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Abstract

Solution PJ.09-W2-44 validation activities validate the integration of demand and capacity measures into the decision-making process in the pre-tactical and tactical phase of air traffic control. This is done through several validation exercises, including real time simulations, shadow mode technique, and feasibility assessments. These exercises provide evidence of the benefits of integrating demand and capacity measures, evaluate the complexity assessment automation support, evaluate the responsibilities and roles of actors involved in the process, and assess the feasibility of using advanced airspace structures and algorithms. Overall, the goal of these validation activities is to ensure the operational feasibility and safety of the solution. This Contextual note provides SESAR (Single European Sky ATM Research) Solution description for industrialisation consideration.

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1 Purpose

This contextual note provides to any interested reader (external and internal to the SESAR programme) an introduction to the SESAR PJ.09-W2-44 Solution in terms of scope, main operational and performance benefits, relevant system impacts. It introduces the technical data pack comprising the SESAR JU deliverables.

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2 Improvements in Air Traffic Management (ATM)

The objective of this solution is to improve the use of airspace capacity for both civil and military users by increasing the granularity and the flexibility in the airspace configuration and management within and across ANSPs' areas of responsibilities. It addresses the integration of Dynamic Airspace Configurations (DAC) concepts and procedures to allow flexible sectorisation boundaries to be dynamically modified based on demand. The Solution emphasises the INAP (Integrated Network management and Air traffic control Planning) timeframe (from -6 hours to -15 min, the limits thresholds adjusted according to local specificities).

DAC aims to optimize airspace usage for civil and military users by providing more granular and flexible airspace configurations within the Air Navigation Service Providers' (ANSPs) areas of responsibility. This involves creating sector designs and dynamically configuring sectors based on predicted traffic and user-preferred trajectories in a complex, free-route environment. DAC is integrated with the INAP system, which considers workload and complexity values. It also considers potential impact assessment for air traffic control operator licenses, international boundaries, and IOP and A/G multi-datalink communication capabilities. DAC is part of a larger project known as Digital Network Management Services, which aims to improve network traffic predictability and shared complexity representation for all actors involved in demand capacity balancing (DCB) and collaborative network performance management.

The Solution addresses four capabilities (as defined in the European ATM Master Plan):

- Air Traffic Flow Management: Adequate automatic support for spot detection, traffic analysis and measure monitoring, including new features to support the analysis and resolution of hotspots, namely what-if and what-else.
- Airspace Configuration Management: Further development of the DAC (Dynamic Airspace Configuration) concept for DCB (Demand and Capacity Balancing) integration, including the implementation of the optimised configurations and the seamless integration of DAC at pre-tactical and tactical phases.
- Collaborative Network Management: Alignment of processes, roles, and measures, ensuring the right level of coordination and shared situation awareness at local, sub-regional and regional network levels.
- Network Situational Awareness: Development of new indicators to fine-tune analysis and ease monitoring, namely the complexity.

The Solution further develops the DAC concept by:

- Developing optimised functions for hotspots resolution based on both capacity and demand measures.
- Defining a Sector Configuration Performance Based Approach according to a set of DAC KPA/KPI Assessment Criteria linked to adequate What-if functions
- Establishing guidelines for the design of DAC airspace basic structures: i.e.: Airspace Building Blocks and Controlling Building Blocks.
- Identifying proper criteria to set the Airspace Block Attributes which optimise Sector Configuration.

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- Integrating the use of complexity, ATCo (Air Traffic Controller) workload and ATCo availability within the sector configuration optimisation process.
- Reinforcing a seamless DCB process (ASM-ATFM-ATC CDM (Collaborative Decision Making) processes).
- Including Cross Border Dynamic Airspace Configurations.
- Fully integrating the concept within the Network Operations Plan (NOP).

Solution W2-44 is related to other SESAR solutions:

- **Solution PJ.07-W2-38** 'Enhanced integration of AU (Airspace Users) trajectory definition and network management processes' for the analysis of the impact of ATM planning on AUs' costs of operations.
- **Solution PJ.07-W2-39** 'Collaborative framework managing delay constraints on arrivals' oversees the development of a collaborative framework involving AUs, NM (Network Manager) and Airports (through Airport Operations Centre -APOC- coordination).
- **Solution PJ.07-W2-40 '**Initial 4D Mission Trajectory development with integrated DMA types 1 and 2 supported by automation and dynamic civil-military CDM' receives information from the NM and uses the functionality developed for W2-44.
- **Solution PJ.09-W2-45** 'Enhanced Network Traffic Prediction and shared complexity representation' (also cancelled and its work continued partly within PJ.09-W2-44 and partly outside the SESAR program), provides the basis for the what-else function, and an enhanced traffic prediction.
- **Solution PJ.09-W2-49** 'Collaborative Network Performance Management' intended to provide a common framework to assess and share network performance. However, this solution was cancelled. Nevertheless, part of the work envisioned within this solution is continued outside the SESAR program.
- **Solution PJ.10-W2-93** 'Delegation of services amongst ATSUs' for cross borders operations describing the delegation roles and responsibilities.

The exercises related to the Solution PJ.09-W2-44 DAC cover six operational improvements (OIs) looking for more flexible and efficient Sector Design and Configuration (SD&C) processes and procedures; higher automation in the Airspace Management (ASM) process; a better use of complexity to support them both; and the achievement of an effective integration of demand and capacity measures to implement DCB processes at INAP timeframe.

The validation of these OIs implicitly validate new roles and responsibilities for the Local Traffic Manager (LTM), Extended ATC (Air Traffic Control) Planner (EAP), and Air Traffic Service Unit (ATSU) Supervisor as well as their system support needs. Moreover, PJ.09-W2-44 validation infrastructure envisages the use of algorithms for facilitating the SD&C and the DAC/DCB integration. PJ.09-W2-44 validation prototypes include:

- Improved ASM and Air Traffic Flow Management (ATFM) tools supporting DAC.
- DCB tools supporting FMP (Flow Management Position) and EAP in the assessment, monitoring, and implementation of the DCB measures, integration of automated complexity assessment, integration of ATCO resource management and sector configuration planning, coordination with DMA (Dynamic Mobile Area) design and integration with NM services.
- Controller Working Position (CWP) support functions to ATC task in DAC environment.

A total of seven validation exercises involving ten European ANSPs (ENAIRE, DSNA, NATS, ENAV, SKYGUIDE, CCL, Naviair, LFV, ACG and PANSA) and EUROCONTROL validates the concept over the

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European Civil Aviation Conference (ECAC) area including validation activities over the European airspace.

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3 Operational Improvement Steps (OIs) & Enablers

The table below presents the OI (Operational Improvement Steps) steps and enablers included in this solution as reflected in the current EATMA (European ATM Architecture) Data set 22. The table indicates if the enabler is used/developed by the solution or if it is optional.

SESAR Solution ID	SESAR Solution Description	Master or Contributing (M or C)	OI Steps ID and Title (from EATMA)	Enablers ID and Title (from EATMA)	OI/EN Coverage
PJ.09-W2-44	Dynamic Airspace Configuration	M	AOM-0805: Collaborative Airspace Configuration	AAMS-13 ASM scenario management sub-system equipped with tools for assessing the impact of airspace changes on capacity	Full use
				AIMS-04 (Optional) Network management functions supported with real-time airspace data	Full Use
				ER-APP ATC 80 Enable ATC System to Use Dynamically-Defined Airspace Reservations	Full Develop
				NIMS-04: ATFCM capacity planning sub-system enhanced to take into account dynamic sector shapes	Full Use
				NIMS-30 ATFCM scenario management equipped with tools for assessing the impact of DAC and	Full Use

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SESAR Solution ID	SESAR Solution Description	Master or Contributing (M or C)	OI Steps ID and Title (from EATMA)	Enablers ID and Title (from EATMA)	OI/EN Coverage
				capacity changes on trajectory efficiency	
				PRO-010 (optional) Procedures to ensure that all actors involved in the airspace reservations are well aware about the real status of airspace availability and subsequent changes	Full Use
			AOM-0809-A: Initial Sector Design and Configurations Unconstrained by Predetermined Boundaries	NIMS-04: ATFCM capacity planning sub-system enhanced to take into account dynamic sector shapes	Full Develop
				NIMS-30 ATFCM scenario management equipped with tools for assessing the impact of DAC and capacity changes on trajectory efficiency	Full Use
				PRO-010 (optional) Procedures to ensure that all actors involved in the airspace reservations are well aware about the real status of airspace availability and subsequent changes	Full Use
			CM-0102-B: Dynamic	AAMS-19 Dynamic Airspace	Full

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SESAR Solution ID	SESAR Solution Description	Master or Contributing (M or C)	OI Steps ID and Title (from EATMA)	Enablers ID and Title (from EATMA)	OI/EN Coverage
			Airspace Management based on complexity	Configuration tools for the Integrated local DCB working position	Develop
			DCB-0210: Full integration of Dynamic Airspace Configurations into DCB	AAMS-02 Dynamic Airspace Configuration tools for the Integrated Network Working Position	Full Develop
				NIMS-30 ATFCM scenario management equipped with tools for assessing the impact of DAC and capacity changes on trajectory efficiency	Full Use
				SVC-073 Consumption of G/G and initial A/G ASM-ATFCM Information Services on Wide Area communications	Full Use
			CM-0104-C: Automated Support to INAP (Integrated Network Management and Extended ATC Planning) Function	ER-APP ATC 17 Enhance Traffic and Flow Management sub-systems to support dynamic flow management in co-ordination with local, regional, and European levels	Full Use
				NIMS-46 Integrated local DCB working position	Full Develop

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SESAR Solution ID	SESAR Solution Description	Master or Contributing (M or C)	OI Steps ID and Title (from EATMA)	Enablers ID and Title (from EATMA)	OI/EN Coverage
				SVC-073 Consumption of G/G and initial A/G ASM-ATFCM Information Services on Wide Area communications	Full Use
			CM-0103-B: Automated Support for Traffic Complexity Assessment	NIMS-36 Enhanced Complexity Assessment Tool	Full Develop

Table 1: SESAR Solution PJ.09-W2-44 Scope and related OI steps/enablers

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4 Background and validation process

Solution PJ.09-W2-44 validation activities aim at achieving V3, thus addressing the blocking issues identified in V2 regarding human performance and safety assessment and addressing the full integration of DAC into DCB in the pre-tactical and tactical phase. To ensure operational feasibility, four operational aspects are relevant to solution PJ.09-W2-44 validation:

- Provide **evidence of the benefits of integrating demand and capacity measures** at INAP phase, in local and Network ATM performance while minimising the impact on AUs performance.
- The **evaluation of the complexity assessment automation support** as an enabler for the integration of demand and capacity measures in INAP phase.
- The evaluation of the **responsibilities and roles of the actors involved in DAC CDM process**, especially at INAP phase when the combined use of demand and capacity DCB measures will take place.
- Feasibility assessment of **the use of DAC airspace advanced type of structures and DAC algorithms** considering an adequate trade-off between the SD&C dynamicity, the level of automation and human factors accountability.

To do so, validation exercises combining FTS (Fast Time Simulations), RTS (Real Time Simulations) and Shadow Mode techniques emulate the full process of DAC SD&C as integrated within the DCB process, including the evaluation of the ATC service in DAC environment once the output of the DCB process is implemented. Most of the exercises contribute in some extent to the four operational aspects mentioned above, the paragraphs below describe how the exercises complement to fully address them.

The evidence of the benefits of integrating demand and capacity measures

The evidence of the benefits of integrating demand and capacity will be provided by demonstrating the concept capability to deliver a DCB plan able to meet performance targets while effectively solving the potential imbalances. Five out of the eight validation activities will be looking at this aspect:

- During the real time simulations, the effectiveness of the imbalance resolution mechanisms was evaluated through the assessment of ATCO experienced workload and Situational Awareness (SA) **(EXE-PJ.09-W2-44-V3-VALP-001 and EXE-PJ.09-W2-44-V3-VALP-005)**.

- It was also evaluated through the assessment of LTM's and Supervisors' workload and situational awareness through shadow mode technique **(EXE-PJ.09-W2-44-V3-VALP-003)**.

- **EXE-PJ.09-W2-44-V3-VALP-004 and EXE-PJ.09-W2-44-V3-VALP-005 RTSs** assessed the DCB resolutions applied by the LTM when they are supported by DAC tools.

The evaluation of the complexity assessment automation support

The use of workload and complexity methods to support ATFCM was integrated in all the exercises previously referred.

- **EXE-PJ.09-W2-44-V3-VALP-004** (with focus in early phase INAP) and **EXE-PJ.09-W2-44-V3-VALP-003** (in the latest INAP phase) evaluated the feasibility of using complexity/workload

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support in the ATFM position; and the roles and responsibilities assigned to the LTM, EAP and Supervisor. **EXE-PJ.09-W2-44-V3-VALP-006** evaluated how to de-complexity of traffic with STAM (Short Term ATFCM Measures) features.

- **EXE-PJ.09-W2-44-V3-VALP-001** evaluated the use of complexity in the support of the airspace configuration process. **EXE-PJ.09-W2-44-V3-VALP-005** used complexity to detect imbalance and allow invoking a DAC algorithm to calculate new sector configurations to solve the imbalance.

- **EXE-PJ.09-W2-44-V3-VALP-007** developed a feasible integration of the ATCo Resource Management process into the DAC ATFCM process based on complexity.

The responsibilities and roles of the actors involved in DAC CDM process

The use of B2B services was put in place to get most of the available trajectory information, ensuring optimal local and network performance. CDM processes were assessed during the pre-tactical and tactical phase including military (**EXE-PJ.09-W2-44-V3-VALP-002**, **EXE-PJ.09-W2-44-V3-VALP-003**, **EXE-PJ.09-W2-44-V3-VALP-008**).

The use of DAC airspace advanced type of structures and DAC algorithms

The simulation of the ATFCM and ATC operations validate the operational feasibility of the advanced airspace structures as well as the DAC algorithms supporting the automation of the airspace configuration as part of the DCB process (**EXE-PJ.09-W2-44-V3-VALP-001, EXE-PJ.09-W2-44-V3-VALP-002**, **EXE-PJ.09-W2-44-V3-VALP-003** and **EXE-PJ.09-W2-44-V3-VALP-005**). DMA Type 1 structures are considered in the case of **EXE-PJ.09-W2-44-V3-VALP-008**. **EXE-PJ.09-W2-44-V3-VALP-003** included cross border ACC (Area Control Centre) and **EXE-PJ.09-W2-44-V3-VALP-007** accounting for the integration of the resource management processes.

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5 Results and performance achievements

Regarding Performance evaluation of the different execution runs, the following text summarises the results presented in the VALR:

- The integration of Dynamic Airspace Configuration (DAC) with Demand Measures allows Air Navigation Service Providers (ANSPs) to plan and manage airspace configurations based on predicted traffic. The integration improves the use of available capacity by reducing coordination workload and balancing workload between sectors. In some cases, DAC also increases capacity by lowering and balancing Hourly Entry Count (HEC) and Occupancy Count (OCC) methods in the solution scenarios compared to the reference ones. The configuration optimizer is a support tool for the LTMs and the SUPs. It allows the early elaboration of the D-day configuration plan and rostering elaboration, as well as increasing the efficiency and available capacity.
- The combination of STAM measures (cherry-picking delays) and rerouting limits the impact of DMAs on civil traffic.
- DAC contributes to have fewer regulations with less delay and fine-tuned parameters.
- Workload is better distributed and more balanced if the sector configuration is carefully selected. In general, workload was considered acceptable for ATC execution.
- Predictability metric improved in the solution scenarios, as the standard deviation of the flight duration variability decreased.
- Cost efficiency improved in the solution scenarios. There was an overall reduction of delays and improvements regarding elaboration times, Situational Awareness, and Mental workload.
- There was a slight improvement on flight efficiency and fuel consumption when including DAC into the DCB process. Even if these results showed that there was not a substantial increase of efficiency, the distribution of complexity over the airspace from the DAC algorithm was improved.
- The number of minor incidents (separation minima infringements) were similar in both reference and solution scenarios. There was no negative impact on safety in the pre-tactical and tactical phase.

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6 Recommendations and Additional activities

The results of the validation process indicate that the OIs and enablers assigned to solution W2-44 are ready for industrialisation. The validation process has covered the application of DAC and STAM, as well as the integration of DAC and DCB, as well as DAC and INAP. It has also addressed issues related to the civil / military integration. The resulting functionality has been integrated into a DCB working position that supports the operation of the LTM actor ensuring that Situational Awareness is maintained or increased during operation.

From a technological standpoint, the validation has proven the viability of the DAC algorithms, including optimal opening schemes and DMA locations. It has also validated improvements in the application of STAM designed to ensure a successful exploration of options using traffic and sector what-if tools. The validation process has also allowed for increases in accuracy and representativity of workload and complexity indicators.

Following validation, recommendations have been made regarding operational requirements and technologies based on inputs from operators. These recommendations primarily identify areas for improving or expanding the operation described in the W2-44 OSED (Operational Service and Environment Description). The recommendations are divided into three sets:

- Those that address the operation of the DAC concept and could be considered for industrialization.
- Those that need further development as part of industrialization.
- Those that lead to expanded capabilities.

Recommendations regarding the operation of the DAC concept:

- Given the current state of technology and tools, the most efficient time to design DAC related measures is the day before operation.
- Sector shapes that are radically different from existing ones are not operationally efficient because there is a risk that ATCO situational awareness is degraded (there is no pre-existing operational experience).
- Sometimes, it is more effective to make smaller changes more frequently to sector shapes instead of radical changes.
- Combining ATCo roster management into the design and application of DAC measures can increase efficiency.
- Cherry picking flights performs better when selecting flights which are close to the end of an existing regulation or to the end of DMA activity.

Recommendations to be considered as part of the industrialization process:

- Training and licensing needs and requirements must be considered to ensure successful implementation.
- A full safety assessment of the operation should be performed.
- Operational criteria must be included in the algorithms when calculating new sector shapes, and these criteria should be chosen as needed by the operator.

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- In high-automation situations, solutions generated by the system may be less socially acceptable than the manual option. As a result, the validation process needs to be adapted to increase the operator's trust in the system.
- To prevent information overload, it is necessary to improve the HMI. One way is by filtering discarded solutions.
- Introducing a feature that allows users to "scroll" through traffic with corresponding sectorisation, both into the future and the past, could provide a significant operational advantage.
- To achieve significant performance improvements in the solution, it is recommended to increase the dynamicity of the new sector calculation through the application of DAC.

Recommendations leading to enhanced capabilities:

- Enhance the operational processes to include continuous automated refinement for maintaining or increasing efficiency and effectiveness.
- To enhance the design of DAC measures, it is recommended to increase the number of optimization criteria by incorporating additional Key Performance Indicators (KPIs), such as occupancy and fuel consumption. This will help to improve the overall performance of the solution.
- It is recommended to improve the What-If tool by adding automated flight and measure selection to expand its capabilities.
- The enhanced DAC algorithm should include user-demanded options like the configuration path and performance improvements such as reducing configuration identification times.
- It is recommended to improve the traffic demand in the pre-tactical time range, specifically from 24 hours to 15 minutes before the time of operation.
- It is recommended to estimate the impact of implementing a demand/capacity measure.
- Develop automated, AI-driven Digital NM Operations Centre (NMOC) functions such as flight selection, measure selection, and coordination frameworks to improve efficiency and coordination at the national level. This should be seen as the counterpart to the Digital assistant to INAP at the local level.

The future steps of the DCB domain rely heavily on digitalizing various tools and processes. This shift towards digitalization will require a change in the validation approach from the traditional waterfall model, which focuses on functionality, to a distributed model. The new model should be based on assessing capability, trust, and completeness, and should be structured around a service-oriented architecture.

Our proposal is to implement a SESAR Digital Sky Demonstrator (DSD) specifically for the DCB area. The DSD will serve as a simulation platform that will bring together different tools and systems used in airspace design, traffic flow management, air traffic control, and flight planning. By involving various stakeholders such as air navigation service providers, network managers, airlines, and airports, we aim to evaluate the benefits and challenges of DCB in terms of efficiency, safety, flexibility, and scalability.

The primary objective of the DSD is to test the technical feasibility and performance of DAC tools and systems. Additionally, the DSD will quantify the operational benefits and impacts of DAC on different actors, identify the main enablers and barriers for DAC deployment, and develop a roadmap for further development and integration of DAC in the SESAR digital sky. To achieve these goals, the DSD will have seven primary objectives:

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1. Optimize airspace and airport capacity utilization by using advanced data analytics to develop algorithms and tools for dynamic airspace configuration, and flexible route planning. These tools will be based on real-time data analysis, weather forecasting, and traffic flow management.
2. Develop real-time demand forecasting and capacity planning tools that enable efficient decision-making for air traffic controllers, airlines, and airport operators. These tools will use advanced data analytics to provide insights into future demand patterns, supporting efficient decision-making.
3. Evaluate the effectiveness of new operational concepts and technologies for improving demand and capacity balancing in a simulated environment. This would include the testing of new automation systems, decision support tools, and communication protocols.
4. Clarify the complementarity and synergy between protection hotspots and other types of hotspots, to better understand how different types of hotspots can be effectively managed in an integrated manner to optimize airspace capacity and reduce delays.
5. Refine the procedures related to the management of infringers in the context of the hotspot management processes. This objective focuses on identifying and communicating infringement information effectively and implementing appropriate penalisation measures.
6. Refine procedures and local DCB systems requirements related to the management of AU Priority (FDCI[1], and UDPP[2]) flights within the context of the hotspot management processes. This objective aims to minimize the impact of these flights on airspace capacity and ensure that they are managed effectively to optimize demand and capacity balancing.
7. Showcase the benefits of SESAR Digital Sky technologies to industry stakeholders, including air navigation service providers, airlines, airports, and regulators. This would involve engaging with stakeholders to gather feedback on the proposed solutions and to demonstrate how the system works.

[1] FDCI: Flight Delay Criticality indicator

[2] UDPP: User Driven Prioritisation Process

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7 Actors impacted by the SESAR Solution

The following is the list of actors impacted by the Solution. The reader is referred to the EATMA website (https://www.eatmportal.eu/) for a full description of each one of them.

- ACC/Approach/TMA Supervisor
- ATC Executive Controller
- ATC Planning Role
- ATSEP Air Traffic Safety Electronics Personnel
- Complexity Manager
- Extended ATC Planner (EAP)
- Flight Data Operator
- Local Capacity Manager
- Local Traffic Manager
- Multi Sector Planner
- Technical Supervisor

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8 Impact on Aircraft System

Not applicable.

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9 Impact on Ground Systems

To support dynamic airspace configuration, ground systems must be able to process and display real-time data from multiple sources, including aircraft, weather sensors, and other systems quickly and accurately. This requires sophisticated software and hardware systems that can process substantial amounts of data in real-time and provide controllers with the information they need to make informed decisions. Additionally, controllers must be trained to use these systems effectively and to respond quickly to changing conditions to ensure the safe and efficient operation of the air traffic system.

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10 Regulatory Framework Considerations

Potential standardisation of Air Traffic Controllers licences regarding the implementation of DAC concept and based on non-geographical licence approach that is tackled by SESAR Wave 2 Solution 73-C. No further activity has been identified on this regard.

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11 Standardization Framework Considerations

No added work found for international standardisation organisations.

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12 Solution Data pack

The Data pack for this Solution includes the following documents:

- OSED/SPR [**D2.1.101 - PJ.09-W2-44-V3 Final SPR-INTEROP/OSED**]: The document provides contextual information, but in terms of operational requirements for solution W2-44. SPR (Safety and Performance Requirements) contains the safety and performance requirements for the Dynamic Airspace Configuration (DAC) concept. INTEROP contains the interoperability requirements.
- Technical Specifications [**D2.1.102 - PJ.09-W2-44-V3 Final TS/IRS**]: This document refines the functional analysis of the Dynamic Airspace Configuration (DAC) concept.
- Validation Report [**D2.1.104 - PJ.09-W2-44-V3 Final VALR (Validation Report)**]: This document provides detailed information about the validation process and results.
- CBA (Cost Benefit Analysis) [**D2.1.103 - PJ.09-W2-44-V3 Final CBA**]: This document presents an analysis of the costs and benefits associated with the implementation and exploitation of the DAC concept.

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