBT Solution, the related Editor is provided to the Complexity Manager. The Editor opens with the Complex Situation/Problem to be solved, as the initial context, along with the related iRBT De-complexing Solution or Pattern to be edited.

Then, the Complexity Manager can perform any desired editing action to build his (her) own iRBT De-complexing Solution.

Naturally, during editing, any update of the Situation/Problem that the iRBT Solution is intended to solve will trigger an update of the edition tool and related relevant elements in order to be sure that the editing is based on the most up-to-date information. That Editing is silent and automatic (background process) for the CAR De-complexing Solutions calculation process.

CM-UC-30 Calculate impact of a Solution on Complexity (What-if).

Goal: Each time an editing action (or a group of actions) is performed, CAR calculates the impact of that edited Solution in terms of Complexity and Co-ordination needs.

Naturally, during evaluation of the impact of a Solution, any update of the Situation/Problem that the De-complexing Solution intended to solve will trigger an update of the impact evaluation in order to be sure that the evaluation (and consequently CAR or Complexity Managers decision) is based on the most up-to-date information.

CM-UC-31 Display Complexity Impact of an Edited Solution (What –if).

Goal: When the impact on Complexity has been (re)evaluated for a manually edited De-complexing Solution, that impact shall be provided for display. Then the Complexity Manager can take his (her), own decision (implement, archive or continue with the manual edition process).

5.2 Operational Scenario 2 – Non-severe capacity shortfalls resolved by STAM Measures with support of local tools

5.2.1 Scenario Summary

This operational scenario describes the detection of four local imbalances of En Route sectors, and the resolution of them by using STAM measures, supported by local tools.

One of them will be discarded thanks to the use of a local complexity tool that predicts complexity will remain at a reasonable level within the sector.

The second one will be solved by level capping a specific flow, departing from a busy airport, so that flights don't enter a saturated upper sector. The third imbalance will happen in the lower sector, implying cherry picking several flights for re-routing (vs. speed regulation protection). The fourth imbalance will be resolved by using the preferred capacity measures.

Dynamic DCB solutions are considered and enriched by the use of the local tools for complexity assessment.

5.2.2 Additional Information and Assumptions

5.2.2.1 Additional Information

The scenario considers one international airport called SUNSPOT, major holiday destination in the Mediterranean, with an important flow connection to central Europe. En Route sectors in the vicinity of the airport are affected by both a significant flow of traffic climbing and descending and high amount of overflights.

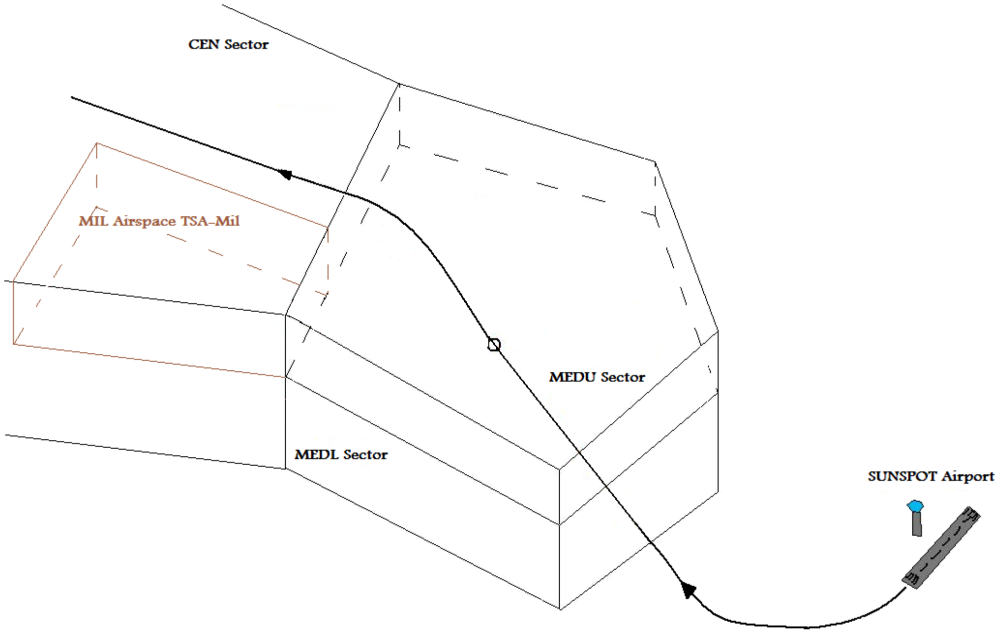

Figure 20: Sectors Configuration

The following sectors are affected by imbalances: Sectors MEDU (Mediterranean Upper), MEDL (Mediterranean Lower), and CEN (Central).

First imbalance (early morning):

- Impacting CEN (Central sector);
- Potential capacity shortfall detected in Entry Rate/Occupancy Count which is discarded thanks to local tools that shows an acceptable level of complexity;
- Monitor that the prediction of NM and local tools were correct.

Second imbalance (mid-morning):

- Impacting Sector MEDU;
- Potential capacity shortfall detected in Entry Rate/Occupancy Count and confirmed by local tools;
- Bunch of departures from SUNSPOT, coming back to central Europe;
- Application of dynamic DCB measures to MEDU, flow level-capping;
- Monitor the effectiveness of the applied DCB measures.

Third imbalance (mid-morning):

- Impacting Sector MEDL;
- Entry Rate/occupancy close to maximum and overload (high complexity) detected by local tools;
- Application of dynamic DCB measures to MEDL, cherry pick re-routing through CEN sector;
- Local tools used to compare potential dynamic DCB solutions;
- Monitor the effectiveness of the applied DCB measures.

Fourth imbalance (afternoon):

- Impacting Sector CEN;
- Entry Rate/occupancy above maximum and overload (high complexity) confirmed by local tools;

- Application of capacity measures at CEN, negotiation with military without success, sector re-configuration is the applied solution;
- Local tools used to compare different sector configurations;
- Monitor the effectiveness of the applied DCB measures.

5.2.2.2 Assumptions

- Connection between actors and network “Information Support System”, all actors connected;
- Indicators for density (i.e. Entry Rate, Occupancy Count) and complexity (i.e. workload) predictions are available within local tools;
- Trajectories are handled on a most appropriate basis: most positive network effect achieved with impact on minimum number of trajectories in least adverse way.

5.2.3 List of Actors

NMOC:

The NMOC actor:

- Provides a framework to allow ACC (LTM) and AU to share information (Network View) and to coordinate (CDM);
- In case of necessary escalation of issues, investigates on alternatives and implements them accordingly;
- Assesses the network impact with other STAM when necessary;
- Implements “classical” regulation when necessary.

ACC (LTM):

The LTM:

- Monitors the demand and capacity within local En Route areas and airfield performance, to ensure awareness of any developing DCB imbalance;
- Receives status information from airfields within their area of responsibility;
- Uses local tools to improve the quality of the workload assessment;
- Identifies periods of excessive workload within the local network and in consequence agrees, coordinates (with LTM and AU) and carries out appropriate mitigation measures as required (STAM dDCB);
- Updates relevant information support systems (Network View) when necessary.

SUNSPOT Airport:

- ATS tower supervisor is aware of the dynamic DCB measure applied;
- ATC Ground controller, informs traffics affected by STAM Level-capping measure when necessary;
- APOC Staff assess impact on fuel consumptions and delays that the measure may have on flights affected.

Destination Airports in Central Europe:

- ATS tower supervisor and APOC staff are informed by the NM system of the flights affected by the applied STAM measures and the estimated delay caused by the measure.

Airspace Users:

The Airspace Users (FOC Staff, Flight Crews) are:

- Involved in the coordination and the implementation of the Dynamic DCB solutions through trajectory revisions.

Military

- Involved in the coordination and the implementation of the Dynamic DCB solutions based on capacity management.

5.2.4 Layered Planning

A general principle of the layered planning process is that all planning benefits from feedback on current events and operations. These are made available through the NOP. The events which take place during each of the planning phases are described in detail in the scenario text as appropriate.

There are three phases: the strategic phase, the pre-tactical phase and the tactical phase.

The scenario takes place at the end of the pre-tactical phase and during the tactical phase, depending on the status of the flight.

5.2.5 Scenario Text

Scenario Part 1: LTM detects an overload of Sector Central (CEN) / CM-UC-04; 05; 06; 07

ACC, 05:00

At 05:00 LTM detects an overload of Central Sector at **09:00-10:00** by detecting that the Entry Rate and Occupancy Counts will be above the prescribed levels for that sector.

LTM then launches the local tools to evaluate complexity on the affected sector. The complexity tool reveals that even if the traffic counts are high, the complexity is not such because the overload is caused mostly by overflights that have compatible flight levels and very few of the traffics are in evolution (climbing or descending). Then, the expected workload is maintained within tolerable thresholds.

LTM therefore decides not to publish the hotspot.

ACC, 05:00-10-00.

LTM continuously monitors the evolution of the CEN sector with the Entry Rate/Occupancy Counts and complexity metrics, in order to confirm the adequacy of the no-measure approach taken.

Scenario Part 2: LTM detects an overload of MEDU Sector CM-UC-04; 05; 06; 07

ACC, 08:30 – Hotspot Detection

LTM detects an imbalance at MEDU Sector. **Entry Rate/Occupancy counts are above acceptable levels at MEDU Sector 11:00-13:00**.

LTM then launches the local tools to evaluate complexity on this sector. The complexity tool confirms that workload is also above tolerable levels at MEDU Sector 11:00-13:00.

Then LTM confirms the **hotspot in MEDU Sector from 11:00 to 13:00** and notifies it to the NOP. A STAM Notification will be sent (hotspot status = proposed).

ACC, 09:00 – Analysis and Preparation

Before evaluating demand measures, LTM tries to adjust the sector configuration to solve the detected demand capacity imbalance. However, no solution is feasible.

Then, LTM analyses the most appropriate STAM measures based on s/her experience and supported by what-if tool (local and NM tools), if available. / **CM-UC-31**

Finally, LTM selects STAM level capping for the flow departing from SUNSPOT airport with destinations in Central Europe. In this way, the proposed STAM solution allows to maintain this traffic into the less loaded MEDL sector, maintaining Entry Rate/Occupancy count and workload within acceptable levels in both MEDU and MEDL sectors. / **CM-UC-19**

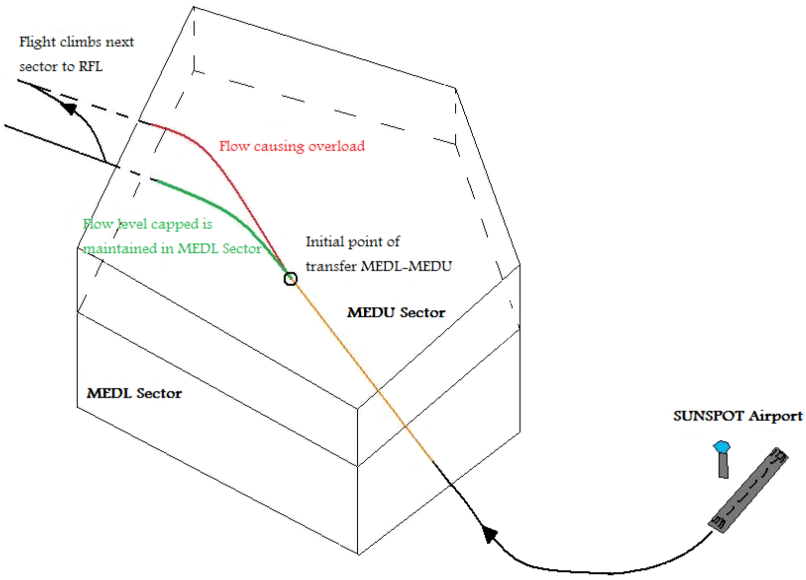

Figure 21: Flow Level Capping MEDL-MEDU Sectors

<u>ACC, 09:45 – Coordination</u> **CM-UC-16; 17**

LTM sends a 'STAM Coordination' message (STAM status = 'proposed'):

- <u>Option 1</u>: LTM checks the Entry Rate/Occupancy Counts in the NM What-if functionality to ensure that the hotspot is solved without affecting the rest of the network;
- <u>Option 2</u>: NM checks the proposed STAM solution to ensure that the hotspot is solved without affecting the rest of the network;
- <u>Option 3</u>: All LTMs affected by the STAM solution check its impact on their area of responsibility to ensure that it is not creating any new imbalance.

As STAM solution is a flow measure, the AUs are not included in the coordination process, they are only notified about the measure taken.

<u>ACC, 10:15 – Implementation and Supervision</u>

When coordination with the affected LTMs is finished, the STAM measure is implemented by the LTM who updates the information support system (Network View) as appropriate.

LTM monitors that the measure taken has properly solved the imbalance detected.

Scenario Part 3: LTM detects an overload of MEDL CM-UC-04; 05; 06; 07

<u>ACC, 10:30 – Detection of new hotspot</u>

During the monitoring of the evolution of hotspot in MEDU, LTM uses NM system and local tools to assess the ER/OC and complexity in his/her area of responsibility, in particular MEDU and MEDL sectors.

The local complexity tool shows that even if ER/OC is close to max levels but not above them for the lower MEDL sector, the implemented STAM measure generates extra conflicts at VOR M at the last part of the hotspot in MEDU (i.e. **12:30 – 13:15**), **increasing significantly the workload of the MEDL sector**.

Although the ER/OCs are under max levels but close to them, MEDL sector has now an imbalance to be resolved. Then LTM confirms the **hotspot in MEDL Sector from 12:30 to 13:15** and notifies it to the NOP. A STAM Notification will be sent (hotspot status = proposed).

<u>ACC, 10:50 – Analysis and Preparation</u> **CM-UC-09**

Before evaluating demand measures, LTM tries to adjust the sector configuration to solve the detected complexity imbalance. However, no solution is feasible.

LTM considers two possible STAM solutions based on his/her expertise:

- Speed regulation protection applied to overflights;
- Cherry-picking of overflights coming from SINTO for rerouting.

LTM uses the what-if functionality of the local complexity tool in order to compare possible dynamic DCB solutions to the hotspot. Speed regulation protection applied to the overflights reduces slightly the ER/OC, however workload remains still high in the sector. **CM-UC-31**

The second option reduces both ER/OC and workload indicators. Therefore, rerouting of cherry-picked overflights to CEN sector, less loaded, is the selected solution. **CM-UC-18**

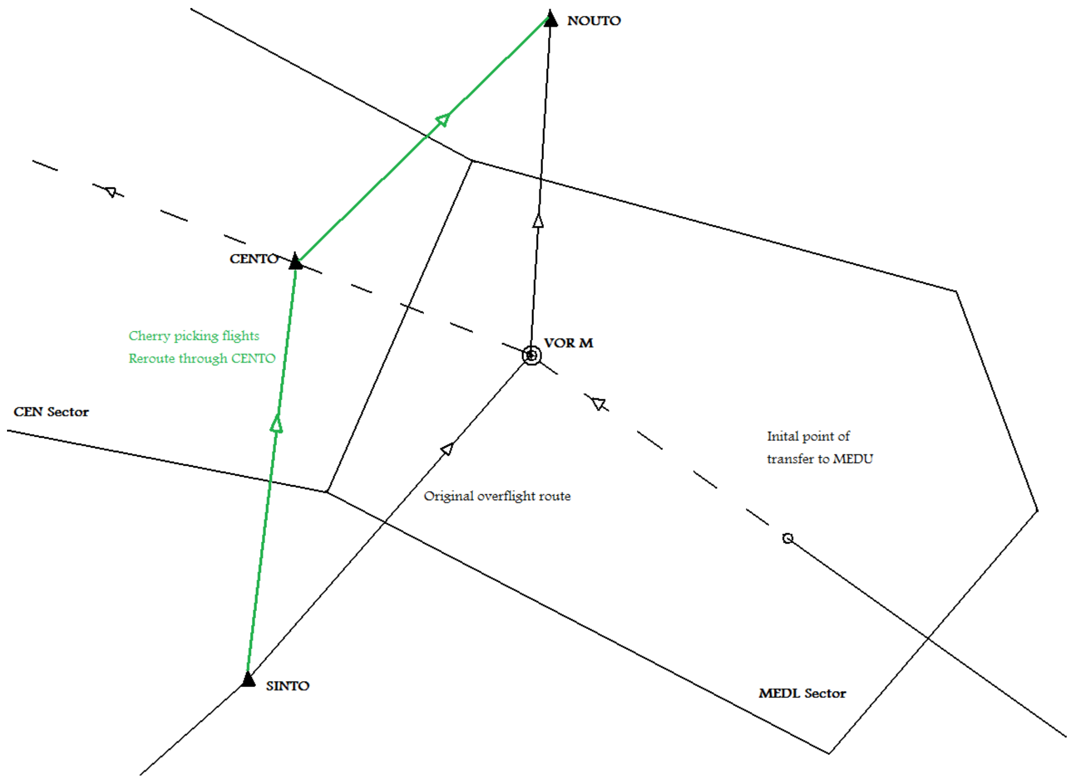

Figure 22: Cherry picking of flights to Re-route through less busy CEN Sector

ACC, 11:20 – Coordination / **CM-UC-16; 17**

LTM sends a 'STAM Coordination' message (STAM status = 'proposed'):

- Option 1: LTM checks the Entry Rate/Occupancy Counts in the NM What-if functionality to ensure that the hotspot is solved without affecting the rest of the network;
- Option 2: NM checks the proposed STAM solution to ensure that the hotspot is solved without affecting the rest of the network;
- Option 3: All LTMs affected by the STAM solution check its impact on their area of responsibility to ensure that it is not creating any new imbalance.

As STAM solution is a cherry-picking measure, the concerned AUs are included in the coordination process and can reject the proposal.

ACC, 11:50 – Implementation and Supervision

When coordination with the affected LTMs and AUs is finished, the STAM measure is implemented by the LTM who updates the information support system (Network View) as appropriate..

LTM monitors that the measure taken has properly solved the imbalance detected.

Scenario Part 4: LTM detects an overload of CEN Sector

ACC, 13:30 – Hotspot Detection **/ CM-UC-04; 05; 06; 07**

LTM detects an imbalance at CEN Sector: **Entry Rate/Occupancy counts are above acceptable levels at CEN Sector 17:00-18:00**. The military area TSA-Mil will be active at that time, increasing the complexity of the sector.

LTM then launches the local tools to evaluate complexity on this sector. The complexity tool confirms that workload is also above tolerable levels at CEN Sector 17:00-18:00/ **CM-UC-09**.

Then LTM confirms the **hotspot in MEDU Sector from 17:00 to 18:00** and notifies it to the NOP. A STAM Notification will be sent (hotspot status = proposed).

ACC, 14:00 – Analysis and Preparation **CM-UC-13; 14; 15**

Then, LTM analyses the most appropriate STAM measures based on s/her experience and supported by what-if tool (local and NM tools), if available. Before evaluating demand measures, LTM tries to adjust the available capacity. In order to have the minimum possible impact on the traffic, two options are identified as capacity management measures:

- Negotiate the delay of the military activity in TSA-Mil to the following hour.
- Modify sector configuration to divide the CEN sector in CENU and CENL from 17:00 to 18:00.

The military partners would have significant trouble to delay the operations due to the lower visibility expected for the later hours. Then, the sector configuration will have to be modified to solve the detected hotspot.

LTM uses local tools to analyse the impact of this sector configuration change. LTM finally finds an acceptable solution with the available resources where other sectors may be combined to allow the opening of CENU and CENL/**CM-UC-31**

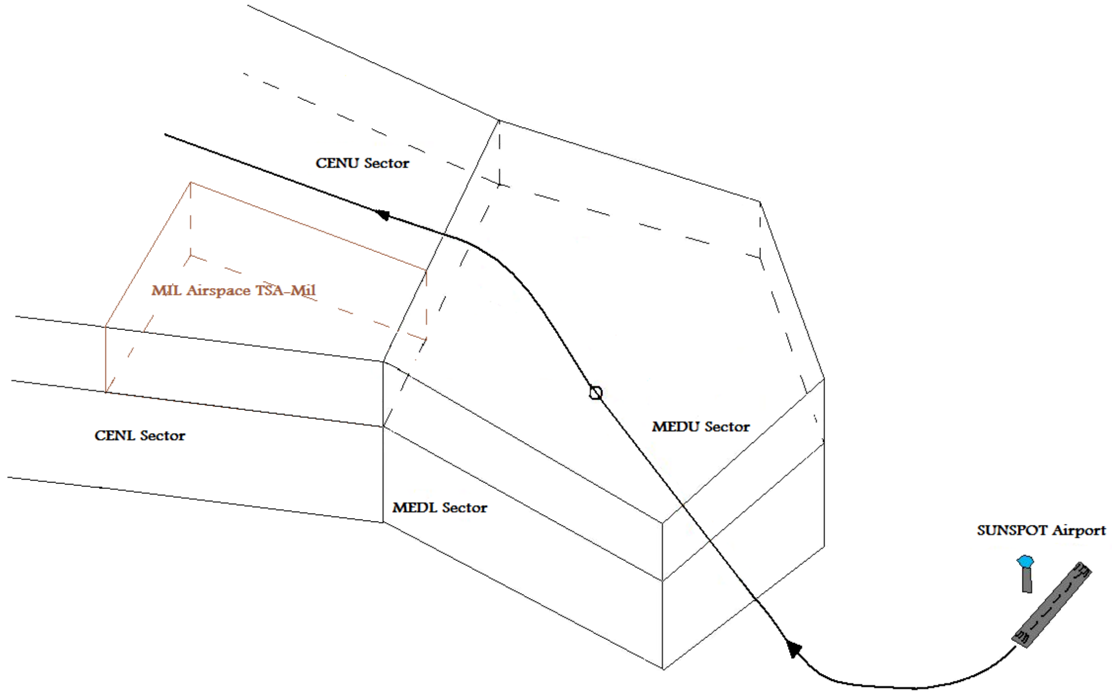

Figure 23: Sector configuration with CEN Sector divided in CENL and CENU

ACC, 15:00 – Hotspot Cancellation

As STAM solution is a sector configuration change, there is no need to coordinate it with any affected LTMs and Airspace Users. The actual implementation of the sector configuration is done in line with local procedures and it is always subject OPS supervisor's concern.

A STAM notification will be sent (hotspot status = cancelled). LTM updates the information support system (Network View) as appropriate.

ACC, 17:00 – Supervision

The new sector configuration is implemented in the operational room. LTM monitors that the measure taken has properly solved the imbalance detected.

5.2.6 Use Cases

CM-UC-04 Identify (Update) a Critical Complexity Situation.

Goal: When the evaluated Complexity is detected as inside the thresholds, the related Complexity situation is marked as Critical (Non-acceptable situation). The resulting actions shall be performed.

CM-UC-05 Display Monitored Complexity.

Goal: When the Complexity is evaluated and classified as Non-critical (with an associated value corresponding to its levels of severity), it is provided for display.

At that point, the Complexity Manager can request details on the displayed Complexity, mark a Situation as Critical if not performed by the system, request De-complexing Solutions (manual request for Solutions calculation) or change some of the CAR Settings and Configuration. From that display, the Complexity Manager can decide that the evaluated complexity is in fact at a Critical level even if it has not been detected by the system. Then the Complexity Manager marks the situation as Critical.

CM-UC-06 Display Complexity Problem.

Goal: When the Complexity is evaluated and classified as Critical (with an associated value corresponding to its levels of gravity), this Complexity is provided for display.

At that point, the Complexity Manager can request details on the displayed Complexity, request Solutions calculation or change some of the CAR Settings and Configuration.

CM-UC-07 Alert a Critical Complexity Problem.

Goal: When a Complexity Problem has been detected (or updated), then depending on the severity, the CAR system alerts the Complexity Manager about it.

At that point, the Complexity Manager can request details about the warned Complexity Problem or change some of the CAR Settings and Configuration..

CM-UC-09 Display Complexity Details on Request.

Goal: When requested by the Complexity Manager, details on a selected Complexity situation are displayed.

That display is updated according to any change occurring in the associated situation.

At that point, the Complexity Manager can change some of the CAR Settings and Configuration, request or mark a Situation as Critical (or not) if that has not been performed by the system.

CM-UC-13 Display De-complexing Solutions Details on Request.

Goal: When requested by the Complexity Manager, details on a selected De-complexing Solution are displayed. That display is updated according to any change affecting the displayed De-complexing Solution.

At that point, the Complexity Manager can select the related De-complexing Solution for implementation or edition, or change some of the CAR Settings and Configuration.

CM-UC-14 Select a Solution for Edition.

Goal: When the De-complexing Solutions are displayed, the CAR system allows the Complexity Manager to select a provided solution for editing. The CAR system detects that selection and triggers the edition process.

CM-UC-15 Select a Solution for Implementation.

Goal: When the De-complexing Solutions are displayed, the CAR system allows the Complexity Manager to select a solution for implementation. The CAR system detects that selection and triggers the implementation process.

CM-UC-16 Manage Co-ordination Requests.

Goal: When Co-ordinations are needed, the CAR system manages the required Co-ordinations through the Systems Co-ordinator. In SESAR Step 1 System coordination is mainly based on procedures with limited automated support. At the end of that process, the implemented Solution (according to its type) shall become the new contract for Complexity Management by all of the involved actors (update of the NOP with the implemented De-complexing solution).

CM-UC-17 Manage a Co-ordination Receipt.

Goal: When a Co-ordination process is required for agreement of a De-complexing Solution implementation, the CAR system manages the required Reception of a Co-ordination Request. The Co-ordination is displayed in the CAR system receiving the Co-ordination Request, in order to allow the involved actors to answer to the Request.

CM-UC-18 Update the iRBTs.

Goal: Once an iRBT De-complexing Solution has been chosen for implementation and the required Co-ordinations are achieved, the CAR system updates all of the relevant Systems with the iRBT(s) contained in the implemented Solution.

CM-UC-19 Update the Flows

Goal: Once a Flow De-complexing Solution has been chosen for implementation and the required Co-ordinations are achieved, the CAR system updates all of the relevant Systems with the modified Flow(s) of traffic contained in the implemented Solution.

CM-UC-31 Display Complexity Impact of an Edited Solution (What –if).

Goal: When the impact on Complexity has been (re)evaluated for a manually edited De-complexing Solution, that impact shall be provided for display. Then the Complexity Manager can take his, (her), own decision (implement, archive or continue with the manual edition process).

6 Requirements

6.1 Operational Requirements related to R1 and R4 exercises

This section includes the traceability of operational requirements with the final versions of 04.02 and 07.02 Step1 DODs ([13] and [14]). In addition, the coverage of the Requirements by the EXE-04.07.01-VP-001, EXE-04.07.01-VP-002, EXE-04.07.01-VP-005 and EXE-05.03-VP-804 which have addressed the SESAR Solution #19 has been detailed.

6.1.1 Group 0001: Complexity features

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0001
Requirement	LTM/EAP shall be able to select the sector configuration from a list of possible ones.
Title	Input: pre-defined sectorisations
Status	<Validated>
Rationale	Decision making process is based on pre-defined sector configurations. CAR tool shall contain the list of possible sector configurations.
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0002
Requirement	LTM/EAP shall be able to check the prediction of Complexity Indicators per sector and per time interval for a given sector configuration.
Title	To predict future complexity indicators
Status	<Validated>
Rationale	CAR tool shall predict and display Complexity Indicators per sector and per time interval for a given sector configuration.
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-SAF1.0045	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-CAP1.0024	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-EAPP.1030	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-EAPP.1020	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-EAPP.1000	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0003
Requirement	LTM/EAP shall be able to check the prediction of Complexity Indicators for both current sector configuration and what-if environment (WIF).
Title	To assess and to predict complexity indicators in “current” and “what-if”

	environment.
Status	<Validated>
Rationale	CAR tool shall be able to assess and predict the Complexity Indicators for : • Current flight plans and sector configuration and, • "What-if" environment (WIF). What-if environment can contain a limited number of alternate scheduled predefined sector configurations and/or manually-created new trajectories
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-CEF1.0011	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Process>	OFA05.03.03	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0004
Requirement	LTM/EAP shall be able to smooth the Complexity Indicators using configurable parameters.
Title	Configurability of the Complexity Indicators figures
Status	<Deleted>
Rationale	CAR tool should allow smoothing of the complexity indicators using configurable parameters (e.g. time interval, number of calculation points within the interval or linear vs. weighted smoothing). According to the operational feedback obtained in the execution of the validation activities, this requirement is unnecessary.
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0006	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Process>	Balance Demand with Resources and Capabilities	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0005
Requirement	LTM/EAP shall be able to smooth metrics using a configurable time window.
Title	Configurability of the Complexity Indicators figures
Status	<Validated>
Rationale	CAR tool should allow smoothing of metrics (e.g. the number of aircraft within the sector, the incoming flows, the number of flights that are climb or descent and the number of potentially interacting pairs of flights) using a configurable time window.

Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0006
Requirement	LTM/EAP shall be able to select Complexity Indicators from: 1.- entry rate or, 2.- occupancy or, 3- ATCO workload.
Title	Complexity Indicators
Status	<Validated>
Rationale	The Complexity Indicators (e.g. entry rate, occupacy or ATCO workload) should be configurable by LTM/EAP in order to make decision.
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
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<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0006	<Partial>
<APPLIES_TO>	<Operational Process>	Balance Demand with Resources and Capabilities	N/A
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0007
Requirement	LTM/EAP shall be able to check the comparison of the predicted Complexity Indicators against the maximum value of the complexity indicator declared as acceptable per sector or group of sectors.
Title	To compare predicted and declared complexity indicators threshold
Status	<Validated>
Rationale	The declared acceptability can be global or specific to each of the sectors, according to the approach on complexity assessment (macroscopic or microscopic).
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
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<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-SAF1.0045	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-EAPP.1030	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A

<APPLIES_TO>	<Operational Process>	Balance Demand with Resources and Capabilities	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0008
Requirement	LTM/EAP should be able to adapt manually the maximum value of the complexity indicators per sector or group of sectors.
Title	To manually adapt declared complexity indicators threshold
Status	<Validated>
Rationale	The declared acceptability may have to be set temporarily lower (or higher) depending on circumstances (e.g. bad weather/turbulence, frequency problems).
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
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<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0006	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Process>	Balance Demand with Resources and Capabilities	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0009
Requirement	LTM/EAP shall receive warnings in case of overload.
Title	Overload warnings
Status	<Validated>
Rationale	Overload: safety reasons
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
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<APPLIES_TO>	<Operational Process>	Balance Demand with Resources and Capabilities	N/A
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0010
Requirement	LTM/EAP shall receive warnings in case of underload.
Title	Underload warnings
Status	<Validated>
Rationale	Underload: efficiency reason (improve the use of human resources)
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0006	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-SAF1.0045	<Partial>
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<APPLIES_TO>	<Operational Process>	Balance Demand with Resources and Capabilities	N/A
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0011
Requirement	LTM/EAP shall be able to manually select the sectorisation wanted for complexity assessment.
Title	To predict future Complexity Indicators for alternative environments
Status	<Validated>
Rationale	Airspace What-if Functionality: CAR tool shall allow the user to manually select the sectorisation wanted for assessment and shall return its complexity indicators´ values.
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-CEF1.0011	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0012
Requirement	LTM/EAP should be able to select a specific prediction time horizon and sectors in order to check all flights and trajectories with their relevant flight details that fall within it.
Title	To display 4D trajectory information of relevant flights
Status	<Validated>
Rationale	Support for decision making
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0013
Requirement	LTM/EAP should be able to select a specific Complexity Indicator prediction in order to check the list of flights contributing to it.
Title	To display a list of flights contributing to a specific Complexity indicator
Status	<Validated>
Rationale	Support for decision making
Category	<Operational>
Validation Method	<Real Time Simulation>

Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0014
Requirement	LTM/EAP shall be able to configure the complexity prediction algorithms or ATCO workload prediction models as well as the required configuration data used by the CAR tool to predict Complexity Indicators.
Title	Ability of supporting algorithms, models and storing outside the process.
Status	<Validated>
Rationale	The ATCO workload prediction model includes controllers' behaviour. CAR tool shall predict Complexity Indicators using complexity prediction algorithms or ATCO workload prediction models.
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0015
Requirement	The output data shall have sufficient level of granularity to support the situation analysis by the LTM/EAP.
Title	To provide output data complying with the configuration parameters
Status	<Validated>
Rationale	Typically Complexity Indicators will be provided per time interval (configurable), for each of the sectors listed in the operational environment and for a specific look ahead time (configurable).
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0016
Requirement	LTM/EAP shall be able to select the time horizon for the complexity prediction.
Title	Configurability of time horizon for the complexity prediction.
Status	<Validated>
Rationale	The time horizon for the complexity prediction shall be configurable. A typical value for the time horizon would be 3 hours.
Category	<Operational>

Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0017
Requirement	LTM/EAP shall be able to request the complexity prediction for the current sector configuration and any what-if plan created manually.
Title	To Calculate complexity for the current sector configuration and any what-if plan.
Status	<Validated>
Rationale	Airspace What-if Functionality: The complexity shall be calculated for the current sector configuration and any what-if plan created by LTM/EAP.
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-CEF1.0011	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0018
Requirement	CAR tool shall assess and predict the ATCO workload based on the controllers' behaviour according to their environment.
Title	Workload calculation
Status	<Validated>
Rationale	N/A
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0019
Requirement	CAR tool should be sufficiently adaptable through adaptation parameters to allow changes in the operational environment, organisation or procedures.
Title	Adapting the computation to evolving operational aspects
Status	<In Progress>
Rationale	This requirement is out of the scope of the SESAR Solution #19. Further validation is needed in SESAR2020.

Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0006	<Partial>
<APPLIES_TO>	<Operational Process>	Balance Demand with Resources and Capabilities	N/A
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0020
Requirement	LTM/EAP shall trigger manually the recalculation of complexity indicators.
Title	Workload recalculation: manual and iterative trigger
Status	<Validated>
Rationale	Typical value for the period is 5 minutes.
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0006	<Partial>
<APPLIES_TO>	<Operational Process>	Balance Demand with Resources and Capabilities	N/A
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0001.0021
Requirement	LTM/EAP should be able to define any change of the sector configuration schedule triggering the system to recalculate the complexity indicators
Title	Workload recalculation: change of the schedule of sector configurations
Status	<Validated>
Rationale	N/A
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0006	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A

6.1.2 Group 0002: Sector configuration optimizer

[REQ]

Identifier	REQ-04.07.01-OSED-0002.0001
Requirement	Upon LTM/EAP request, CAR tool should propose the optimal sector configuration from a list of possible sector configurations.
Title	To propose the optimal sector configuration
Status	<Validated>

Rationale	N/A
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-CEF1.0011	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0002.0002
Requirement	Upon LTM/EAP request, CAR tool should propose the optimal sector configuration based on the executive controller workload calculation.
Title	To propose the optimal sector configuration
Status	<Validated>
Rationale	N/A
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-CEF1.0011	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0002.0003
Requirement	Upon LTM/EAP request, CAR tool should calculate Complexity Indicators and then propose the optimum sector configuration schedule taking into account the following criteria: 1.- Minimum number of opened sectors 2.- Workload between sectors shall be as balanced as possible 3.- The number of open sectors shall not be higher than the maximum operable sectors (it will depend of the staff available) (offline and online configurable) 4.- Transition between configurations shall be “non-traumatic (offline and online configurable) 5.- Sectorisation should be applied during a minimum duration (configurable) 6- Sector overload should be minimised.
Title	To calculate optimum predefined sector configuration
Status	<Validated>
Rationale	N/A
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-CEF1.0011	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0002.0004
Requirement	LTM/EAP shall be able to designate airspace volumes as not being available for the computation of the optimum sector configuration schedule by the system.
Title	Airspace not available
Status	<In Progress>
Rationale	This requirement refers to airspace volumes not available to civil traffic, due to military activities, environmental restrictions, etc. This requirement is out of the scope of the SESAR Solution #19. Further validation is needed in SESAR2020.
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-CEF1.0011	<Partial>
<APPLIES TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES TO>	<Operational Focus Area>	OFA05.03.03	N/A

6.1.3 Group 0003: Flight plan What-if

[REQ]

Identifier	REQ-04.07.01-OSED-0003.0001
Requirement	LTM/EAP shall be able to request the complexity prediction for the real trajectories and any amended individual trajectories created manually.
Title	To Calculate complexity for the manually amended individual trajectories.
Status	<Validated>
Rationale	Trajectory What-if functionality: The complexity outputs of manually amended individual trajectories, both for real and What-If trajectories shall be calculated.
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-ENV1.1022	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-ENV1.1023	<Partial>
<APPLIES TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

6.1.4 Group 0004: HMI

[REQ]

Identifier	REQ-04.07.01-OSED-0004.0001
Requirement	LTM/EAP shall to be able check errors, warnings and system messages.
Title	To display errors.
Status	<Validated>
Rationale	Requirement related to the usability of the complexity. Errors, warnings and system messages shall be displayed to LTM/EAP.
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-HMI.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-HMI.0003	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-HMI.0006	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0004.0002
Requirement	LTM/EAP shall be able to check the graphical representation of complexity versus time dynamically updated with a visual indication of current time.
Title	HMI: figures evolving with the time
Status	<Validated>
Rationale	Requirement related to the usability of the complexity.
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0006	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-HMI.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-HMI.0003	<Partial>
<APPLIES_TO>	<Operational Process>	Balance Demand with Resources and Capabilities	N/A
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0004.0003
Requirement	LTM/EAP shall be able to select a sector configuration and check the predicted Complexity Indicators for the selected sectors.
Title	To select and display sectorisation and related complexity indicators
Status	<Validated>
Rationale	Requirement related to the usability of the complexity
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-HMI.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-HMI.0003	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0004.0004
Requirement	LTM/EAP shall be able to check the visual representation of the complexity indicators vs time aiming at giving a graphic picture that includes all the information needed for selecting and monitoring the optimum sector configuration schedule for a time period..
Title	HMI configuration: 3 hours sector configuration
Status	<Validated>

Rationale	The time period is typically 3 hours.
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0006	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-HMI.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-HMI.0003	<Partial>
<APPLIES_TO>	<Operational Process>	Balance Demand with Resources and Capabilities	N/A
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

6.1.5 Group 0005: Platform requirements

This section lists the platform requirements which will be satisfied by both prototypes and platform.[5]

[REQ]

Identifier	REQ-04.07.01-OSED-0005.0001
Requirement	CAR tool shall be capable of processing environmental data (elementary sectors, waypoints, air blocks, sector configurations...).
Title	To process environmental data
Status	<Validated>
Rationale	N/A
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0006	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0022	<Partial>
<APPLIES_TO>	<Operational Process>	Balance Demand with Resources and Capabilities	N/A
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0005.0002
Requirement	CAR tool shall be capable of processing Flight Plans and EFD data from ETFMS.
Title	To process Flight Plans and EFD data from ETFMS
Status	<Validated>
Rationale	To build traffic demand
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance

[5] Although the requirements included in this section are not expected at OSED level, the MUAC prototype is an 'in-house' developed one. The P10.08.01 TS includes only the system requirements related to prototypes developed in the scope of the project. Then, as a compromise solution, it was decided to include this section.

<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0022	<Partial>
<APPLIES TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0005.0003
Requirement	The 4D predicted trajectories should have the sufficient level of detail to ensure that sector proximity can be computed for each flight.
Title	Computing Sector proximity
Status	<In Progress>
Rationale	Sector proximity refers to when an aircraft is soon entering a sector. This requirement is out of the scope of the SESAR Solution #19. Further validation is needed in SESAR2020.
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0022	<Partial>
<APPLIES TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0005.0004
Requirement	The 4D predicted trajectories shall have the sufficient level of detail to ensure calculation of the number of aircraft evolving vertically.
Title	Computing aircraft evolving vertically.
Status	<Validated>
Rationale	N/A
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0022	<Partial>
<APPLIES TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0005.0005
Requirement	The complexity prediction shall request accurate 4D Trajectories Forecast data for the maximum allowable time horizon.
Title	Configurable window prediction time – 4D data availability.
Status	<Deleted>
Rationale	This requirement is not relevant.
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0005.0006
Requirement	The 4D predicted trajectories shall have the sufficient level of detail to compute the parameters characterizing the complexity indicators and shall be received by the CAR tool.
Title	Required 4D trajectories predicted data
Status	<Validated>
Rationale	N/A
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0022	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-0005.0007
Requirement	The CAR tool should provide recording facilities with a level of granularity compatible with after runs' analysis.
Title	To record outputs to later post-analysis
Status	<Validated>
Rationale	N/A
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-0001.0022	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

6.2 Additional Operational Requirements related to R5 exercises

6.2.1 Complexity features

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0001
Requirement	LTM/EAP shall be able to check the individual contribution of each flight to the workload for a certain timeframe and specific sector.
Title	Individual contribution of each flight to workload
Status	<Validated>
Rationale	Support for decision making (preparation and analysis of trajectory measure).
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance

<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0003	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0015
Requirement	MSP shall be able to check the prediction of Complexity Indicators in his/her sector/sectors and per time interval for the sector configuration in operation.
Title	Complexity Prediction for MSP
Status	<Validated>
Rationale	Support for decision making (preparation and analysis of trajectory measure).
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-SAF1.0045	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-CAP1.0024	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-EAPP.1030	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-EAPP.1020	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-EAPP.1000	<Partial>
<APPLIES_TO>	<Operational Process>	Balance Demand with Resources and Capabilities	N/A
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

6.2.2 Local Tools support for STAM processes

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0002
Requirement	CAR tool shall merge flight information from NM and local ATC systems to generate the traffic demand (i.e. set of trajectories).
Title	Generation of the traffic demand
Status	<Validated>
Rationale	Building traffic demand
Category	<Operational>
Validation Method	<Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0003
Requirement	CAR tool shall be connected with NM system via B2B connection to support the STAM processes.
Title	Connection to NM system
Status	<Validated>
Rationale	Local tools can support the LTM/EAP during the different phases of the STAM process.

Category	<Operational>
Validation Method	<Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0004
Requirement	CAR tool shall share information about the individual contribution of each flight to the workload for a certain time and specific sector with NM system.
Title	Information shared with NM system
Status	<Validated>
Rationale	Interoperability between NM system and local tools.
Category	<Operational>
Validation Method	<Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0005
Requirement	CAR tool shall support the LTM/EAP for the CDM coordination with other relevant stakeholders (NM, ANSPs and AUs) affected by a potential trajectory measure.
Title	CDM coordination of potential trajectory measure
Status	<In Progress>
Rationale	Local Tools support for the M-CDM processes. This requirement is out of the scope of the SESAR Solution #19. Further validation is needed in SESAR2020.
Category	<Operational>
Validation Method	<Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A

6.2.3 Trajectory What-if[6]

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0006
Requirement	Upon LTM/EAP or MSP request, the trajectory what-if functionality shall predict and assess the complexity indicators for every potential trajectory measure on an individual flight or traffic flow.
Title	Trajectory what-if functionality assessment

[6] Trajectory what-if is based on the most accurate trajectory prediction system feature, available in the moment of application.

Status	<Validated>
Rationale	Support for decision making: The user needs to understand the complexity that will result from the application of trajectory changes to a flight or traffic flow.
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-EAPP.1030	<Partial>
<APPLIES_TO>	<Operational Process>	Balance Demand with Resources and Capabilities	N/A
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0007
Requirement	Upon LTM/EAP or MSP request, the trajectory what-if functionality shall present the complexity prediction for a certain timeframe, specific sector or group of sectors.
Title	Trajectory what-if functionality presentation
Status	<Validated>
Rationale	N/A
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-EAPP.1030	<Partial>
<APPLIES_TO>	<Operational Process>	Balance Demand with Resources and Capabilities	N/A
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0008
Requirement	The LTM/EAP or MSP shall select a trajectory (cherry picking) or a group of trajectories (flow) to plan a potential trajectory measure.
Title	Selection of flight in trajectory what-if functionality
Status	<Validated>
Rationale	N/A
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<APPLIES_TO>	<Operational Process>	Balance Demand with Resources and Capabilities	N/A
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0009

Requirement	In the Trajectory What-If environment, the LTM/EAP or MSP shall test trajectory measures such as flight level change and/or rerouting.
Title	Trajectory modifications available into the trajectory what-if functionality
Status	<Validated>
Rationale	N/A
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-SAF1.0045	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-07.02-DOD-EAPP.1030	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0010
Requirement	The trajectory what-if functionality shall have available a catalogue of pre-defined trajectory scenarios to be used by LTM/EAP or MSP.
Title	Pre-defined scenarios into the trajectory what-if functionality
Status	<Validated>
Rationale	Support for decision making: The LTM/EAP or MSP shall select pre-defined trajectory scenarios in order to know their impact on complexity.
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0011
Requirement	In the Trajectory What-If environment, the LTM/EAP or MSP shall plan a potential trajectory measure in graphical mode through change of route level or time.
Title	Graphical mode of trajectory what-if functionality
Status	<In Progress>
Rationale	This requirement is out of the scope of the SESAR Solution #19. Further validation is needed in SESAR2020.
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

6.2.4 Integration with METEO Tool

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0012
Requirement	The system shall be connected to METEO tool and use information from

	it to evaluate complexity indicators.
Title	Connection with METEO tool
Status	<Deleted>
Rationale	The METEO information will be used to improve the accurate of the complexity calculations. However, the integration of meteorological information to improve complexity assessment has been considered in Step2 (CM-0103-B).
Category	<Operational>
Validation Method	<Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A

6.2.5 Platform requirements

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0013
Requirement	CAR tool shall record complexity indicators evolution through time for post-analysis purpose.
Title	Post-analysis of complexity indicators
Status	<Validated>
Rationale	N/A
Category	<Operational>
Validation Method	<Real Time Simulation><Shadow Mode>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

6.2.6 Integration with E-AMAN

The following requirements have been updated/added taking into account the results from the integrated validation EXE-05.03-VP-804 performed by sWP05.03 within Release 5 framework contributing to SESAR Solution #19 [19]. This exercise was executed in close coordination with EXE-04.07.01-VP-005 [18].

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0014
Requirement	CAR tool shall assess complexity indicators taking into account the impact of the tasks delegated to the Executive Controller - speed changes and TTL/TTG indication monitoring - in order to facilitate building the arrival sequence in the En Route phase by means of TTL/TTG per flight provided by the E-AMAN.
Title	Impact of AMAN sequence targets in the complexity prediction
Status	<In Progress>
Rationale	Recommendation for CAR tool improvement before its deployment.
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance

<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

[REQ]

Identifier	REQ-04.07.01-OSED- REL5.0016
Requirement	CAR tool shall present information if an aircraft is included in an arrival sequence managed by an AMAN.
Title	Integration on the CAR tool of information about whether an aircraft is within an AMAN sequence
Status	<In Progress>
Rationale	Recommendation for CAR tool improvement before its deployment.
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A

[REQ]

Identifier	REQ-04.07.01-OSED- REL5.0017
Requirement	CAR tool shall highlight if an aircraft included in an arrival sequence managed by an AMAN has a TTL/TTG constraint.
Title	Integration on the CAR tool of TTL/TTG information.
Status	<In Progress>
Rationale	Recommendation for CAR tool improvement before its deployment.
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0002	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.03	N/A

[REQ]

Identifier	REQ-04.07.01-OSED-REL5.0018
Requirement	CAR tool shall highlight if an aircraft included in a sequence managed by an AMAN has a speed constraint already imposed.
Title	Integration on the CAR tool of speed constraint information
Status	<In Progress>
Rationale	Recommendation for CAR tool improvement before its deployment.
Category	<Operational>
Validation Method	<Real Time Simulation>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance

<SATISFIES>	<ATMS Requirement>	REQ-04.02-DOD-0005.0005	<Partial>
<APPLIES_TO>	<Operational Process>	Perform Extended ATC Planning	N/A
<APPLIES_TO>	<Operational Focus Area>	OFA05.03.04	N/A

6.3 Information Exchange Requirements

The following capabilities will be deployed to support Step 1 in the Ground Domain:

- ER ATC System communications: As the coordination between them is inside the boundaries of the ATC System, no external interface exists with the rest of the domains.
- ER ATC System – NMOC/ETFMS communication: To perform the Complexity Computation, information coming from NMOC/ETFMS is needed. This information is sent by NMOC/ETFMS function through:
  - an EFD message in ADEXP format using the AFTN protocol. The standards for EFD messages in ADEXP format and AFTN protocol are described in[23][24][25];
  - a B2B service.

  In addition, some complexity indicators such as the individual contribution of each flight to the sector complexity could be sent to NMOC.

  Information Exchange Requirements related to this capability are detailed in Table 18. These requirements are based on AIRM model defined by WP08.

Additional communications between ER ATC System and NMOC/ETFMS will be established by means of B2B services in order to support the STAM processes at local level. Please note that the IER related to NM and B2B exchange for application and communication of STAM are treated in P13.02.03 D303 – Enhanced DCB OSED for Step1 [16], since the P04.07.01 is treating only the requirements specific for the local tools.

[IER]

Identifier	Name	Issuer	Intended Addressees	Information Element	Involved Operational Activities	Interaction Rules and Policy	Status[7]	Rationale	Satisfied DOD Requirement Identifier	Service Identifier
IER-04.07.01-OSED-CAR1.0001	Complexity Count per sector	Local complexity tool	NM system	Complexity per sector	STAM (hotspot detection phase)	N/A	<In progress>	Complexity per sector supports the detection of hotspots.	REQ-07.02-DOD-0001.0007<Partial>	N/A

[7] Please note that P04.07.01 exercises were performed at local level and so, the Exchange Information with ATFCM through SWIM services was an assumption taking also into account that the validation objectives could be achieved without SWIM. However, EXE-13.02.03-VP-700 addressed the information exchange requirements related to CM-0103-A OI step through B2B services (within the SESAR Sol. #17).

Identifier	Name	Issuer	Intended Addressees	Information Element	Involved Operational Activities	Interaction Rules and Policy	Status[7]	Rationale	Satisfied DOD Requirement Identifier	Service Identifier
IER-04.07.01-OSED-CAR1.0002	Complexity Count per flight	Local complexity tool	NM system	Individual complexity contribution per flight	STAM (analysis and preparation of STAM measures)	N/A	<In progress>	Individual complexity contribution per flight supports the selection of the flights candidate for STAM measures.	REQ-07.02-DOD-0001.0007<Partial>	N/A
IER-04.07.01-OSED-CAR1.0003	Update Airspace Configuration	ACC Supervisor; LTM; EAP	Network Manager	Sector Configuration	Update Airspace Structure	N/A	<In progress>	Any update of the sector configuration performed to solve local complexity imbalances should be communicated to the European Network Manager	REQ-07.02-DOD-0001.0007<Partial>	N/A
IER-04.07.01-OSED-CAR1.0004	Fight Data	NM system	Local complexity tool	Flight Data	Complexity Assessment	N/A	<In progress>	Complexity tool will evaluate the complexity indicators based on the traffic demand built on local and network data.	REQ-07.02-DOD-0001.0010<Partial>	FlightPlanDataD istr bution

Table 18: IER layout

7 References

7.1 Applicable Documents

This document complies with the requirements set out in the following documents:

[1] IS SESAR Template Toolbox, Ed. 03.01.03

[2] IS SESAR Requirements and V&V Guidelines, Ed. 03.01.00

7.2 Reference Documents

The following documents were used to provide input/guidance/further information/other:

[3] P04.07.01 D13 'Step1 Final Validation Report – 1', Ed. 00.01.00

[4] B.4.3 D95 'Architecture Description Document Step1 (2014 edition)', Ed. 00.02.02

[5] B.04.01 D108 'Performance Framework for SESAR Transition', Ed. 00.04.00

[6] OATA Operational Scenario and Use Case Guide V1.0

[7] Traffic Complexity Management Concept, v 1.1, EUROCONTROL ATC Domain, 30.01.2008.

[8] Air Traffic Management Execution Processes; Complexity Management v 0.3

[9] DSNA/DTI/R&D Research Project S2D2

[10] DSNA/DTI/R&D Research Project CASSOS

[11] Traffic Management System (TMS Level 1) Maastricht Upper Area Control Centre (MUAC)

[12] P04.07.01 – D01 'Consolidation of previous studies (STEP 1)', Ed. 00.01.00

[13] P04.02 D98 'WP4 Detailed Operational Description Step1', Ed. 00.07.01

[14] P07.02 D29 'Step1 Release5 Detailed Operational Description (DOD)', Ed. 00.04.01

[15] ATM Master Plan, Data Set 15, December 2015;

[16] P13.02.03 D303 – Enhanced DCB OSED for Step1, Ed. 00.05.00.

[17] P04.07.01 D14 'Step1 Final Validation Report – 2', Ed. 00.02.00

[18] P04.07.01 D72 'Step1 Final Validation Report – 3'. Ed. 00.02.00

[19] sWP05.03 D99 'Validation Report EXE-05.03-VP-804', Ed. 00.00.07

[20] P04.07.08 D78 'Step1 V2 Validation Report (Extended ATC Planner) VP-687', Ed. 00.01.02

[21] P04.07.01 D62 'Step1 V3 Interim Complexity Management OSED', Ed. 00.01.01

[22] 8.1.3.D45_AIRM Model v4.0.0

[23] AFTN ICAO Annex 10 - Aeronautical Tele-communications Volume 2

[24] Standard document for ATS Data Exchange Presentation (ADEXP), EUROCONTROL, Edition 3.0

[25] ATFCM User's Manual, EUROCONTROL, Edition 15.0

[26] B.04.02 D106 'Transition ConOps SESAR 2020', Ed. 01.00.00

Appendix A Detailed Description of Lyapunov Approach

A.1 The principle behind

Two different algorithms are investigated, both based on aircraft trajectories, measuring convergence between them:

- **Convergence algorithm**:

  The principle of the convergence algorithm is to measure the reduction of relative distance between nearby aircraft. The value of this reduction is weighted by the distance between those aircrafts (distant aircrafts will have less impact than close aircrafts, for the same convergence value). The convergence indicator is calculated on a 3D map, and then is summed for the different sectors.

  This algorithm is not as thorough as the Lyapunov algorithm but is faster to compute.

- **Lyapunov algorithm:**

  The principle of the Lyapunov algorithm is to measure the sensibility to initial conditions in a field of speed vectors including all the aircrafts.

  First, a non-linear field of vectors V=f(x,y,z) is calculated from the present aircraft, using a method developed by ENAC. This field attributes a speed to each point of the airspace, this speed matching the speed of the aircraft in the points where there is an aircraft.

  In a second step, the algorithm measures the sensibility to initial conditions, assessing the change of proximity of two aircrafts in close locations. The idea is that the more they converge (the distance between them is reducing), the more complicated is the situation in that point.

A.2 Convergence algorithm

A.2.1 Objective

The convergence indicator is used to quantify the geometric structure of the speed vectors of airplanes present in a sector. Thus, for identical proximity values, the convergence indicator allows us to distinguish between converging and diverging aircraft.

When a dense zone has been identified, the zone may be characterized using the rate of convergence of the aircraft present in this area. This indicator is higher the closer the aircraft and the faster the convergence.

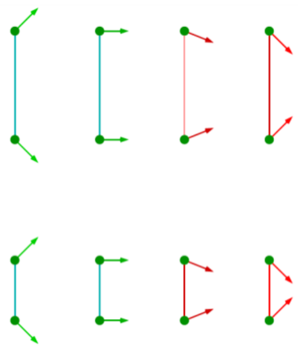

Figure 24: Convergence Indicator Example

The speed distributions are identical in the top 4 situations and the bottom 4 situations; however, the relative distance is smaller in the bottom 4 situations. The most critical situation is located at the bottom right (strong convergence and low relative distance).

Thus, in the example shown in Figure 24, the convergence indicator is used to provide an unambiguous classification of the eight situations. Each situation corresponds to two aircraft, for which the relative distance is constant (higher in the top four cases) and the relative speed varies from strong divergence to strong convergence.

In the case of divergence, the indicator will be null, and for convergences, it will be increasingly high as the relative distance diminishes and the relative speed increases.

A.2.2 Calculation Method

Let us take two moving points *i* and *j* (see Figure 25); the ***level of variation of their relative distance*** is:

$$r_{ij} = \frac{\partial}{\partial t}(d_{ij})$$

where d j is their reduced relative distance. Thus, a pair of airplanes converges if, and only if, this level of variation is negative; convergence becomes increasingly rapid as the absolute value of this level increases.

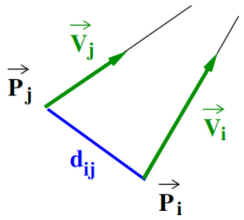

Figure 25: Moving Points

The variation of the relative distance between two airplanes (d_{ij}) indicates whether or not they are converging, and at what speed.

Let $\overrightarrow{p_{ij}}$ be the reduced relative position vector and $\overrightarrow{v_{ij}}$ the reduced relative speed vector:

$$\overrightarrow{p_{ij}} = \left| \begin{array}{c} \frac{x_j - x_i}{a} \\ \frac{y_j - y_i}{a} \\ \frac{z_j - z_i}{h} \end{array} \right. \qquad \overrightarrow{v_{ij}} = \left| \begin{array}{c} \frac{v_{xj} - v_{xi}}{a} \\ \frac{v_{yj} - v_{yi}}{a} \\ \frac{v_{zj} - v_{zi}}{h} \end{array} \right.$$

r_{ij} is thus given by:

$$r_{ij} = \frac{\partial}{\partial t}\|\vec{p}_{ij}\|_2 = \frac{\partial}{\partial t}\sqrt{\vec{p}_{ij} \cdot \vec{p}_{ij}} = \frac{\vec{p}_{ij} \cdot \vec{v}_{ij}}{d_{ij}}$$

In reality, the risk associated with the convergence of a pair of aircraft also depends on the relative distance between airplanes. We must therefore simultaneously account for the speeds and relative distances of each pair of aircraft. One possible form of a convergence indicator associated with an airplane i is given below:

$$Cv(i) = \lambda_c \sum_{j/r_{ij} \leq 0} -r_{ij}.e^{-\frac{1}{2}(\alpha_c.d_{ij})^2}$$

where λ_c and α_c are weighting coefficients.

Thus, for each airplane i, it is possible to calculate a proximity value P(i) and a local convergence level Cv(i) in order to locate it in a referential of which the axes are the proximity and the convergence level (see Figure 26).

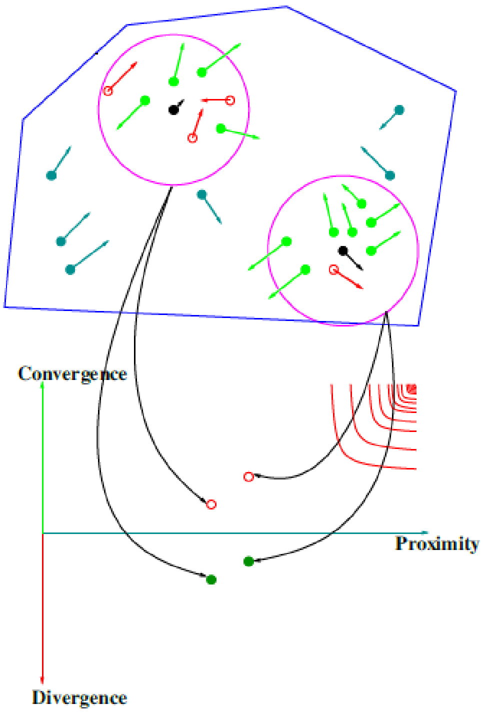

Figure 26: Proximity and Convergence Levels

In this figure, two airplanes are represented in a proximity/convergence referential. The airplanes located in the top right zone are the most critical (strong convergence with high proximity).

A.2.3 Examples and Results

We tested this indicator using the same simulation files as before. For all of the traffic in French airspace in the course of a day and for each time step, each airplane present in the space is represented by a cross.

The whole set of crosses is forming a cloud (see Figure 27) in which we are able to easily identify critical aircraft (top right).

As in the case of proximity, the convergence indicator can be mapped. The map associated with the artificial situation involving four groups of eight aircraft (as before) is shown in Figure 28.

From this figure, we show that only the two non-organized situations (pure conflict and random situation) are identified by the indicator.

The two indicators discussed above (proximity and convergence) are calculated by the aggregation of local influences between pairs of aircraft. This approach can prove limiting in certain situations, and in consequence we have developed an extension of these principles to the level of airplane clusters.

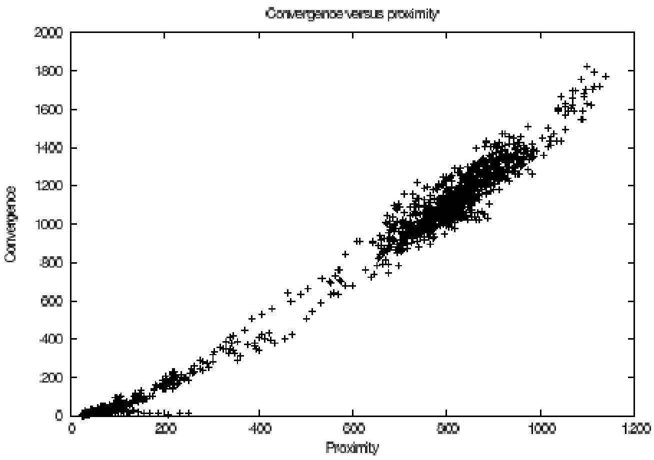

Figure 27: Convergence and proximity calculated for a day of French air traffic.

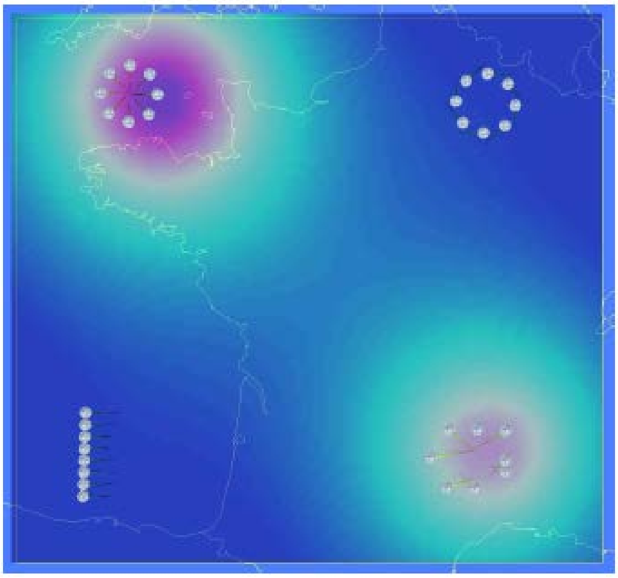

Figure 28: Convergence map for four groups of eight airplanes

A.3 Lyapunov Algorithm

A.3.1 Dynamic System Modelling of Aircraft Trajectories

Linear Modelisation

The key idea is to model the set of aircraft trajectories by a linear dynamical system which is defined by the following equation:

$$\dot{\vec{X}} = \mathbf{A} \cdot \vec{X} + \vec{B}$$

where $\vec{X}$ is the state vector of the system:

$$\vec{X} = \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

Matrix A and vector $\vec{B}$ are the parameters of the model.

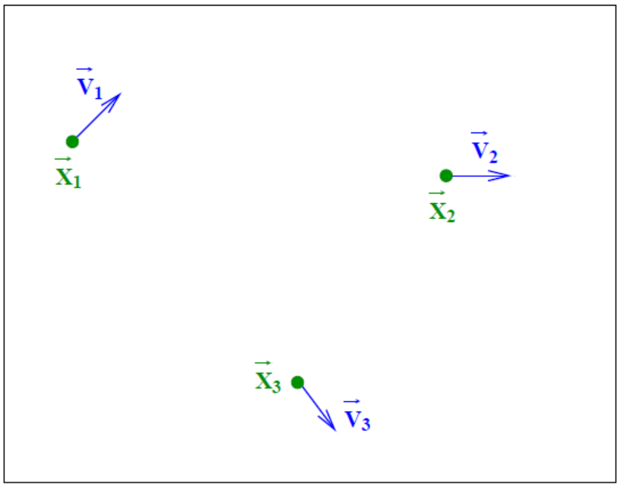

Figure 29: Sample of Aircraft positions and speeds

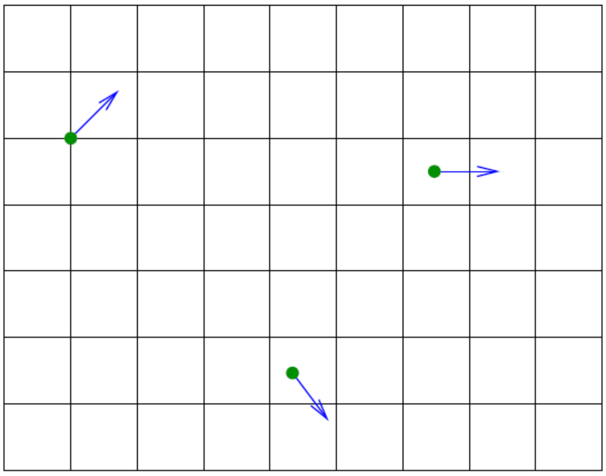

Figure 30: Placing the samples on a grid

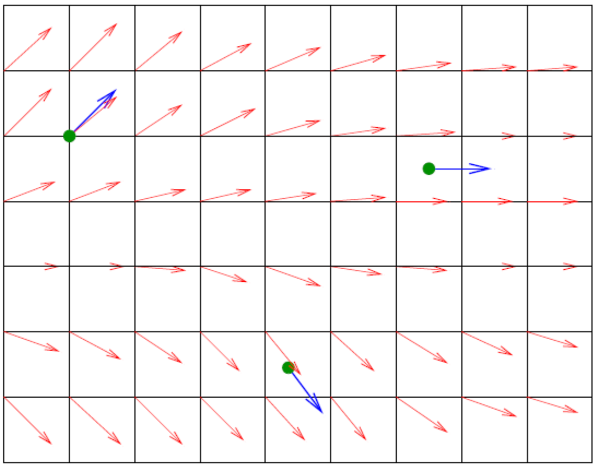

Figure 31: Building the speeds field on the grid

Based on a set of observations (positions and speeds), one has to find a dynamical system which fits those observations.

Suppose that N obervations are given:

Positions :

$$\vec{X}_i = \begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix}$$

and speeds :

$$\vec{V}_i = \begin{bmatrix} vx_i \\ vy_i \\ vz_i \end{bmatrix}$$

A LMS procedure is applied in order to extract the matrix A and the vector $\vec{B}$.

When real part of the eigenvalues of matrix A is positive, the system is in expansion mode and when they are negative, the system is in contraction mode.

Furthermore, the imaginary part of such eigenvalues are related with curl intensity of the field.

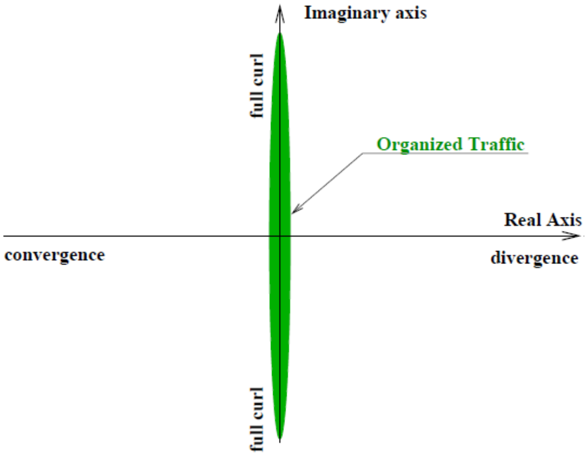

Figure 32: Properties of Matrix A

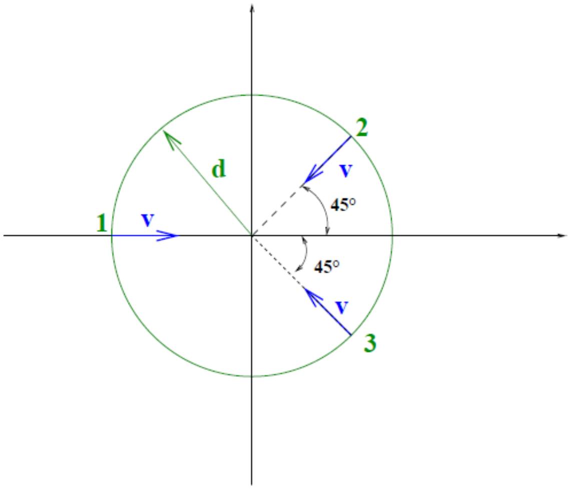

Figure 33: Example of situation

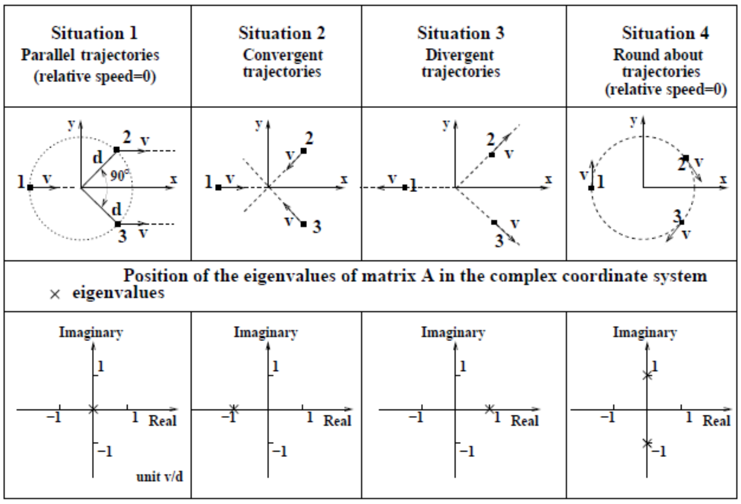

Figure 34: Position of the eigenvalues of matrix A in different situations

The linear model gives a global tendency of the traffic situation, but it does not exactly fit with all traffic situation.

A non linear extension is therefore needed.

Non-Linear extension

We will now look for a new model in the following form:

$$\dot{\vec{X}} = \vec{f}(\vec{X})$$

While trying to optimize f() such that:

$$minE = \sum_{i=1}^{i=N} \|\vec{V}_i - \vec{f}(\vec{X}_i)\|^2$$

and

$$min \int_{\mathbb{R}^3} \|\Delta\vec{f}(\vec{x})\|^2 d\vec{x} \quad \text{with} \quad \Delta\vec{f} = \begin{bmatrix} \frac{\partial^2 f_x}{\partial x^2} + \frac{\partial^2 f_x}{\partial y^2} + \frac{\partial^2 f_x}{\partial z^2} \\ \frac{\partial^2 f_y}{\partial x^2} + \frac{\partial^2 f_y}{\partial y^2} + \frac{\partial^2 f_y}{\partial z^2} \\ \frac{\partial^2 f_z}{\partial x^2} + \frac{\partial^2 f_z}{\partial y^2} + \frac{\partial^2 f_z}{\partial z^2} \end{bmatrix}$$

Exact Solution (Amodei)

$$\vec{f}(\vec{X}) = \sum_{i=1}^{N} \mathbf{\Phi}(\|\vec{X} - \vec{X}_i\|).\vec{a}_i + \mathbf{A}.\vec{X} + \vec{B}$$

with

$$\mathbf{\Phi}(\|\vec{X} - \vec{X}_i\|) = \mathbf{Q}(\|\vec{X} - \vec{X}_i\|^3)$$

and

$$Q = \begin{bmatrix} \partial^2_{xx} + \partial^2_{yy} + \partial^2_{zz} & 0 & 0 \\ 0 & \partial^2_{xx} + \partial^2_{yy} + \partial^2_{zz} & 0 \\ 0 & 0 & \partial^2_{xx} + \partial^2_{yy} + \partial^2_{zz} \end{bmatrix}$$

Figure 35: Exact Solution in Space

The next step consists in building non linear extension in space and time:

$$\dot{\vec{X}} = \vec{f}(\vec{X}, t)$$

We are now looking for f() such that:

$$minE = \sum_{i=1}^{i=N} \sum_{k=1}^{k=K} \|\vec{V}_i(t_k) - \vec{f}(\vec{X}_i, t_k)\|^2$$

And

$$min \int_{\mathbb{R}^3} \int_t \|\Delta \vec{f}(\vec{x})\|^2 + \|\frac{\partial \vec{f}}{\partial t}\|^2 d\vec{x}dt$$

Exact Solution (Puechmorel and Delahaye)

$$\vec{f}(\vec{X}, t) = \sum_{i=1}^{N} \sum_{k=1}^{K} \mathbf{\Phi}(\|\vec{X}(t) - \vec{X}_i(t_k)\|, |t - t_k|).\vec{a}_{i,k} + \mathbf{A}.\vec{X} + \vec{B}$$

with

$$\mathbf{\Phi}(r, t) = \mathbf{diag}\left(\frac{\sigma}{r.\sqrt{\pi}}.erf\left[\frac{r}{\sigma}.\frac{1}{\sqrt{2 + \theta.|t|}}\right]\right)$$

Figure 36: Exact Solution in Space and Time

Gradient close form

$$\frac{\partial \Phi(r, t)}{\partial x} = (\alpha - \beta).x$$

with

$$\alpha = \frac{2.\sigma}{r^2.\pi}.\frac{1}{\sqrt{2 + \theta.|t|}}.e^{-\frac{r^2}{\sigma^2.(2+\theta.|t|)}}$$

$$\beta = \frac{\Phi(r, t)}{r^2}$$

$$r = \sqrt{x^2 + y^2 + z^2}$$

Figure 37: Gradient close form

Building a complexity map

We will try to characterize how fast two neighboring dynamical system trajectories diverge.

Let $\gamma(t, s), t : [a, b], s \in V$ be a family of trajectories of the dynamical system in the neighborhood V of a given point s_0

We assume that the nominal trajectory is $t \mapsto \gamma(t, s_0)$

A perturbed trajectory is $t \mapsto \gamma(t, s)$ with $s \in V$.

Divergence to nominal trajectory with respect to time is thus $\|\gamma(t, s_0) - \gamma(t, s)\| = D(t, s)$

When $t \mapsto \gamma(t, s)$ is the solution of a differential equation with initial condition $\gamma(0, s) = s$, it is possible to show that D itself satisfies a differential equation.

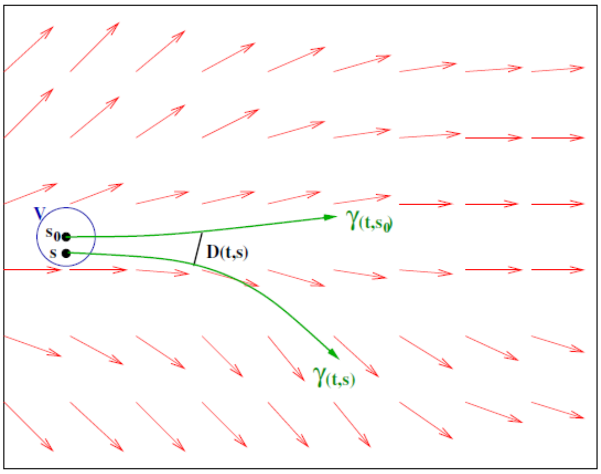

Figure 38: Sensibility to initial conditions

The value of D(t; s) is the result of a cumulative process.

Assume that $\gamma(t,s)$ is defined to be a flow:

$$\frac{\partial\gamma(t,s)}{\partial t} = F(t,\gamma(t,s)) \quad \gamma(0,s) = s$$

with F a smooth vector field.

Given a nominal trajectory $\gamma(t,s_0)$, then divergence of nearby trajectories can be found up to order one in $\|s-s_0\|$ by solving :

$$\frac{\partial D(t,s)}{\partial t} = DF(t,\gamma(t,s_0)).D(t,s) \quad D(0,s) = \|s-s_0\|$$

with DF the jacobian matrix of F (with respect to s).

Since the previous equation is linear, it can be described by a matrix M(t) that obeys :

$$\frac{dM(t)}{dt} = DF(t,\gamma(t,s_0)).M(t) \quad M(0) = Id$$

This equation is called the variational equation of the flow.

The variational equation describes in some sense a linear dynamical system "tangent" to the original one.

Let $U^t(t)\Sigma(t)V(t) = M(t)$ be the SVD decomposition of M(t).

The Lyapunov exponents are mean values of the logarithms of the diagonal elements of $\Sigma(t)$:

$$\kappa(s) = -\frac{1}{T}\int_0^T \log(\Sigma_{ii}(t))dt \quad \forall\Sigma_{ii}(t) \leq 1$$

Given an initial point, the Lyapunov exponents and the associated SVD decomposition provide us with a decomposition of space in principal directions and corresponding convergence/divergence rate.

It is a localized version of the complexity based on linear systems.

Appendix B New Information Elements

N/A

-END OF DOCUMENT-