Exploratory Research Report

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Abstract

This report summarises the validation activities conducted within the HUCAN project, which aimed to develop a certification-aware design approach for ATM solutions that leverage advanced automation and artificial intelligence (AI). The project delivered two SESAR solutions: SOL.0445, which proposes a holistic certification approach for highly automated ATM systems; and SOL.0446, which offers preliminary guidelines for integrating AI certification objectives into SESAR validation frameworks. Supported by a Stakeholder Consultation Group and an Expert Group, validation activities confirmed the overall feasibility and relevance of the approach, while also identifying areas for improvement, particularly with regard to integrating industrial practices. The results support the continued refinement and application of the HUCAN framework, consistent with its early maturity level (TRL 2).

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HUCAN

HOLISTIC UNIFIED CERTIFICATION APPROACH FOR NOVEL SYSTEMS BASED ON ADVANCED AUTOMATION

HUCAN

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1 Executive summary

This report presents an overview of the validation activities carried out within the HUCAN project, which aimed to develop a certification-aware design approach for Air Traffic Management (ATM) solutions based on advanced automation and Artificial Intelligence (AI). The project delivered two SESAR Solutions:

- SOL.0445: A holistic and iterative certification approach for ATM systems with higher levels of automation, embedding certification objectives from the early design stages.
- SOL.0446: A set of preliminary guidelines offering practical recommendations to integrate AI certification objectives into SESAR validation frameworks.

Validation activities focused on collecting feedback on the relevance and applicability of the proposed solutions. An initial Stakeholder Consultation Group (SCG) helped shape the direction by providing input on research and certification needs. For the validation phase, an Expert Group (EG) was established, comprising representatives from regulatory authorities, developers and deployers, and R&I experts.

The SCG confirmed a positive reception of the HUCAN approach. While participants found many elements of the framework readily understandable, dimensions such as Human Agency, Liability, Fairness, and Diversity & Social Wellbeing required further expert input. The discussions highlighted the importance of a multidisciplinary team, as well as the interdependence and evolution of different dimensions across the development lifecycle.

The EG generally provided positive feedback on the validity and practical value of the HUCAN approach (solution SOL.0445), especially in light of the specific certification challenges associated with AI and advanced automation in aviation. Developers and deployers recommended adapting the associated toolbox to better align with current industrial validation practices, to enhance its usability and applicability in future R&I activities. They reported challenges in implementing the proposed process and workflow and suggested the development of dedicated operational guidelines. Additional recommendations included refining the toolbox to better reflect established industrial practices. Overall, there was strong appreciation for the integration of certification aspects within the existing Key Performance Areas (KPAs) traditionally used in the design and validation of aviation solutions. This approach was valued for building upon established knowledge and practices, rather than requiring the development of entirely new skillsets.

In perspective, the quality and significance of the validation results for the HUCAN preliminary guidelines (solution SOL.0446) can be considered moderate, primarily due to limitations such as the limited number of participants and interactions, as well as contextual conditions affecting the applicability of the validation approach. Nonetheless, the validation activities confirmed the overall feasibility of the HUCAN preliminary guidelines. Importantly, these limitations do not negatively impact the maturity assessment of the concept, which remains consistent with its current early-stage development level (TRL 2).

Co-funded by the European Union

2 Introduction

2.1 Purpose of the document

The HUCAN project proposes a novel approach for certification-aware design and validation of new ATM systems embedding higher levels of automation, including those based on AI and Machine Learning (ML). The proposed approach is intended to support both the approval/certification and the design phases of such technologies.

According to the SESAR 3 JU Project Handbook (SESAR, 2024), the Exploratory Research Report (ERR) is intended to consolidate the results obtained by an exploratory research project once the validation activities, experiments, etc, have been completed.

This document illustrates the results of the validation process, according to the strategy defined in the Project Management Plan (PMP, D1.7) and in the Exploratory Research Plan (ERP, D1.2). In addition, the Validation Report (D4.3) of the HUCAN approach, as well as the Guidelines Validation Report (D5.1) should be read as integral parts of this report.

2.2 Intended readership

This document is addressed to the SESAR community, as well as to granting, regulatory, and certification bodies concerned with the scientific robustness of the proposed solutions. It aims to provide a contribution in promoting certification-aware design and validation approaches, thereby fostering future R&I in AI and high-level automation for aviation, and contributing to a more seamless transition from research to market deployment.

2.3 Background

The HUCAN approach is intended to support both the approval/certification and the design phases of automation and AI-powered technologies, developing to this end two products, which have been identified as the solutions produced by the project: (1) a new holistic and unified certification method for highly automated systems, whose main target users are EASA, national aviation authorities, qualified entities, and ANSPs, and (2) a set of suitable design guidelines and associated toolkit for streamlining the development of automation and AI-powered technologies.

For the design and development of such products, the project reviewed the most prominent trends and challenges in automation and AI research and applications regarding ATM systems, also analysing possible approaches developed in other socio-technical and safety-critical domains, and taking into account all possible impacts of higher levels of automation, including those on ATCOs licence and training.

A parallel analysis of certification approaches, legal and regulatory features, and critical issues of such technologies was carried out. Case studies focusing specifically on capacity on demand and dynamic airspace were considered in order to evaluate the quality of the findings that emerged from the theoretical research, and to inform the design of both the approval/certification approach and the design guidelines produced by the project.

Accordingly, HUCAN solutions have drawn on the results previously developed within the project and documented in the following deliverables:

- D3.1 – *Certification methods and automation: benefits, issues and challenges*;
- D3.2 – *Innovative approaches to approval and certification*;
- D4.1 – *Case studies introduction: level of automation analysis and certification issues*; and
- D4.2 – *Performance-based requirements for advanced automation*.

In addition, the project's research strategy has also built upon insights from prior research initiatives, as listed in the following table (Table 1).

Project	Subject/Relevance	Partner
ASCOS	The ASCOS (Aviation Safety and Certification of new Operations and Systems) project was financed by EC/FP7. It is especially relevant for changes which challenge existing approval approaches, either because of novel technologies or because they impact multiple approval domains.	NLR DBLUE
ALIAS and ALIAS II	The SESAR project ALIAS (Addressing Liability Impact of Automated Systems), and its follow-up ALIAS II allow the development of the Legal Case. The Legal Case is a methodological tool intended to support the integration of automated technologies into complex systems. More specifically, it is aimed at identifying and addressing liability issues in automated ATM systems, ensuring that these issues are clearly identified and dealt with at the right stage in the design, development, and deployment process.	EUI DBLUE
EvoATM	The SESAR project EvoATM studied the optimal allocation of elementary en-route middle airspace sectors in order to minimise the ATCO workload, without violating critical thresholds (safety separation), nor degrading in Capacity and considering possible constraints (such as technical problems, staffing issues, controller shifts). Its proof of concept is one of the case studies addressed by HUCAN.	CIRA
NUVASC 2021-2023	NUVASC 2021-2023 is a national project aimed to model AI algorithms to support the controller in decision making when applying final approach procedures (e.g., Point Merge System trombone routes). Using the Trombone procedure, aircraft join the final approach via a fixed path. Its proof of concept is one of the case studies of HUCAN.	CIRA
ARGOS	ARGOS is a MUAC project to safely handle increased traffic scenarios with the same number of ATCOs as today. The system can automatically issue the necessary operational clearances to safely handle basic traffic situations and aid the controller in handling complex traffic situations. DBLUE elaborated a report about the	DBLUE

	possible liability issues related to the implementation of this tool. The analysis applied the Legal Case methodology and highlighted relevant issues about innovative standardization policies regarding personnel training and performance and safety certification requirements. ARGOS is one of the case studies of HUCAN.	
PJ34 AURA	SESAR2020 IR project PJ34 AURA provided requirements, processes and use cases for application of Dynamic Airspace reconfiguration in U-space Airspace and validated them. Its proof of concept is one of the case studies of HUCAN.	D-Flight

Table 1. Previous research projects of interest to HUCAN

2.4 Structure of the document

This document is structured into five sections. Following the introduction, readers will find an overview of the context of this ERR. This provides an overview of the project and related SESAR solutions, as well as a brief description of the research strategy, the validation activities defined in the ERP, and the deviations that have emerged. Next come the validation results and conclusions, complemented by a set of recommendations. A complete overview is available in the Executive Summary.

2.5 Glossary of terms

Term	Definition	Source of the definition
Advanced Automation	It refers to the use of a system that, under certain conditions, operates without direct human intervention.	ISO/IEC 22989:2022(en), 3.1.7
Air Traffic	All aircraft in flight or operating on the manoeuvring area of an aerodrome.	ICAO Annex 11 - ATS
Artificial Intelligence	Technology that can, for a given set of human-defined objectives, generate outputs such as content, predictions, recommendations, or decisions influencing the environments they interact with.	EASA AI Roadmap 2.0
Air Traffic Management	The dynamic, integrated management of air traffic and airspace including air traffic services, airspace management and air traffic flow management - safely, economically and sufficiently - through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions.	ICAO Doc 4444 - ATM

Certification	Any form of recognition in accordance with this Regulation, based on an appropriate assessment, that a legal or natural person, product, part, non-installed equipment, equipment to control unmanned aircraft remotely, aerodrome, safety-related aerodrome equipment, ATM/ANS system, ATM/ANS constituent or flight simulation training device complies with the applicable requirements of this Regulation and of the delegated and implementing acts adopted on the basis thereof, through the issuance of a certificate attesting such compliance	Regulation (EU) n. 2018/1139 Article 3(9)
ATM/ANS	Air traffic management and air navigation services cover all of the following: the air traffic management functions and services as defined in point (10) of Article 2 of Regulation (EC) No 549/2004; the air navigation services as defined in point (4) of Article 2 of that Regulation, including the network management functions and services referred to in Article 6 of Regulation (EC) No 551/2004, as well as services which augment signals emitted by satellites of core constellations of GNSS for the purpose of air navigation; flight procedures design; and services consisting in the origination and processing of data and the formatting and delivering of data to general air traffic for the purpose of air navigation	Regulation (EU) n. 2018/1139 Article 3(5)
ATM/ANS System	The aggregation of airborne and ground-based constituents, as well as space-based equipment, that provides support for air navigation services for all phases of flight	Regulation (EU) n. 2018/1139 Article 3(7)

Table 2. Glossary of terms

2.6 List of acronyms

Term	Definition
AA	Advanced Automation
AI	Artificial Intelligence
AMPLE3	SESAR3 ATM Master Planning and Monitoring
ANS	Air Navigation Service(s)

ATCO	Air Traffic Control Officer
ATM	Air Traffic Management
DES	Digital European Sky
DMP	Data Management Plan
EASA	European Union Aviation Safety Agency
EC	European Commission
ECTL	Eurocontrol
EG	Expert Group
ERP	Exploratory Research Plan
EU	European Union
EUROCAE	European Organisation for Civil Aviation Equipment
GA	Grant Agreement
HE	Horizon Europe
HF	Human Factor(s)
HRL	Human Readiness Level
HUCAN	Holistic Unified Certification Approach for Novel systems based on advanced automation
ID	Identifier
ISO	International Organization for Standardization
IT	Information Technologies
KPA	Key Performance Area
KPI	Key Performance Indicator
LOA	Level(s) of Automation
M	Month
ML	Machine Learning
MUAC	Maastricht Upper Area Control Centre

PEARL	Performance Estimation, Assessment, Reporting and simulation
PO	Project Officer
R&I	Research & Innovation
RMT	Rule Making Task
SESAR	Single European Sky ATM research
SESAR 3 JU	SESAR 3 Joint Undertaking
SRIA	Strategic Research and Innovation Agenda
TRL	Technology Readiness Level
VALP	Validation plan
VALR	Validation Report
WG	Working Group

Table 3. List of acronyms

3 Context of the exploratory research report

3.1 The HUCAN project: a summary

The HUCAN project addressed the legal and regulatory challenges associated with an Air Traffic Management (ATM) environment featuring higher levels of automation. This goal was designed in line with the SESAR JU's Strategic Research and Innovation Agenda (SRIA) (SESAR JU, 2020), which highlights the need for new methodologies to validate and certify advanced automation (AA). These methodologies must ensure transparency, legal compliance, robustness and operational stability in all conditions while accounting for a future ATM ecosystem built on multiple AI-driven systems with a human-centric approach. Accordingly, the HUCAN project proposes a novel framework for certifying and approving next-generation ATM-related airborne and ground systems incorporating higher levels of automation, including AI- and machine learning-based systems.

From the beginning of the project, however, the legal framework on Artificial Intelligence (AI) and AA has considerably changed, especially in the European Union. In particular, with the entrance into force of the EU AI Act (Reg. (EU) 2024/1689[2]) these evolutions have been affecting the general audience as well as the aviation domain.

Accordingly, the project has read its objectives in light of these advancements, particularly focusing on the applicability of EASA strategic objectives for the certification of AI in aviation (EASA, 2023; EASA, 2024 (a); EASA, 2024 (b)) throughout the SESAR development pipeline.

Against this background, the HUCAN project has developed a certification-aware design approach and a set of preliminary operative guidelines to support the application of certification-aware design in R&D projects on AI and advanced automation in aviation. This commitment produced two SESAR solutions:

- **SOL.0445 – New holistic certification approach for novel ATM related systems based on higher levels of automation**, a holistic and iterative design approach that gradually incorporates strategic AI certification objectives and requirements since the early development cycles of ATM systems based on higher levels of automation.
- **SOL.0446 – Preliminary Guidelines to design ATM-related systems based on higher levels of automation**, a set of operative recommendations to integrate and meet the certification objectives prescribed for AI into the SESAR validation frameworks.

This contribution is in line with the approach and methodologies provided by SESAR 3 JU Project Handbook (SESAR, 2024) and the guidance defined by the SESAR ATM Masterplan 2025 (SESAR, 2025).

[2] Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (Artificial Intelligence Act).

3.2 Summary of the exploratory research plan

3.2.1 Exploratory research plan purpose

The HUCAN project differs from other initiatives funded under the flagship on *Capacity on demand and dynamic airspace* and more generally under SESAR Exploratory Research framework. Rather than introducing a novel technical solution, the HUCAN research approach capitalised on well-established use cases and uses proposed scenarios and developed a certification-aware design approach and a set of preliminary operative guidelines to support the application of certification-aware design in R&D projects on AI and advanced automation in aviation.

In light of this and consistently with Grant Agreement (GA) Annex 1, HUCAN defined the ERP, which can be presented as follows (Table 4).

Scope	Objective	SESAR solution	WP	Deliverable
A novel approach for the certification and approval of new ATM-related airborne and ground systems embedding human-centric AA, including those based on AI-powered solutions	OBJ.1 Landscape of AA within the EU Digital Strategy for Mobility and ATM	SOL.1 Holistic certification approach and method for novel ATM-related systems based on higher levels of automation	WP2	D2.1 Advanced automation in aviation
	OBJ.2 Solid EU legal and regulatory framework on certification in aviation and ATM		WP3	D3.1 Certification methods and automation: benefits, issues and challenges
				D3.2 Innovative approaches to approval and certification
	OBJ.3 Novel methods and procedures of certification of highly		WP4	D4.1 Case studies introduction: level of automation analysis and certification issues

	automated systems			D4.2 Performance based requirements for advanced automation
				D4.3 Validation Report
				D4.4 Holistic approach to approval and certification of automated systems
	OBJ.4 Specific guidelines and toolkit for AA-based ATM systems design	SOL.2 Preliminary Guidelines to design ATM-related systems based on higher levels of automation	WP5	D5.1 Guidelines Validation report
				D5.2 Preliminary guidelines for advanced automation systems design and toolkit for guidelines application

Table 4. HUCAN exploratory research plan

The HUCAN validation scope focuses on Objectives 3 and 4, with the aim of validating the two solutions. As HUCAN relies primarily on desk research and expert consultation, and is expected to achieve an exit TRL2, the Expert Group (EG) was deemed the most suitable technique for validating these outcomes. By collecting qualitative data—such as expert opinions, comments, and suggestions—the EG enables an objective evaluation of the quality of the work. Additionally, the Stakeholder Consultation Group (SCG) established within the project has also been consulted to ensure broader validation and alignment.

Accordingly, the validation activity was primarily intended to gather feedback on the overall soundness of the proposed research approach and the general usefulness of the resulting outcomes, with a view to informing future improvements. More information about the validation activities carried out for each HUCAN solution is available in D4.3 – *Validation Report* and D5.1 – *Guidelines Validation Report*.

3.2.2 Stakeholder participation in HUCAN validation activities

In line with the guidelines provided by the European Commission (EC) on Ethics and Data Protection in EU-funded research projects, and the HUCAN policy on data protection (as outlined in the DMP – D1.1), this document does not disclose the names of the experts involved in the validation activities, but rather reports the number of people involved and the projects that they represent, or their roles and areas of expertise, in order to balance transparency with privacy. Their feedback and comments are presented in anonymous and aggregated form.

3.2.2.1 HUCAN SCG composition and activities

Consistently with the GA and EPR, HUCAN established an SCG to collect preliminary feedback on the usefulness of a holistic approach to certification, inviting participants to evaluate the framework outlined during desk research, also in light of EASA guidance. These objectives were pursued through a two-iteration workshop integrated into WP3 research activities.

The workshop for the first iteration was held in M9 (May 2024). The Consortium has strategically decided, in accordance and with the help of HUCAN PO, to involve select SJU projects, particularly those aligned with the SESAR flagship of *Capacity-on-demand and dynamic airspace*, *Artificial Intelligence for aviation* and *Civil-military interoperability and coordination*. These projects were chosen based on their demonstrated interest in connecting with the HUCAN project, either due to their existing focus on certification challenges or the recognition of certification's importance within their scope.

The first iteration of the workshop involved the following projects (Table 5).

Project acronym	Project name	Flagship	Project type
SMARTS	Smart sectors	Capacity on demand and dynamic airspace	ER
HARMONIC	Harmonised network through smart technology and Collaboration	Civil military interoperability and coordination	IR
ISLAND	Intelligent suite for local and network demand and capacity balance	Capacity on demand and dynamic airspace	IR
FASTNet	Future Data Services and Applications for airports and Network	Capacity on demand and dynamic airspace	Fast track
KAIROS	Unlocking the potential of AI-based Weather forecasts for Operational Benefits	Capacity on demand and dynamic airspace	Fast track

MITRANO	Mission Trajectory in ATC and Network Management Operations	Civil-military interoperability and coordination	IR
ASTRA	AI-enabled tactical FMP hotspot prediction and resolution	Artificial intelligence for aviation	ER

Table 5. Projects involved in the first iteration of the workshop

The feedback collected from the SCG was further complemented by additional inputs gathered from participants in a second delivery of the same workshop conducted during the AI Flagship Event in Rome, held just prior to the SESAR Innovation Days 2024 (November 2024, M15).

The second iteration of the workshop involved the following projects (Table 6).

Project acronym	Project name	Flagship	Project type
AI4HyDrop	AI-based Holistic Dynamic Framework for a safe Drone's Operations in restricted and urban areas.	U-space and urban air mobility	ER
AMPLE3	SESAR3 ATM Master Planning and Monitoring	Transversal	Fast track
ANTICIPATE	Absorb Nearby Tidy Identified Candidates for Ideal Parteking Available Temporal Extra-capacity	Capacity on demand and dynamic airspace	ER
ASTAIR	Auto-Steer Taxi at Airport	Connected and automated ATM	ER
ASTRA	AI-enabled tactical FMP hotspot prediction and resolution	Artificial intelligence for aviation	ER
ATM-Excite	Advancing Civil-Military Interoperability and Coordination through Excellence in Science and Technology	Civil-military interoperability and coordination	ER
AWARE	Achieving human-machine collaboration with artificial situational awareness	Artificial intelligence for aviation	ER
CODA	Controller adaptive Digital Assistant	Connected and automated ATM	ER

DARWIN	Digital Assistants for Reducing Workload & Increasing collaboration	Artificial intelligence for aviation	ER
ENGAGE 2	TSESAR 3 Knowledge Transfer Network	Transversal	ER
HAIKU	Human AI teaming Knowledge and Understanding for aviation safety	HORIZON-CL5-2021-D6-01-13	N/A
HARMONIC	Harmonised network through smart technology and Collaboration	Civil-military interoperability and coordination	IR
Hypersolver	Artificial Intelligence controller able to manage Air traffic Control (ATC) and Air Traffic Flow Management (ATFM) within a single framework	Connected and automated ATM	IR
JARVIS	Just a rather very intelligent system	Artificial intelligence for aviation	IR
RESPONSE	REduced or Single Pilot Operation iNcapacitation Safety Enhancement	Air-ground integration and autonomy	ER
KAIROS	Unlocking the potential of AI-based Weather forecasts for Operational Benefits	Capacity on demand and dynamic airspace	Fast track
ORCI	Optimised Runway Centreline Interception	Artificial intelligence for aviation	ER
SynthAIr	Improved ATM automation and simulation through AI-based universal models for synthetic data generation	Artificial intelligence for aviation	ER
TADA	Terminal Airspace Digital Assistant	Air-ground integration and autonomy	ER
TRUSTY	Trustworthy intelligent system for remote digital tower	Artificial intelligence for aviation	ER

Table 6. Projects involved in the second iteration of the workshop

The discussions across the two iterations of the workshop revealed consistent outcomes. Overall, the holistic approach proposed by HUCAN was well received by participants. The activities demonstrated

that while some of the dimensions identified in the HUCAN framework were readily accessible to most participants, others—such as Human Agency, Liability, Fairness, and Diversity and Social Wellbeing—required further input from experts specialising in specific topics.

The discussions also revealed that the relevance of the various dimensions proposed by the framework may differ depending on the viewpoint of those applying it, thereby reinforcing the importance of a multidisciplinary team approach. It became evident that clusters can form among the dimensions, and that decisions aimed at improving one dimension can have a significant impact on others. Furthermore, the perceived importance of each dimension appears to evolve as a solution matures—certain dimensions may become more or less manageable at different stages of development.

3.2.2.2 HUCAN EG composition and activities

The two feedback collections, dedicated to the certification-aware design approach (WP4) and of the design support guidelines and the related toolkit (WP5), used the EG to collect feedback on the application of the solutions to project use cases, thereby testing their suitability, coherence and practical applicability in practice.

As part of WPs 4 and 5, and in line with the GA and the ERP, HUCAN validation activities consisted of meetings and interviews with qualified experts to collect feedback, comments and suggestions on the usefulness and applicability of the proposed approach (D4.4), and on the preliminary guidelines and toolkit supporting the harmonization between SESAR innovation and EASA certification processes (D5.2). These activities took place online between Months 20 and 22 (April and June 2025) and used both synchronous and asynchronous modalities.

Validation activities concerning the involvement of qualified experts for judgment analysis involved the following people (Table 7) according to the schedule below (Table 8).

Organisation	Role	Expertise
EASA	ATM/ANS Expert	ATM/ANS
EASA	Manager of the WG on EASA AI Roadmap	Software
EASA	WG on the EASA AI Roadmap	ATM/ANS
EASA	WG on the EASA AI Roadmap	HF
EASA	WG on the EASA AI Roadmap	HF
ECTL-MUAC	Head of ATM Development	ATM/ANS
ECTL-MUAC	Cognitive Ergonomist	HF
Deep Blue	Expert in SESAR ER	HF
Deep Blue	Expert in SESAR IR	HF

Deep Blue	Expert in SESAR ER/IR	Energy and environment

Table 7. Experts involved in validation activities

Organisation	Activity	Purpose	Iterations
EASA	Online feedback collection meetings	Collecting feedback and comments from the regulatory bodies regarding the validity and usefulness of the HUCAN approach	2
ECTL-MUAC	Online feedback collection meetings	Collecting feedback and comments from developers and deployers regarding the validity and usefulness of the HUCAN approach	2
ECTL-MUAC	Review of documents	Collecting feedback and comments from developers and deployers regarding the general usefulness and applicability of the HUCAN approach	1
Deep Blue	Online feedback collection meetings	Collecting feedback and comments from R&I experts on the validity and usefulness of the HUCAN approach, in relation to the specific needs of SESAR projects	3

Table 8. Validation plan and scheduling

3.2.3 Summary of validation objectives and success criteria

Considering the evolving legal and regulatory framework throughout the HUCAN project, as well as the refinement of the project's initial positioning, the scope and description of the validation exercise have been revised from what was originally outlined in the ERP. As a result, the objective initially identified as TVAL.01.01—focusing on the general validation of the HUCAN approach to certification—has been divided into two distinct sub-objectives. The first, designated as OBJ-HUCAN-TRL2-TVAL.01.01, aims to assess the validity and usefulness of the approach with respect to certification needs in the aviation domain concerning AI and advanced automation. The second, OBJ-HUCAN-TRL2-TVAL.01.02, evaluates the broader usefulness and applicability of the approach within research and innovation (R&I) initiatives. The validation objective TVAL.02.0—focusing on the general validation of the preliminary guidelines— also needed minor refinements. The following table reports the new descriptions of both.

Due to the specific nature of the HUCAN project and the adopted validation strategy, the layout differs slightly from the template versions. In particular, the columns dedicated to exercise validation objectives and success criteria were removed, since their contents correspond to the previous ones (Table 9).

SESAR solution validation objective	SESAR solution success criteria	Coverage and comments on the coverage of SESAR solution validation objective in exercises SOL.1# and SOL.2#
OBJ-HUCAN-TRL2-TVAL.01.01	The EG provides positive feedback on the validity and usefulness of the HUCAN approach, in light of the specific AI and AA certification needs and expectations in the aviation domain	SOL.1#
OBJ-HUCAN-TRL2-TVAL.01.02	The EG provides positive feedback on general usefulness and applicability of the HUCAN approach into R&I initiatives, in general and within the SESAR framework	SOL.1#
OBJ-HUCAN-TRL2-TVAL.02	The EG provides positive feedback on the validity and comprehensiveness of the preliminary guidelines and toolkit, in light of the specific needs of SESAR R&I initiatives related to the alignment of design and validation activities with certification requirements for AI and AA in the aviation domain	SOL.2#

Table 9. HUCAN Validation objectives and success criteria

3.2.4 Validation assumptions

The HUCAN project is based on initial and intermediate assumptions which first emerged from a study of the state of the art, and were subsequently refined based on feedback collected with the support of the Stakeholder Consultation Group (SCG). The main assumptions that form the basis of the certification-aware approach to design and validation can be summarised as follows:

1. Future R&I projects focusing on AA and AI will increasingly be required to consider certification constraints and objectives from the earliest stages of system design. What is currently being observed is a growing awareness across the aviation research and innovation ecosystem that certification will no longer be an end-of-pipeline concern for solutions with a high maturity level, but rather an integral part of design planning, affecting strategic decisions throughout the development lifecycle.

2. Well-established certification processes are proving inadequate in the face of the challenges posed by highly automated solutions, particularly those based on AI. As documented by regulatory entities and granting authorities' initiatives, there is a growing need for adaptable,

context-aware certification pathways that can be tailored to operational scenarios, technology maturity levels and automation profiles.

3. As certification becomes a strategic consideration from the outset, R&I actors will need to develop internal capabilities—not only in terms of technical expertise, but also regulatory literacy, particularly given the rapid evolution of regulatory ecosystems related to AI. Cross-functional collaboration (e.g., engineering, human factors, legal, ethics) will be essential to navigate this complexity.

4. The certification of solutions involving human-machine interaction in operational environments—particularly those with high levels of automation—requires novel design and validation approaches. These approaches should take into account the medium- and long-term implications of technology deployment, considering their impacts on the operational context, modes of use, ethical aspects of interaction, and the human operator's capacity to maintain or regain control when necessary.

Due to the maturity level of SESAR-SOL.0445, it was not possible to apply the method directly. As previously mentioned, the EG was therefore engaged to help investigate the project's contribution in relation to these assumptions, as part of a feedback collection exercise.

3.2.5 Validation exercises list

In light of the considerations regarding the developments that occurred over the course of the HUCAN project, the updated descriptions of the validation exercises are provided below (Tables 10, 11, 12 and 13).

Identifier	TVAL.01.0[HUCAN]-[SOL.1]-TRL1
Title	Validation of the workflow of the certification-aware design and validation approach and the related methodological toolbox (D4.4)
Description	The feedback collection involves regulatory bodies, developers and deployers and SESAR R&I experts. The exercise is structured in two phases: • presentation of the HUCAN approach (process and toolbox) • collection of feedback, comments and suggestions
KPA/TA addressed	Human factors, accountability, responsibility, liability, safety, resilience, security, environmental sustainability, societal sustainability, and efficiency
Addressed expected performance contribution(s)	The expected contribution(s) aim(s) to: • Assess the validity of the new approach • Assess the general usefulness of the new approach in R&I • Assess the applicability of the approach in R&I

	• Refine the approach, if needed
Maturity level	TRL2
Use cases	UC4
Validation technique	Expert group
Validation platform	N/A
Validation location	Online
Start date	M18
End date	M22
Validation coordinator	DBL
Status	<closed>
Dependencies	N/A

Table 10. Exercise SOL.1#

Linked Element Type	TVAL.01.0
<SESAR Solution>	TVAL.01.0
<Project>	HUCAN
<Sub-Operating Environment>	N/A
<Validation Objective>	OBJ-HUCAN-TRL2-TVAL-001

Table 11. Exercise SOL.1# Trace

Identifier	TVAL.02.0[HUCAN]-[SOL.2]-TRL1
Title	Validation of the Preliminary guidelines for advanced automation systems design and toolkit for guidelines application (D5.2)
Description	The feedback collection involves regulatory bodies, developers and deployers and SESAR R&I experts. The exercise is structured in two phases: • presentation of the HUCAN preliminary guidelines • collection of feedback, comments and suggestions

KPA/TA addressed	Safety, Security, HF, Ethics
Addressed expected performance contribution(s)	The expected contribution(s) aim(s) to: • Assess the validity of research approach and outputs • Assess the usefulness of the preliminary guidelines in R&I • Refine the preliminary guidelines , if needed
Maturity level	TRL2
Use cases	N/A
Validation technique	Expert group
Validation platform	N/A
Validation location	Online
Start date	M18
End date	M22
Validation coordinator	DBL
Status	<closed>
Dependencies	N/A

Table 12. Exercise SOL.2#

Linked Element Type	TVAL.02.0
<SESAR Solution>	TVAL.02.0
<Project>	HUCAN
<Sub-Operating Environment>	N/A
<Validation Objective>	OBJ-HUCAN-TRL2-TVAL-002

Table 13. Exercise SOL.2# Trace

3.3 Deviations

3.3.1 Deviations with respect to the S3JU project handbook

In line with the project objectives and research methodology as outlined in the proposal and approved in the GA, the Consortium has worked with the PO to proceed as described above. This approach, while deviating from the validation strategies conventionally adopted for concepts and technical solutions, has been mutually agreed.

3.3.2 Deviations with respect to the exploratory research plan (ERP)

As explained in D4.3 and D5.1, the deviations from the ERP can be summarised as follows:

- The UCs addressed by the project (D4.1) were utilised for the development of the certification-aware approach. Consequently, using only these scenarios for validating the approach would have compromised the substance and reliability of the final results.
- The scope of the first validation exercise (TVAL.01.0[HUCAN]-[SOL.1]-TRL1) was limited to UC4 – *Dynamic Allocation of Traffic between ATCO and System* – as this solution includes various dynamic automation modes, some of which are enabled by non-AI-based systems.
- The direct involvement of regulatory bodies, along with R&I experts familiar with the SESAR validation framework, offers more relevant and insightful information regarding the validity and usability of the approach for both its intended application and potential future use.

4 Validation results

4.1 Summary of project validation results

HUCAN carried out two exercises to verify the solutions developed within the project, with the variations and deviations documented above (§ 3).

The table below summarizes the results of these validation exercises, as updated and restructured in the present document (Table 14). Due to the specific nature of the HUCAN project and the adopted validation strategy, the layout of the validation reporting differs slightly from the standard SESAR template. In particular, the columns typically dedicated to the SESAR solution validation objective title and SESAR solution success criterion ID have been omitted, as they are not applicable in this context.

SESAR solution validation objective ID	SESAR solution success criterion	SESAR solution validation results	SESAR solution validation objective status
OBJ-HUCAN-TRL2-TVAL.01.01	The EG provides positive feedback on the validity and usefulness of the HUCAN approach, in light of the specific AI and AA certification needs and expectations in the aviation domain	The EG provided positive feedback	OK
OBJ-HUCAN-TRL2-TVAL.01.02	The EG provides positive feedback on general usefulness and applicability of the HUCAN approach into R&I initiatives, in general and within the SESAR framework	The EG generally provided positive feedback on the overall usefulness of the HUCAN approach. However, developers and deployers recommended adapting the toolbox to better align with current industrial validation practices, particularly to ensure its applicability in future R&I initiatives.	OK
OBJ-HUCAN-TRL2-TVAL.02	The EG provides positive feedback on the validity and comprehensiveness	The EG acknowledged the validity and comprehensiveness of	OK

SESAR solution validation objective ID	SESAR solution success criterion	SESAR solution validation results	SESAR solution validation objective status
	of the preliminary guidelines, in light of the specific needs of SESAR R&I initiatives related to the alignment of design and validation activities with certification requirements for AI and AA in the aviation domain	the gap analysis comparing the EASA and SESAR frameworks, and overall feedback was positive. However, EASA has recommended taking into account the two classes of systems — airborne and ground — during the harmonization of processes, as they may result in specific differences	

Table 14. Summary of validation exercises results

4.2 Detailed analysis of project / SESAR solution validation results per validation objective

4.2.1 OBJ-HUCAN-TRL2-TVAL.01 results

As reported in D4.3, the Expert Group (EG) provided overall positive feedback on the validity and usefulness of the HUCAN approach, particularly with regard to its process workflow. From a practical perspective, developers and deployers offered suggestions to enhance the methodological toolbox, noting that the current version could be integrated with other methodologies already used in industrial practice. With a view to the potential evolution and consolidation of the HUCAN approach, they recommended considering alternative references to support the applicability of the solution beyond EU-funded research initiatives.

The following two tables summarise the key feedback from EG members, structured by validation sub-objectives and grouped according to their respective affiliations (Table 15).

OBJ-HUCAN-TRL2-TVAL.01.01		
Organisation	**Feedback**	**Comment(s)/Suggestion(s)**
EASA	Positive	The early integration of certification alignment into the initial development phases of solutions was perceived positively. This approach was considered potentially

OBJ-HUCAN-TRL2-TVAL.01.01		
Organisation	**Feedback**	**Comment(s)/Suggestion(s)**
		promising in fostering greater consistency across institutional guidance on AI within the R&I domain.
ECTL-MUAC	Positive	The approach was generally perceived as positive, particularly because it introduces a dedicated stage for considering emerging certification objectives related to AI. This allows for the identification and mapping of potential gaps within internal procedures and standards that may need to be addressed to meet those objectives.
Deep Blue	Positive	The themes of certification alignment and certification-aware solution design had not yet emerged as key concerns, but they contribute to raising awareness both in the application of the guidance provided by the EASA AI Roadmap within R&I initiatives and in supporting exploitation efforts within the SESAR framework.
OBJ-HUCAN-TRL2-TVAL.01.02		
Organisation	**Feedback**	**Comment(s)**
EASA	Positive	There was generally positive feedback regarding both the process and the supporting toolbox.
ECTL-MUAC	Positive	Developers and deployers generally acknowledged the value and usefulness of the approach, as well as its potential to raise awareness of certification aspects and speed up the development pipeline. However, as they do not have specific expertise in this area, they also reported some difficulties in handling the outlined process and workflow for applying the new approach, and suggested complementing it with dedicated operative guidelines. With the same purpose of smoothing the integration of this approach, they also suggested refining the toolbox to better reflect current industrial validation practices and enhance its applicability in future R&I initiatives (e.g. Safety Case, IT Security Assessment and HF Assessment).
Deep Blue	Positive	There was general appreciation for the integration of certification considerations within the existing Key Performance Areas (KPAs) typically used for solution design and validation in aviation. This approach was valued

OBJ-HUCAN-TRL2-TVAL.01.01		
Organisation	**Feedback**	**Comment(s)/Suggestion(s)**
		for building on existing expertise rather than requiring entirely new specialisations.

Table 15. OBJ-HUCAN-TRL2-TVAL.01 Results - Detailed overview

4.2.2 OBJ-HUCAN-TRL2-TVAL.02 Results

As reported in D5.1, overall the EG provided positive feedback on the usefulness and comprehensiveness of the HUCAN preliminary guidelines, particularly with regard to gap analysis carried out on the SESAR subprocesses.

The consulted experts provided positive feedback, particularly appreciating that the topic of certification was addressed contextually, within the existing SESAR subprocesses. This approach allows for the consolidation and reinforcement of existing know-how within the SESAR community, while maintaining sufficient flexibility to support exploratory research alongside compliance considerations.

The following two tables summarise the key feedback from EG members, grouped according to their respective affiliations (Table 16).

OBJ-HUCAN-TRL2-TVAL.02		
Organisation	**Feedback**	**Comment(s)/Suggestion(s)**
EASA	Positive	EASA acknowledged the potential benefits of the preliminary guidelines in supporting the harmonisation of objectives and processes between SESAR and EASA. In particular, while recognising that the two authorities have different mandates, it appreciates the value of collaboration from the early design stages, as promoted by the guidelines, and the importance of avoiding siloed approaches. EASA also recognises that initiating aligning early—especially in emerging areas such as AI—is a sound approach. Based on this, EASA confirmed its willingness to review the preliminary guidelines and recommended improving alignment with current industrial certification practices for both airborne and ground systems.
Deep Blue	Positive	The consulted experts provided positive feedback, particularly appreciating that the topic of certification was addressed contextually, within the existing SESAR subprocesses. This approach allows for the consolidation and reinforcement of existing know-how within the SESAR community, while maintaining sufficient flexibility to

OBJ-HUCAN-TRL2-TVAL.02		
Organisation	**Feedback**	**Comment(s)/Suggestion(s)**
		support exploratory research alongside compliance considerations.

Table 16. OBJ-HUCAN-TRL2-TVAL.02 Results - Detailed overview

4.3 Confidence in validation results

4.3.1 Limitations of validation results

The HUCAN validation results offer valuable insights into the feasibility and potential benefits of supporting certification alignment in R&I initiatives since the early stages of development. However, some limitations restrict the generalisation of these findings:

- **Limited number of participants and interactions:** Due to scheduling and availability constraints, the number of experts directly consulted for validation, as well as opportunities for discussion, were limited.
- **Conditions affecting applicability:** Given the current maturity level and the availability of case studies, only a partial examination of challenges that may arise in the practical application of the preliminary guidelines within R&I initiatives was possible.

Overall, the validation confirms the feasibility of the HUCAN preliminary guidelines. Importantly, the limitations described above do not negatively impact the maturity assessment of the concept, given its current low maturity level—TRL2.

4.3.1.1 Quality of validation results

Validation results are primarily based on qualitative data. This includes the feedback, comments and suggestions collected over the course of online meetings, review of documents and e-mail exchanges that occurred in the interaction with the members of the EG.

Considering the role of the organisations involved in the EG, the expertise of the individuals participating, and their experience with the topics addressed, the results collected can be assessed as **medium** – reliable and relevant in relation to the project's objectives and its final TRL.

4.3.1.2 Significance of validation results

Given the validation technique employed and the structure of the exercise, it is not possible to estimate the statistical significance of the collected data. Consequently, the considerations outlined in the previous paragraphs remain applicable.

5 Conclusions and recommendations

5.1 Conclusions

Overall, the validation activities provided positive outcomes, confirming the general validation of the HUCAN certification-aware design approach and the preliminary guidelines.

Early contributions from a Stakeholder Consultation Group (SCG) were instrumental in defining the research direction, particularly by identifying key needs and expectations in the areas of research and certification. The SCG expressed overall support for the HUCAN framework. While many aspects of the approach were easily understood and deemed relevant, certain dimensions were identified as requiring further specialist expertise, underscoring the importance of involving multidisciplinary teams. These activities also revealed how the relevance and interconnection of different framework dimensions can shift throughout the development lifecycle.

Looking at SESAR-SOL.0445, the EG appreciated the soundness and practical utility of the HUCAN approach. However, developers and deployers pointed to the need for the toolbox to be further refined and better aligned with current industrial validation processes, in order to improve its usability in future R&I contexts. They also identified difficulties in applying the proposed process and recommended the creation of dedicated operational guidelines to facilitate adoption. However, there was widespread recognition of the value in incorporating certification considerations within the existing Key Performance Areas (KPAs) used for aviation system design and validation—an approach that was seen as complementary to established practices, avoiding the need for entirely new methodologies.

Considering SESAR Solution 0446, there was a general endorsement of the usefulness and completeness of the gap analysis conducted between the SESAR validation framework and the EASA concept paper. These were recognised for their future potential to not only streamline research and development efforts towards market readiness but also to enable a more informed approach to addressing the implications of automation and AI level classification in view of future certification requirements. The gap analysis is also seen as a means to consolidate and strengthen existing expertise within the SESAR community, while maintaining the necessary flexibility to accommodate exploratory research alongside compliance-driven objectives. More broadly, it is recommended that the rationale and methodology underpin both the gap analysis and the development of the associated toolkit, consolidating the approach within SESAR with further studies.

The overall quality and significance of the results can be viewed as promising, especially considering the early stage of development. While factors such as the limited number of participants and specific contextual conditions may influence the generalization of the outcomes, these do not diminish the demonstrated maturity of the concept, which is well aligned with its current TRL 2 status

5.1.1 Conclusions on project

The proposed solutions establish a solid foundation for further refinement and integration, particularly considering the anticipated evolution of regulatory frameworks and industrial practices.

Regarding **SESAR Solution 0445**, future developments are expected to focus on developing guidelines for applying the certification-aware design method, as well as adapting the associated toolbox by incorporating additional methodologies aligned with current industrial practices.

For **SESAR Solution 0446**, potential advancements include extending the toolkit's capabilities to address the gaps identified within the SESAR framework. The rationale underpinning this solution also holds promise for adaptation and broader application in other R&I contexts.

Furthermore, the development of a dedicated, and possibly partially automated, tool to support the certification-aware design process represents a valuable next step to facilitate practical implementation and improve usability.

5.1.2 Conclusions on concept clarification, technical aspects and performance assessment

To date, the HUCAN approach is aligned with EASA Concept Paper Issue 2.0 and incorporates objectives defined for Level 1 and Level 2 machine learning applications (EASA, 2024). However, it is designed to be potentially extensible to Level 3 AI applications and other AI techniques, in anticipation of future developments and the consolidation of certification and regulatory requirements.

The approach offers value in two main ways. First, it allows solution owners and development teams to assess the certification implications of their design decisions early, recognizing that higher levels of AI typically come with increased certification burdens. Additionally, it supports a gradual integration of relevant certification objectives throughout the system lifecycle, enabling the implementation of consistent and forward-compatible design and development choices.

From a practical standpoint, the feedback collected reflected general interest in the advancements achieved within HUCAN. At the same time, it highlighted some implementation challenges, particularly regarding the operationalisation of the gaps described in D5.2. While the process is well understood conceptually, applying it in practice is not always straightforward. To address this, it is recommended that the approach be supported by detailed, application-oriented guidelines. The approach was considered promising, although further refinements will be needed to fully address the scope of the EASA concept paper and the SESAR framework, in order to obtain a comprehensive view of both overlaps and gaps. Overlaps may offer opportunities for easier alignment and harmonization, while gaps will require careful analysis to identify potential challenges. Moreover, the methodology adopted in D5.2, together with the supporting toolkit, proved to be both practical and effective in delivering concrete results and actionable recommendations

From a technical and organisational perspective, the next step is to integrate the approach and guidelines into internal design and development processes within organisations involved in aviation R&I. This integration could extend beyond SESAR, applying more broadly to entities and processes aligned with current industrial best practices.

5.2 Recommendations

Given the strong interdependence between the HUCAN project and the ongoing development of the regulatory and certification landscape, future R&I initiatives should proactively consider both the current discussions and anticipated developments in these areas.

It is therefore recommended to closely follow the evolution and consolidation of the guidance frameworks being developed by EASA and the European Commission, particularly those emerging from initiatives such as the Rule Making Task RMT.0742 – Artificial Intelligence Trustworthiness. These regulatory efforts are expected to significantly influence the way AI-based systems are certified in the aviation domain.

In parallel, the contribution of international standardisation bodies, especially EUROCAE and ISO, should not be overlooked. Notably, attention should be given to the ongoing work of EUROCAE WG-114, including the forthcoming ED-324 standard (*Process Standard for Development and Certification Approval of Aeronautical Products Implementing AI,* expected by 2026), currently in draft form and expected to be published by the end of 2025. Similarly, several strategic standards developed under ISO/IEC JTC 1/SC 42—such as:

- ISO/IEC 42001:2023 – AI Management System,
- ISO/IEC 23894:2023 – Guidance on AI Risk Management,
- ISO/IEC 23053:2022 – Framework for AI Systems Using Machine Learning, and
- ISO/IEC 42005:2025 – AI System Impact Assessment

—offer relevant frameworks to guide certification-aware system design and validation.

Aligning with these emerging regulatory and standardisation instruments will be essential to ensure that the proposed approach remains legally robust, future-proof, and consistent with international best practices.

Internally, SESAR has already initiated a revision of its validation methodology, in part to address the unique challenges introduced by AI-based solutions. In this context, strong synergies have been identified between HUCAN and other SESAR3 initiatives, such as:

- AMPLE3 – SESAR3 ATM Master Planning and Monitoring (GA ID 101114738)
- PEARL – Performance Estimation, Assessment, Reporting and Simulation (GA ID 101114676)

Monitoring the results of these projects will help reinforce and build upon the work initiated by HUCAN. At the same time, HUCAN's results—particularly its certification-aware approach—may serve as a valuable contribution to shaping future validation strategies within SESAR and beyond.

From a practical standpoint:

- For SESAR Solution 0445, future research should focus on consolidating the method, especially in response to validation feedback, with particular emphasis on real-world application through use cases and the systematic collection of lessons learned.
- For SESAR Solution 0446, the next steps could include extending the gap analysis approach to applications beyond the SESAR framework, and providing guidelines and toolkits to support the integration of new regulatory references into design and validation processes.

Over the longer term, it may be worthwhile to explore the development of a support system capable of automating more repetitive or standardised tasks, thus enhancing efficiency and consistency in applying the certification-aware design approach.

6 References

6.1 Applicable documents

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

Performance management

[1] SESAR 3 JU, Project Handbook, Edition 02.00, 19 December 2024

Validation

[2] SESAR 3 JU, Project Handbook, Edition 02.00, 19 December 2024

Programme management

[3] 101114762, HUCAN, Grant Agreement, 17.05.2023

[4] SESAR 3 JU, Project Handbook, Edition 02.00, 19 December 2024

6.2 Reference documents

[5] EC, Ethics and data protection (Guidance note), 5 July 2021

[6] EASA, Artificial Intelligence Roadmap 2.0 – Human-centric approach to AI in aviation, Version 2.0, March 2023

[7] EASA, EASA Concept Paper: Guidance for Level 1 & 2 machine learning applications. A deliverable of the EASA AI Roadmap, Issue 02, March 2024 [EASA 2024(a)]

[8] EASA, EASA AI Days – High level conference, Cologne, Germany, 2nd and 3rd July 2024 (Day 1 Presentations) [EASA, 2024(b)]

[9] HUCAN, Deliverable 1.1 – Data management plan, Edition 01.00, 30 November 2023

[10] HUCAN, Deliverable 1.2 – Exploratory research plan, Edition 02.00, 29 February 2024

[11] HUCAN, Deliverable 4.4 - Holistic approach to approval and certification of automated systems, Edition 01.00, 30 June 2025

[12] SESAR JU, Strategic Research and Innovation Agenda – Digital European Sky, Luxemburg, September 2020.