USE OF AI IN CLIMB AND DESCENT CALCULATION

Safety support case

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Abstract
This Safety Support Case (SSC) has been developed to support the use case “Climb and Descent” under exploratory development by the NM Lab. The SSC will be used in support of the Guidance Material being developed by EASA. The “Climb and Descent” Sequence of the NM Lab is intended to improve the 4D trajectory calculation of flights especially during tactical phases, by better prediction of climb and descent rates with the use of Machine Learning / Deep Learning techniques.

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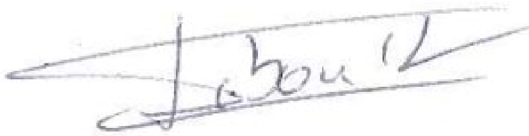
Francois TRIBOULET ATM/ANS Expert Coordinator EASA – SNE EUROCONTROL Head of Technical Development Section DECMA/PCS		03.02.2021
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Table of Contents

LIST OF TABLES IN MAIN DOCUMENT

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1 Introduction

1.1 Document purpose

This Safety Support Case (SSC) has been developed to support the use case "Climb and Descent" under exploratory development by the NM Lab. The SSC will be used in support of the Guidance Material being developed by EASA.

The "Climb and Descent" Sequence of the NM Lab is intended to improve the 4D trajectory calculation of flights especially during tactical phases, by better prediction of climb and descent rates with the use of Machine Learning / Deep Learning techniques.

The calculation of a 4D trajectory is a complex exercise, which depends on many parameters. The current algorithm faces some uncertainties, limiting the correctness of the calculation. This has direct effect during two important phases of the flight, i.e. when the flight is in its climb phase or descent phase. Some reasons are that some parameters cannot be correctly assessed few hours before the flight is ready to take-off (e.g. take-off mass of the aircraft).

It is expected that the climb and descent rate could be better predicted when learning from the past flown flights.

The SSC is developed in accordance with the applicable provisions of Regulation No 2017/373 laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight. The SSC provides the argumentation and evidence that the operational services[1] provided by NMOC will behave and continue to behave as specified in the respective service specification following the implementation of Artificial Intelligence (AI) in support of the 4D flight trajectory calculation during the climb and descent phases of a flight.

To this end the SSC documents the results of the safety support assessment (SSA) of the change (implementation of AI in flight trajectory calculation), and establishes the necessary and sufficient set of safety support requirements to ensure the behaviour of the NM operational services is not adversely affected.

This report may support the SSA of the operational implementation of AI in the NM functional system.

1.2 Document Overview

This SSC includes 8 chapters and 2 annexes.

Chapter 1 provides general introduction to the document, describes the purpose and scope of the SSC and provides a short overview of the process applied in the safety support assessment of the change. It also offers explanation of the safety related terms and of the acronyms used throughout the document.

[1] Flight planning service, ATFCM service and CCAMS service

Chapter 2 includes the description of the change subject to safety support assessment.

Chapter 3 contains the analysis of the failures and failure conditions associated to the change, for their potential impact on the operational service performance, outputs and degraded modes. It includes also the analysis of degraded modes' causal factors and the inventory of the derived safety support requirements.

Chapter 4 contains the evaluation of the behaviour of the changed system in the absence of failures and establishes safety support requirements for 'normal operation'.

Chapter 5 contains the list of assumptions made during the safety support assessment and provides the justification of assumptions' validity.

Chapter 6 defines the monitoring criteria to be used to demonstrate that the operational services will continue to behave only as specified following the implementation of the change.

Chapter 7 contains the justification of the safety support requirements' satisfaction.

Chapter 8 presents the assessment of the change impact on the NM operational service specifications and BSSC.

Chapter 9 contains the SSA conclusions.

Annex 1 contains the detailed FMEA and causal analysis results.

Annex 2 contains the list of participants to the SSA.

1.3 Safety Support Assessment Process

The safety support assessment of the change (use of AI in 4D flight trajectory calculation) documented in this report has been carried out in compliance with the requirements included in Regulation No 2017/373 and its associated AMCs and GMs [RD1] for service providers other than ATS providers.

The first step is the understanding and scoping of the change. It includes determination of the changed/new components of the NM Functional system (FS), impacted (directly and indirectly) components of the NM FS, interfaces and interactions, and its operational context.

The second step of the safety support assessment is the assessment of failure conditions and analysis of causal factors. The Failure Mode and Effect Analysis (FMEA) technique was used to identify functional system failures, which can cause the services to behave in a non-specified manner, namely through a different to the specified service output (e.g. lost, incorrect, delayed). Failure modes are linked (traceable) to the degraded mode(s) that can be caused by the failure. Where appropriate internal (safety support requirements) and external mitigations (assumptions) have been derived to reduce or prevent undesired failure effects.

The degraded mode causal analysis (causal analysis), has been performed by means of facilitated structured brainstorming. It enabled the identification of the potential contribution of the changed and impacted elements of the NM functional system to the occurrence of the degraded modes, as well as the establishment of safety support requirements to control the occurrence of the degraded modes and hence the service behaviour.

The third step is the evaluation of the behaviour of changed system in the absence of failures (called often "success case") in order to prove that the FP/ATFCM/CCAMS services will behave and continue to behave as specified in the respective service specifications or, in case of modified behaviour, to update the respective service specification(s) following the applicable procedures.

The fourth step will be the provision of the needed arguments and justification to demonstrate compliance with the safety support requirements. This step will be completed within a future NM release, subject to a positive implementation decision by the appropriate NM entity.

1.4 Definitions, Acronyms and Abbreviations

1.4.1 Definition of Terms

Table 1-1 below provides the definitions of the safety related terms used in this specification.

Terms	Definitions
degraded mode	A reduced level of service caused by equipment outage or malfunction, staff shortage or procedures becoming inadequate in particular, abnormal situations.
functional system	A combination of procedures, human resources and equipment, including hardware and software, organised to perform a function within the context of ATM/ANS.
incorrect	inaccurate; wrong
inadequate	not achieving the expected objective; inappropriate or inefficient and/or insufficient
service availability	The probability that a service will behave as specified in a given time interval when provided and used under stated conditions in a normal operational environment.
service reliability	The probability that a service will behave as specified without failure under the stated conditions for a stated period of time.
service integrity	The overall completeness, accuracy and consistency of the service output over a specified period of time.
total loss	total failure of a function; service not available or no data provided to any user
valid	complete and correct

Table 1-1: Definition of terms

1.4.2 Acronyms

Table 1-3 below provides the explanation of all acronyms used throughout the document.

Acronym	Explanation
AI	Artificial Intelligence
ATFCM	Air Traffic Flow and Capacity Management
ATM	Air Traffic Management
ATC	Air Traffic Control
ATS	Air Traffic Services
BSSC	Baseline Safety Support Case
CACD	Collaborative Airspace and Capacity Database
CCAMS	Centralised Code Assignment and Management System
CCF	Common Cause Failure
CSO	Customer Technical Service Desk & Operations
EASA	European Aviation Safety Agency
ETFMS	European Traffic Flow Management System
FMEA	Failure Mode Analysis
FS	Functional System
FP	Flight Planning (service)
IFPS	Integrated Initial Flight Plan Processing System
NM	Network Manager
NMOC	Network Manager Operational Centre
SLA	Service Level Agreement
SSA	Safety Support Assessment
SSC	Safety Support Case

Table 1-2: Acronyms

1.4.3 List of referenced documents

[RD1] Commission Implementing Regulation (EU) 2017/373 of 1 March 2017 laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight, repealing Regulation (EC) No 482/2008, Implementing Regulations (EU) No 1034/2011, (EU) No 1035/2011 and (EU) 2016/1377 and amending Regulation (EU) No 677/2011

[RD2] Commission Implementing Regulation (EU) 2019/123 of 24 January 2019 laying down detailed rules for the implementation of air traffic management (ATM) network functions and repealing Commission Regulation (EU) No 677/2011.

[RD3] Flight planning service specification, edition 2.0

[RD4] Flow and capacity management service specification , edition 2.0

[RD5] CCAMS service specification, edition 2.0

[RD6] NM Baseline Safety Support Case, Edition 1.5

2 Change Description

Scope

The change involves implementation of Artificial Intelligence for the estimation of the aircraft climb and descend rates for the purpose of 4D flight trajectory calculation by NM systems. This will be a new software module to be integrated in the current NM systems' software in the form of AI libraries, referred to further in this document as "AI module".

The AI module will run on the same virtual machines and server configurations that host the IFPS, ETFMS and PREDICT processes. Hence, there is no change to the equipment hardware, infrastructure COTS software and their configuration.

Impacted FS components, interfaces and interactions

The AI module shall have an interface to Curtain (application software) to deliver the predicted climb or descent rate based on past data. Curtain builds or modifies the 4D trajectory of a flight by using the predicted vertical climb or descent rates by the AI module to compute of the climb and descent curves of the 4D flight trajectory.

Curtain needs be modified in order to support the interaction with the AI module and processing of the climb and descent rate predictions delivered by the latter.

Curtain is shared between different NM backend systems, notably IFPS (Initial Flight Plan System) and ETFMS (Extended Traffic & Flow Management System) and PREDICT. This means that the output of curtain – the 4D trajectory - is used by the IFPS/ETFMS/PREDICT critical processes (e.g. Message handler, Profiler) to deliver the various components of the Flight planning, ATFCM and CCAMS services.

The provision of the Airspace data services is not impacted by the change. The environment (CACD) data used in the 4D trajectory calculation (e.g. taxy times, runways in use, etc.) remain unchanged, as well as the procedure for their input and update.

The human and procedure elements of the NM functional system are not impacted by the change, either. Human operators will be able to check whether the computed 4D flight trajectories are realistic (function available today, too) and will continue to use them in accordance with the applicable procedures to deliver the specified operational services.

3 Assessment of failure conditions and component failures

3.1 Purpose

The purpose of the assessment of functional system component failures and failure conditions is to:

1. Identify the potential changes to the behaviour of NM operational services that may be caused by failures, malfunctions or incorrect operation of the changed or impacted functional system elements, as identified in chapter 2.
2. Determine the effect of such failures on the service output, the impacted service performance criteria and the associated degraded mode(s), if applicable.
3. Determine the potential causal factors of the analysed system/component failures.
4. Determine the associated internal mitigations (safety support requirements) and assumptions, which could reduce or prevent failure effects and thus minimise/prevent the impact on the service behaviour.

3.2 Failure Mode Analysis

3.2.1 Degraded modes of service delivery

The FMEA technique was used to analyse potential failures of the NM functional system, assess their impact on the service outputs (e.g. missing, partial, corrupted output, etc.) and establish the effects of these failures on the service behaviour.

The scope of the FMEA was limited to the changed and impacted elements of the NM functional system. Only credible failure modes, related to the change subject to the assessment, were analysed in the process. No new service degraded mode was identified by the analysis; however failures of the AI module or the modified Curtain may cause some of the already specified degraded modes of the FP, ATFCM or CCAMS services.

Depending on the exposure to the failure mode in terms of number of 4D flight trajectories affected by the software failure two types of degraded modes can be caused by a failure, notably related to:

- service integrity, when one or few flight trajectories are affected;
- service availability, when several to many or all flight trajectories are affected.

Table 3-1 below provides a summary of the FMEA output. The detailed FMEA results have been captured in the table provided in Annex A of the report.

Service	Affected service component	Degraded mode	Impacted service performance	FMEA case reference
Flight planning service	Flight plan message processing and distribution	DGM10 - Incorrect or partial flight plan data provided to users.	integrity	CnD-01 CnD-02(1) CnD-04(2) CnD-05 CnD-07 CnD-08 CnD-09 CnD-10
		DGM06 - Total IFPS service interruption	availability	CnD-02(2) CnD-03 CnD-08
ATFCM service	Load and capacity monitoring; Demand-capacity balancing; FM Helpdesk	DGM15 - Incorrect demand data and/or demand-capacity balancing and/or corrupted helpdesk support;	integrity	CnD-02(1) CnD-08 CnD-10
		DGM11 - Total ETFMS service interruption, and	availability	CnD-02(2) CnD-03 CnD-08
CCAMS service	Assignment and distribution of SSR codes	DGM19 - Incorrect SSR code assignment	integrity	CnD-02(1) CnD-08 CnD-10
		DGM17 - Total CCAMS service interruption	availability	CnD-02(2) CnD-03 CnD-08

Table 3-1: FMEA summary table

3.2.2 Effect mitigations and assumptions/conditions

The FMEA provided for the identification of a number of mitigations, some of which captured as safety support requirements in Table 3-2, section 3.5 of this report. The purpose of these mitigations is to prevent the failure or reduce the probability of failure occurrence, or to protect against an occurred failure to result in a degraded mode.

Also, the FMEA allowed for the identification of possible external mitigations of the potential failures by the users of the NM operational services. The mitigation potential of these mitigations has not been considered in this SSA (these are mitigations for the provision of the ATS services by the users) but they have been included in the FMEA table provided in Annex A for completeness and reference in case of AI operational implementation.

The assumptions made during the FMEA are listed in chapter 5.

3.3 Causal Analysis

3.3.1 Purpose

The purpose of the causal analysis is to:

1. Analyse the FS failures considered by the FMEA and identify the possible causal factors related to the changed and/or impacted FS elements.

2. Identify an appropriate and sufficient set of safety support requirements to control the failure rate and, respectively, the degraded mode occurrence.
3. Record any related conditions and assumptions that may apply and impact on the effectiveness of the safety support requirements.

3.4 Process Overview

The causal analysis was carried out in the form of guided brainstorming sessions with competent technical staff. All failure modes identified by the FMEA were analysed for potential causal factors related to the change under assessment. Where appropriate safety support requirements were established to prevent or reduce the likelihood of causal factor occurrence. The full list of the safety support requirements established by the FMEA and the causal factor analysis is provided in section 3.5.

The analysis was reviewed and validated by competent technical and safety staff.

The detailed causal analysis is provided in Annex A of this report.

All assumptions made in the course of the safety support assessment have been documented in chapter 4 of this report.

3.5 Safety Support Requirements

Table 3-2 contains the inventory of the safety support requirements, i.e. the necessary means and measures derived by the safety support assessment to ensure that NM operational services will behave as specified following the implementation of AI for the estimation of aircraft climb and descend rates. The table provides traceability to the mitigated service degraded modes, and receptively the service performance.

No transition safety support requirements have been derived as the implementation of AI for the aircraft climb and descend rate estimation does not require a transition period.

ID	Safety support requirement	Mitigated degraded mode	Impacted service performance
R-01	Curtain shall implement alternative way of prediction calculation (e.g. based on fall-back BADA table).	DGM06 DGM10 DGM11 DGM15 DGM17 DGM19	integrity availability
R-02	The AI component shall return error code in case it is able to detect an incorrect prediction.	DGM10	integrity
R-03	Curtain shall implement means to detect incorrect prediction provided by the AI component.	DGM10	integrity

ID	Safety support requirement	Mitigated degraded mode	Impacted service performance
R-04	Curtain shall perform validation check of the AI prediction using a set of established criteria.	DGM10 DGM15 DGM19	integrity
R-05	Rules for use of alternative prediction computation by curtain shall be implemented.	DGM-10	integrity
R-06	Learning assurance shall be applied to the AI module to optimise the model generalisation.	DGM10	integrity
R-07	Carry out adequate tests of the AI module.	DGM10	integrity
R-08	Carry out focused TensorFlow tests.		
R-09	Measure the time to obtain a prediction and trigger alarm in case a defined threshold has been reached.	DGM06 DGM11 DGM17	availability
R-10	Design and execute dedicated test to refine the prediction validity threshold.	DGM10 DGM15 DGM19	integrity
R-11	Carry out load tests (at development and verification level).	DGM06 DGM11 DGM17	availability
R-12	Ensure resources (e.g. memory, disk space, CPU load) monitoring in operations.		
R-13	Comply with the SWAL4 requirement for IFPS/ETFMS.	DGM10 DGM15 DGM19	integrity

Table 3-3: Safety support requirements

4 Behaviour in the absence of failures

To ensure the completeness of the change argument documented in this report, there is a need to analyse the behaviour of changed and impacted components of the NM Functional system in the absence of failures in order to prove that the FP/ATFCM/CCAMS services continue to behave as specified in the respective service specifications or, in case of modified behaviour, to update the respective service specification(s).

The objective of AI implementation is to improve the 4D trajectory calculation of flights by better prediction of aircraft climb and descent rates, i.e. to improve the accuracy of the 4D trajectory portions related to the climb and descent phases of the flight compared to the use of a static aircraft performance database (BADA) to derive the climb and descent rates. A credible estimation of the degree of accuracy improvement is not feasible before the operational evaluation of the change due to the intrinsic to the ATM system factors that impact on the flight trajectories and cannot be predicted (accurately), such as:

- ATM tactical restrictions and clearances, in particular those related to the climb/descent phases and the associated climb/descent rates;
- Aircraft operating procedures, e.g. the index the crew is asked to fly to;
- The actual aircraft take-off mass;
- Mismatch of the weather phenomena encountered along the planned aircraft trajectory with the forecast.

In view of the above, the following qualitative high level safety requirement has been derived:

The use of AI-predicted climb and descent rates in 4-D trajectory calculation shall, in general, improve the accuracy of the calculated aircraft trajectories compared to the use of BADA to predict the climb and descent rates.

Note: The words “in general” is used as, depending on the individual flight and ATM system state, the flight trajectory calculated using the legacy method (based on BADA) may be as good as the one calculated with the help of AI (e.g. no ATM restrictions on climb/descent, aircraft flown to manufacturers advice, etc.).

In order to achieve the above high level objective the following safety support requirements have been placed on the changed and impacted by the change FS elements:

- **R-14**. The AI/ML component shall use industry recognised technology (e.g. Deep Neural Network) for training the prediction model. The use of TensorFlow shall be considered.
- **R-15**. The AI/ML component shall ensure correct generalisation capabilities which shall be verified by means of pre-operational evaluation with real flight plan data and, if necessary, improved.
- **R-16**. The AI/ML component shall expose an interface which shall be consumed by Curtain.
- **R-17**. The AI/ML component shall be able to process up to 100 requests per second Curtain shall send prediction request to the AI/ML component upon identification of the need to build a new or update an existing 4D trajectory.
- **R-18**. Curtain shall process the climb and descent rate predictions delivered by the AI/ML component.

5 Assumptions

Table 4-1 below contains the list of assumptions made during the safety support assessment that may apply and impact on the effectiveness and/or availability of the mitigation means and measures. It traces the assumptions and conditions to the associated degraded modes where they have been raised. The table also provides justification that the assumptions are correct and valid

ID	Assumption/ Condition	Degraded Modes	Justification
A-01	Exhaustion of system resources will not only affect the AI module, but Curtain and other system processes, too.	DGM06 DGM11 DGM17	The AI module, Curtain and other critical system processes use the same computing resources (disk, memory and CPU).
A-02	By design, consecutive incorrect rate prediction for different flights cannot occur.	DGM10 DGM19	Successive incorrect rate predictions due to AI design issues will be identified during the software development and integration testing phase, and the AI predictive model will be enhanced consequently.
A-03	Failure of Curtain to compute an alternative prediction cannot occur for all flights.	DGM10 DGM19	This is a legacy function that has been proven in operation since years.

Table 4-1: Assumptions

6 Monitoring Criteria

6.1 Introduction

As per Regulation 2017/373 [RD1], monitoring criteria is to be used to demonstrate that following the change, the service(s) affected by the change behaves and continue to behave only as specified in the specified context.

6.2 Integrity

The criterion about the correctness and consistency of the service output (integrity) is measured by:

- the number of reported and investigated occurrences of incorrect FP/ATFCM/CCAMS service output caused by failures/malfunctions of the AI module, i.e. occurrences of incorrect output (e.g. incorrect FPL distribution, incorrect demand data) provision over a 12-month rolling period (24/7 operations) when the service is provided and used in accordance with stated conditions in a normal operational environment;
- the recovery time determined as the time taken from the reception of occurrence report by the Technical helpdesk until the correct service output is restored.

6.3 Reliability

The criterion is measured by:

- the number of the unplanned FP/ATFCM/CCAMS service/service component interruptions per defined period of time (normally, 12-month rolling period) due to exceedance of a defined “error rate” threshold for trajectory calculation.

6.4 Availability

The criterion is measured by:

- The number of hours the FP/ATFCM/CCAMS service were unavailable per defined period of time (normally, 12-month rolling period) due to unplanned service interruptions caused by exceedance of a defined “error rate” threshold for trajectory calculation.

7 Safety Support Requirements Satisfaction

This chapter provides the needed assurance that the safety support requirements listed in section 3.5 are implemented, as required in order to ensure that NM operational services (flight planning, ATFCM and CCAMS) will continue to behave only as specified in the respective service specifications.

[To be completed, when and as appropriate].

SSR ID	SSR description	Mitigated degraded mode	SSR satisfaction justification	Justification reference
R-01	Curtain shall implement alternative way of prediction calculation (e.g. based on fallback BADA table).	DGM06 DGM10 DGM11 DGM15 DGM17 DGM19	[to be completed]	e.g. specification document
R-02	The AI component shall return error code in case it is able to detect an incorrect prediction.	DGM10		
R-03	Curtain shall implement means to detect incorrect prediction provided by the AI component.	DGM10		
R-04	Curtain shall perform validation check of the AI prediction using a set of established criteria	DGM10 DGM15 DGM19		
R-05	Rules for use of alternative prediction computation by curtain shall be implemented.	DGM10		
R-06	Learning assurance shall be applied to the AI module to optimise the model generalisation.	DGM10		
R-07	Carry out adequate tests of the AI module.	DGM10		
R-08	Carry out focused TensorFlow tests.			
R-09	Measure the time to obtain a prediction and trigger alarm in case a defined threshold has been reached.	DGM06 DGM11 DGM17		
R-10	Design and execute dedicated test to refine the prediction validity threshold.	DGM10 DGM15 DGM19		
R-11	Carry out load tests (at development and verification level).	DGM06 DGM11 DGM17		
R-12	Ensure resources (e.g. memory, disk space, CPU load) monitoring in operations.			
R-13	Comply with the SWAL4 requirement for IFPS/ETFMS.	DGM10 DGM15 DGM19		
R-14	The AI/ML component shall use industry recognised technology (e.g. Deep Neural Network) for training the prediction model. The use of TensorFlow shall be considered.	n/a (normal operation)		

SSR ID	SSR description	Mitigated degraded mode	SSR satisfaction justification	Justification reference
R-15	The AI/ML component shall ensure correct generalisation capabilities which shall be verified by means of pre-operational evaluation with real flight plan data and, if necessary, improved.	n/a (normal operation)		
R-16	The AI/ML component shall expose an interface which shall be consumed by Curtain.	n/a (normal operation)		
R-17	The AI/ML component shall be able to process up to 100 requests per second Curtain shall send prediction request to the AI/ML component upon identification of the need to build a new or update an existing 4D trajectory.	n/a (normal operation)		
R-18	Curtain shall process the climb and descent rate predictions delivered by the AI/ML component.	n/a (normal operation)		

Table 6-1: Requirements implementation evidence

8 Impact on service specifications and BSSC

8.1 Impact on the service specifications

The change (implementation of AI for the estimation of climb and descend rates in the 4D flight trajectory calculation) does not have any impact on the NM operational service specifications for:

- The change introduces an alternative way of aircraft climb and descend rate prediction used in the calculation of the 4D trajectories and will be implemented within the part of the NM FS - application software – that is outside the scope of the service specifications.
- The change does not in any way alter the service components and functions, the service context, the interfaces and interactions with users and NM/users' responsibilities.
- The described service degraded modes are not affected - no changed or new degraded modes have been identified by the SSA.
- Service performance criteria on availability and reliability and the related monitoring criteria, specified in the BSSC, are not impacted and remain as defined.

8.2 Impact on BSSC

The change has been analysed for the potential impact on the NM BSSC [RD-06]. The results of the analysis are summarised below:

- ***Service descriptions***. There is no impact on the service descriptions as the descriptions do not include any reference to the Functional System (FS) architecture, and in particular the software components that enable the provision of the Flight planning, ATFCM and CCAMS services.
- ***Failure analysis and degraded modes***. There is no impact on the failure mode analysis (FMEA) and on the degraded modes identified in the BSSC as the analysis and the definition of the degraded mode are done at the level the service provision/service output and do not refer to the components (e.g. application software modules) of the NM FS (people, procedures and equipment) supporting the service provision.
- ***Degraded mode causal analysis***. The degraded mode causal analysis (FTA) is not impacted due to the level of granularity of the identified causal factors (basic FT events). The basic events related to the failure or malfunction of the application SW layer are defined at the level of IFPS/ETFMS critical processes (e.g. Profiler, Message handler) and do not identify the failure/malfunctions of the lower level software components. Consequently, all the safety support requirements (SSR) identified by the FTA remain valid and unaffected. Notwithstanding this, the requirements of permanent nature identified by this SSA (R01 to R07, R10, R13 and R14) need to be added to the list of BSSC safety support requirements.
- ***CCF analysis***. All potential contributors to CCF identified in the BSSC and the related safety support requirements have been analysed for any potential impact of the change. No impact on the potential CCF and related requirements has been identified.
- ***BSSC assumptions***. There is no impact on the assumptions established in chapter 7 of the BSSC. The assumptions concern the user actions in case of degraded modes of NMOC service provision and do not depend on the algorithm used in the NM FS for the calculation of 4D flight trajectories.

9 Conclusion

The safety support assessment (SSA) of the use of AI for the estimation of climb and descend rates in the 4D flight trajectory calculation is valid and complete for:

- The SSA has correctly defined the scope of the change, including any potential direct or indirect impact on the components of the NM functional system, its interfaces and interactions. This is a relatively simple change introducing one new software component (AI module) and changes to one existing software component (Curtain) of the NM FS. The human and procedures elements of the FS are not affected.

- Potential failure conditions and failures of the changed and impacted elements have been identified, assessed for their impact on the service and, the related degraded modes of service delivery have been established. The scope of the functional failure analysis documented in section 3.2 and Annex 1 covers the new and the changed elements of the FS.
- The possible causal factor that can lead to the failure of the NM FS components, impacted by the change, have been identified. The causal factor analysis documented in section 3.3 and Annex 1 covers the new and the changed elements of the FS.
- A sufficient and appropriate set of safety support requirements, documented in section 3.5, has been placed on the new and changed (impacted) FS elements to control the likelihood of occurrence of the degraded modes and ensure that specified service behaviour continues to be achieved in case of software malfunctions or failures.
- The behaviour of the new and changed components in normal operating conditions (absence of failures) has been analysed in order to prove that the NM operational services impacted by the change will continue to behave as specified in the respective service specifications. An appropriate set of performance related success case safety support requirements has been derived and documented in section 4.
- The SSA has confirmed that the NM operational service specifications remain valid and correct.
- Appropriate monitoring criteria have been specified to support continuous verification of the system and NM service performance and behaviour.

Annex 1 - Detailed FMEA and causal analysis results

The embedded MS Excel file contains the detailed failure modes analysis of the change under assessment, as well as the causal factor analysis presented on separate sheets.

Climb'n Descent - AI FMEA.xlsx

Annex 2 - List of participants to the SSA

The table below presents the participants to the SSA sessions that have supported the development of this report in the period November 2020 – January 2021.

Name	Role
Francois TRIBOULET	ATM/ANS Expert-Coordinator, EASA - SNE
Eric LIGONNET	Technical team lead for ASM, NMD
Benjamin CRAMET	NM Lab Manager, NMD
Andrew SIMPSON	System Architect, NMD
Philippe WAROQUIERS	Senior Development Leader for NeOS, NMD
Alexander KRASTEV	Senior safety expert, NMD

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