Final Project Report

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Abstract

P04.07.01 addressed the Complexity Assessment and Resolution concept, with the objective of providing automated support based on the complexity prediction for identifying, assessing and resolving local complexity situations based on complexity prediction.

In this context, P04.07.01 covered the SESAR Solution #19 (Automated Support for Traffic Complexity Detection and Resolution' which is part of PCP under ATM Functionalities AF#4 'Network Collaborative Management'.

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00.01.01	05/10/2016	Final	ENAIRE	Version delivered to SJU

00.02.00	14/10/2016	Final	ENAIRE	Update with comments from SJU assessment report.

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This deliverable consists of SJU foreground.

Acronyms

Acronym	Definition
ACC	Area Control Centre
ATC	Air Traffic Control
ATCo	Air Traffic Controller
ATM	Air Traffic Management
ATFCM	Air Traffic Flow and Capacity Management
CAR	Complexity Assessment and Resolution
DAC	Dynamic Airspace Configuration
DCB	Demand Capacity Balancing
DS	Data Set
INAP	Integrated Network Management and Extended ATC Planning
INTEROP	Interoperability
KPA	Key Performance Area
OI	Operational Improvement
OSED	Operational Service and Environment Definition
SPR	Safety and Performance Requirements
TRL	Technology Readiness Level
TSA	Temporary Segregated Area

1 Project Overview

The main goal of this project was to develop and validate the Complexity Assessment and Resolution (CAR) concept which addresses the automated support for identifying, assessing and resolving local complexity situations based on complexity prediction.

The key feature for the success of CAR is the use of complexity metrics that encapsulate the relationship between workload and traffic. In particular, within P04.07.01, three different approaches were used to assess complexity: Algorithmic, Cognitive and Lyapunov-Convergence.

Complexity Assessment and Resolution (CAR) in ATM is performed within several different time horizons from short term planning to execution phase, which could be up to 3 hours and down to 20 minutes before sector entry. Complexity Management for ATC sectors is firstly handled by the local Network Management Function through enhanced ATFCM processes.

1.1 Project progress and contribution to the Master Plan

'Time Based Operations' context:

In the 'Time Based Operations' context, P04.07.01 was focused mainly on two Operational Improvements covering SESAR Solution #19 'Automated Support for Traffic Complexity Detection and Resolution':

- Automated Support for Traffic Complexity Assessment: CM-0103-A;
- Automated Controller Support for Trajectory Management: CM-0104-A.

In support to other projects, P04.07.01 also contributed to validate the following Operational Improvement:

- Dynamic Sectorisation based on complexity: CM-0102-A addressed by SESAR Solution #66 'Automated Support for Dynamic Sectorisation';

SESAR Solution #19 'Automated Support for Traffic Complexity Detection and Resolution':

This solution was validated though a series of activities including Real Time simulations and Shadow-Mode trials, focusing on the validation of the automated support to detect and resolve local complexity imbalances based on complexity prediction:

- First Real-Time Simulation performed in MUAC was focused on assessing the quality of the complexity prediction, the usability of a complexity tool and the use of the airspace what-if functionalities. The Algorithmic and Cognitive models were used to predict complexity supporting the detection of local complexity imbalances and the evaluation of the most appropriate sector configuration to solve them;
- Second validation activity performed in Reims ACC complemented the previous one through a sequence of Real-Time Simulations and Shadow-Mode Trials. The Lyapunov-Convergence model was used to predict complexity supporting the identification of local complexity imbalances;
- Third Real-Time Simulation performed in Madrid ACC assessed the use of a complexity tool to identify local complexity imbalances as well as to prepare and solve them by implementation of individual trajectories changes in tactical phase. The Cognitive model was used to predict complexity supporting the detection of local complexity imbalances and the analysis of the potential trajectory measures to solve them.

Finally, it is important to note that within the scope of this Solution, P04.07.01:

- supported technical project P10.08.01 to develop two different prototypes including Lyapunov-Convergence and Cognitive models to predict complexity which were integrated into CO-FLIGHT and iTEC validation platforms respectively;
- contributed to an in-house development in MUAC of a third prototype, providing the operational requirements.

'Trajectory Based Operations' context:

In the 'Trajectory Based Operations' context, P04.07.01 initiated the development and validation of the Complexity Assessment and Resolution concept from V1 maturity level, contributing to the following Operational Improvements:

- Dynamic Airspace Management based on complexity: CM-0102-B;
- Automated Support for Traffic Complexity Assessment: CM-0103-B;
- Automated Support to INAP (Integrated Network Management and ATC Planning) function: CM-0104-B.

Validation activities at V1 maturity level allowed the validation of the initial operational feasibility of the Complexity Assessment and Resolution (CAR) concept by means of Expert Groups and Fast-Time Simulations as well as the definition of the some elements of the concept.

Moreover, two validation activities at V2 maturity level contributed to the assessment of:

- the operational feasibility of the use of automated tools by means of Real-Time Simulations to provide accurate and timely complexity prediction in order to detect upcoming congestions and resolve them by providing alternative proposals for dynamic airspace adaptations (within the framework of the Dynamic Airspace Configuration concept developed by P07.05.04). The cognitive model was used to predict complexity supporting the detection of local imbalances and the identification of potential solutions based on DAC concept;
- the complexity management tuning and parametrization and the operational use of local ATFCM tool based on complexity/workload prediction by means of Shadow Mode and Gaming Techniques. The Algorithmic model was used to predict complexity.

  Please note that this validation activity was performed in close coordination with an internal Programme in MUAC called 'From ATFCM to ATC'.

Moreover, these validation activities allowed refining the operational requirements related to the application of the CAR concept in a 'Trajectory Based Operations' context.

Operational Improvements and Enablers

The following table shows the Operational Improvements Steps and the Enablers that the project P04.07.01 has worked on.1

The Operational Improvement Steps and the Enablers under the scope of this document are referenced to the Integrated Roadmap DS15.2

Please note that the definition of these Operational Improvements will be updated in further DS campaign in order to reflect properly the final P04.07.01 conclusions and recommendations on the CAR concept (e.g. backlog of CM-0104-A).

Moreover, it is important to highlight that P04.07.01 has not addressed all the procedural and SWIM enablers linked to Operational Improvements under the scope of this document. The procedural enablers, in particular PRO-220a and PRO-220b, should be also reviewed in further DS campaign.

1Term 'Mid V3' means 'Ready for Large Scale Demonstration but some remaining V3 validation is required'.
2 Please note that the titles of the CM-0102-A and CM-0102-B OI Steps are provided as in DS16 in order to avoid misunderstandings due to the duplicity of titles in DS15.

Code	Name	Project contribution	Maturity at project start	Maturity at project end
CM-0102-A	Dynamic Sectorisation based on complexity	P04.07.01 contributed to its validation through the exercise VP-001, demonstrating that the complexity prediction is an enabler to support the dynamic sectorisation based on predefined sector configuration at a time closer to the execution.	End V2	End V3
CM-0103-A	Automated Support for Traffic Complexity Assessment	P04.07.01 developed, validated (through exercises VP-001, VP-002 and VP-005) and provided recommendations on the use of the three different approaches for the complexity prediction in order to identify complexity imbalances and prepare and analyse potential measures to solve them. In addition, the related aspects of the procedural enabler PRO-220a 'ATC Procedures related to Detection and Resolution of Complexity, Density and Traffic Flow Problems' have been covered. Algorithmic approach is mature enough for deployment and also Cognitive one although further improvements are needed (during V4 phase). Lyapunov-Convergence approach need further work to reach the required maturity level.	End V2	End V3
CM-0104-A	Automated Controller Support for Trajectory Management	P04.07.01 contributed through exercise VP-005 to validate the operational feasibility of the automated support for the tactical application of trajectory management measures in order to solve complexity imbalances. In addition, the related aspects of the procedural enabler PRO-220a 'ATC Procedures related to Detection and Resolution of Complexity, Density and Traffic Flow Problems' have been covered. Analysis and preparation of trajectory management measures including what-if functionalities is at the end of V3 level. However, although the coordination and implementation phases have	V2	Mid V3

		been covered, further work is needed to reach the end of V3 level.		
CM-0102-B	Dynamic Airspace Management based on complexity	P04.07.01 developed and validated (through exercises VP-003 and VP-765) the automated support for the Dynamic Sectorisation based on workload and complexity prediction, in a Trajectory Based Operations context. Further validations are needed to assess the impact on performance (e.g. safety - situational awareness) and quantify benefits in order to reach the end of V2.	V1	Mid V2
CM-0103-B	Automated Support for Traffic Complexity Assessment	P04.07.01 developed and validated (through exercises VP-003 and VP-765) the automated support for upcoming congestions detection and based on the traffic workload and finding potential solutions based on workload and complexity prediction in a Trajectory Based Operations context. Further work is still needed to improve the precision and reliability of the complexity prediction in order to reach the end of V2.	V1	Mid V2
CM-0104-B	Automated Support to INAP (Integrated Network Management and ATC Planning) function	P04.07.01 developed at initial V2 maturity level the automated support to Integrated Network Management and ATC Planning (INAP) function in a Trajectory Based Operations context. Validation and refinement of associated processes and roles and responsibilities related to INAP are still needed (PJ.09).	V1	Early V2

In the Time Based Operations context, SESAR Project 04.07.01 has contributed to the SESAR Solution #19 'Automated Support for Traffic Complexity Detection and Resolution'.

1.2 Project achievements

Time Based Operations Context:

P04.07.01 validated SESAR Solution #19 'Automated Support for Traffic Complexity Detection and Resolution' which reached V3 maturity level.

The use of automated tools to predict complexity in terms of workload was assessed as feasible and appropriate to identify complexity imbalances and analyse potential measures to solve them. These automated tools would include both the complexity prediction functionality and the what-if functionality to analyse the most adequate solutions to cope with overload periods.

It was demonstrated that the roles related to the application of the Complexity Assessment and Resolution (CAR) concept in the 'Time Based Operations' context are ACC Supervisor and Local Traffic Manager (LTM).

Regarding performance benefits, the results of the validation activities showed an improvement in Safety and Fuel-efficiency. Conversely, Predictability (measured as En Route variability) worsened with the application of CAR concept. Initial estimations on Capacity and Cost Efficiency were provided through the analysis of the accuracy of the prediction and the qualitative assessment of workload.

Please note that the main KPA impacted by the application of the CAR concept is Capacity assessed by B04.02 and B04.01 experts concluding a 3% increase, although there are trade-offs depending on the operating environment with other KPAs such as Cost Efficiency through ATCo productivity.

Finally it is important to note that P04.07.01 has contributed to the AF#4 'Network Collaborative Management' ATM Functionality, addressing the AF4-4_01 requirement3.

'Trajectory Based Operations' Context:

The Complexity Assessment and Resolution (CAR) concept within the 'Trajectory Based Operations' Context was developed from V1 to mid V2 maturity level.

There was a positive evolution of the tasks related to the concept development and the validation activities provided promising results related to the operational feasibility of the CAR concept integrated into DCB processes (INAP function) as well as the usability of the supporting tools for complexity prediction.

Moreover, a preliminary assessment of impact on KPAs was performed. The optimisation of airspace configuration supported by the use of a complexity tool showed a positive impact on capacity, cost efficiency and safety.

1.3 Project Deliverables

The following table presents the relevant deliverables that have been produced by the project.

Reference	Title	Description
D01	STEP1 Consolidation of previous studies	The project started with a consolidation of the information of previous studies related to the complexity management concept in order to ensure the viability of starting the project in V3.
D13	STEP1 Final Validation Report-1	Results analysis and conclusions from the validation activity performed at V3 maturity level which addressed the application of CAR concept based on Algorithmic Approach in the 'Time Based Operations' context. Validation Report associated with SESAR Solution #19.
D14	STEP1 Final Validation Report-2	Results analysis and conclusions from the validation activity performed at V3 maturity level which addressed the application of CAR concept based on Lyapunov-Convergence approaches in

3 Planned trajectory information, network information and recorded analytical data from past operations shall be used for predicting traffic complexity and potential overload situations, allowing mitigation strategies to be applied at local and network levels.

		the 'Time Based Operations' contex. Validation Report associated with SESAR Solution #19.
D72	STEP1 V3 Validation Report 3	Results analysis and conclusions from the validation activity performed at V3 maturity level which addressed the application of CAR concept based on Cognitive approach and the complexity resolution through tactical trajectory management in the 'Time Based Operations' context. Validation report associated with SESAR Solution #19.
D02	STEP1 Assessment of Benefits and Costs	Study of the economic feasibility of the implementation and deployment of the CAR tools in High Density ACCs
D68	STEP1 V3 Final Complexity Management OSED	Description of CAR concept in the 'Time Based Operations' context, including operating methods as well as operational scenarios and requirements. OSED associated with SESAR Solution #19
D69	STEP1 V3 Final Complexity Management SPR	Safety and Performance requirements for CAR concept in the 'Time Based Operations' context. SPR associated with SESAR Solution #19.
D70	STEP1 V3 Final Complexity Management INTEROP	Interoperability requirements for CAR concept in the 'Time Based Operations' context. INTEROP associated with SESAR Solution #19.
D25	STEP2 Initial Validation Report	Design as well as results analysis and conclusions from the initial validation activities performed at V1 maturity level which addressed the application of CAR concept in the 'Trajectory Based Operations' context.
D75	STEP2 V2 Final Validation Report	Results analysis and conclusions from the validation activities performed at V2 maturity level which addressed the application of CAR concept in the 'Trajectory Based Operations' context.
D39	STEP2 V2 Final OSED	Description of CAR concept in the 'Trajectory Based Operations' context, including operating methods as well as operational scenarios and requirements.
D40	STEP2 V2 Final Safety and Performance Requirements (SPR)	Safety and Performance requirements for CAR concept in the 'Trajectory Based Operations' context.
D41	STEP2 V2 Final Interoperability Requirements (INTEROP)	Interoperability requirements for CAR concept in the 'Trajectory Based Operations' context.

1.4 Contribution to Standardisation

The project has not contributed to any standardisation activities.

1.5 Project Conclusion and Recommendations

'Time Based Operations' context:

Conclusions:

The following concepts elements addressed by SESAR Solution #19 reached the V3 maturity level:

- Complexity Assessment to detect potential overloads from three hours to 20 minutes before sector entry through:
  - Algorithmic Approach (ready to be deployed);
  - Cognitive Approach (mature enough to be deployed although some improvements are needed before implementation such as enriching the workload computation with specific parameters of each sector or introducing corrective factors for the assessment of the contribution of each flight to the complexity of the sector);
- Automated support to analysis and preparation of potential solution by means of trajectory or capacity management, including Trajectory and Airspace What-if functionality.

The project confirmed that the ACC Supervisor and Local Traffic Manager (LTM) roles are responsible for the tasks associated with the previous aspects of the CAR concept. But the final decision on which specific actor should be assigned to those roles is strongly dependant on the local geographical and operational environment.

However, additional concept elements related to the automated support for trajectory management, in particular, the coordination and implementation phases, still requires further work to reach the end of V3 maturity level in SESAR 2020, both at concept (operating procedures and related roles) and validation level.

Moreover, it should be noted that Lyapunov-Convergence Approach to predict complexity requires further work to reach the end of V3 maturity level.

Recommendations:

Based on the conclusions described above, the following recommendations are formulated for the V4 phase in the context of the forthcoming SESAR 2020:

- The information provided by the complexity tool could be improved by providing additional information that contribute to increase the situational awareness in the decision making process;
- The usability of the complexity tool interface could be improved by making it more intuitive and flexible;
- Additional Fast Time Simulations or mathematical modelling techniques are recommended to quantify capacity (En Route throughput) improvements.

'Trajectory Based Operations' context

Conclusions:

In the context of the 'Trajectory Based Operations', the validation activities performed by P04.07.01 lead to the following conclusions:

- The CAR concept in the 'Trajectory Based Operations' is mainly in mid stage of V2;

- The use of the cognitive approach model to assess workload indicators based on the newest psychological theories was shown as feasible although further work should be performed to ensure a full calibration;
- The algorithmic approach model to assess complexity provided very useful and reliable information (workload prediction) to support the decision making process related to the complexity resolution. Providing the complexity method (i.e. parameters and weightings in the algorithm) to the user should allow them understanding the workload prediction;
- The automated complexity prediction, the what-if and sectorisation optimizer functionalities of the local complexity prototype were considered useful to support human actor in the detection of complexity imbalances as well as in their resolution by means of the selection of the most appropriate airspace configuration or the application of STAM. Nevertheless, future V2 work is required to improve the usability of these functionalities;
- The graphical presentation of the air situation is useful for the human operator, increasing the situational awareness;
- The integration of the complexity tool with rostering tool proved to be very useful to increase ATCo productivity;
- The use of METEO information to predict complexity was basic and not fully automated. Further work should be performed to achieve a full automation;
- A preliminary assessment of impact on KPAs was performed. The optimisation of airspace configuration supported by the use of a complexity tool showed a positive impact on capacity, cost efficiency and safety.

Recommendations:

Based on the conclusions described above, the following recommendations are formulated to evolve the CAR concept development and validation in SESAR 2020:

- For fine adjustment of the cognitive model parameters in a 'Trajectory Based Operations' context, a sensitivity analysis should be performed to evaluate the effect of a change in them on the output. This will allow identifying the most critical parameters in the model;
- Tuning parameters in the algorithmic approach should be performed in order to achieve an appropriate support to INAP processes;
- Analysis of the use of intelligent self-learning automated processes in post-analyses in order to allow a dynamic approach for parameters tuning in the algorithmic approach within reasonable cost of maintenance;
- Further validation activities should be performed in order to quantify properly the benefits from the CAR concept fully integrated into the DCB processes;
- Automated approach to integration of TSA data for high complexity ATM environments supporting DAC management. The areas with lower complexity levels don't require full automation;
- Roles and responsibilities related to the INAP processes should be further investigated in order to ensure that safety levels are maintained;
- Further work is needed for establishing links between the local working methods in ATFCM and ATC and the distribution of the INAP tasks between the actors.

Moreover, the scope of SESAR Solution #19 was limited and some conceptual elements of the initial concept didn't reach end V3 maturity level. So, the following recommendations were stated paving the way for the further work in SESAR 2020:

- Further concept development and validations integrating CAR concepts with new controller tools and sector team operations adapted to new roles as Extended ATC Planner (EAP) or Multi Sector Planner (MSP) should be performed;
- The trajectory management measures coordination with adjacent centres should be further investigated;

- Refinement of the operational procedures for trajectory management measures implementation is required;
- The improvement of the trajectory demand thanks to downlink of aircraft trajectory should be addressed.

2 References

[1] SESAR Programme Management Plan, Edition 03.00.01

[2] European ATM Master Plan

[3] Multilateral Framework Agreement ("MFA") signed between the SJU, EUROCONTROL and its 15 selected members on August 11, 2009, amended on 14 June 2010, 19 October 2010 and 2 July 2012

[4] B.01 Integrated Roadmap, DataSet 15, December 2015

[5] 04.07.01, Step1 Consolidation of previous studies, D01, Edition 00.01.00, 13/12/2010

[6] 04.07.01, Step1 Assessment of Benefits and Costs, D02, Edition 00.01.01, 02/09/2016

[7] 04.07.01, Step1 Final Operational Requirements (version 1), D03, Edition 00.01.02, 03/03/2011

[8] 04.07.01, Step1 Final Operational Concept (final version), D04, Edition 00.01.00, 05/07/2012

[9] 04.07.01, Step1 Final Operational Concept (version 1), D05, Edition 00.01.00, 03/03/2011

[10] 04.07.01, Step1 Final Safety and Performance Requirements (SPR) (version 1), D07, Edition 00.01.00, 03/03/2011

[11] 04.07.01, Step1 Final Safety and Performance Requirements (SPR) (final version), D08, Edition 00.01.00, 05/07/2012

[12] 04.07.01, Step1 Final Interoperability Requirements (INTEROP) (version 1), D09, Edition 00.01.00, 03/03/2011

[13] 04.07.01, Step1 V3 Validation Plan, D11, Edition 00.02.00, 14/10/2012

[14] 04.07.01, Step1 Validation Exercise 1, D12, Edition 00.01.00, 29/02/2012

[15] 04.07.01, Step1 Final Validation Report-1, D13, Edition 00.01.00, 29/02/2012

[16] 04.07.01, Step1 Final Validation Report-2, D14, Edition 00.02.00, 30/04/2015

[17] 04.07.01, Step2 Initial Operational Concept - output 4.2, D16, Edition 00.01.00, 28/12/2012

[18] 04.07.01, Step2 V2 Validation Plan, D23, Edition 00.01.00, 05/12/2014

[19] 04.07.01, Step2 Initial Validation Report, D25, Edition 00.02.00, 19/04/2013

[20] 04.07.01, Step2 Preliminary OSED, D26, Edition 00.02.00, 18/03/2016

[21] 04.07.01, Step2 Preliminary Safety and Performance Requirements (SPR), D28, Edition 00.01.00, 17/12/2015

[22] 04.07.01, Step2 Preliminary Interoperability Requirements (INTEROP), D29, Edition 00.01.00, 23/12/2015

[23] 04.07.01, Step2 V2 Initial Validation Report, D37, Edition 00.02.00, 02/12/2015

[24] 04.07.01, Step2 V2 Final OSED, D39, Edition 00.01.01, 06/09/2016

[25] 04.07.01, Step2 V2 Final Safety and Performance Requirements (SPR), D41, Edition 00.01.01, 06/09/2016

[26] 04.07.01, Step2 V2 Final Interoperability Requirements (INTEROP), D42, Edition 00.01.01, 06/09/2016

[27] 04.07.01, Step1 V3 Interim Complexity Management OSED, D62, Edition 00.01.01, 14/07/2015

[28] 04.07.01, Step1 V3 Interim Complexity Management SPR, D63, Edition 00.01.01, 16/07/2015

[29] 04.07.01, Step1 V3 Interim Complexity Management INTEROP, D64, Edition 00.01.01, 30/04/2015

[30] 04.07.01, Step1 V3 Validation Plan (final version), D65, Edition 00.01.02, 01/09/2014

[31] 04.07.01, Step2 V2 Assessment of Costs and Benefits, D67, Edition 00.01.00, 27/09/2016

[32] 04.07.01, Step1 V3 Final Complexity Management OSED, D68, Edition 00.02.00, 04/10/2016

[33] 04.07.01, Step1 V3 Final Complexity Management SPR, D69, Edition 00.02.00, 23/09/2016

[34] 04.07.01, Step1 V3 Final Complexity Management INTEROP, D70, Edition 00.02.00, 23/09/2016

[35] 04.07.01, Step1 V3 Validation Plan (final version Edition 2), D71, Edition 00.02.00, 03/12/2015

[36] 04.07.01, Step1 Final Validation Report 3, D72, Edition 00.02.00, 21/09/2016

[37] 04.07.01, Step2 V2 Validation Plan (final version), D74, Edition 00.01.01, 18/08/2016

[38] 04.07.01, Step2 V2 Final Validation Report, D75, Edition 00.01.01, 28/09/2016

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