Final Technical Specification: 4DWxCube - Sub-regional MET prototypes

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Abstract

The 4DWxCube Domain System is being developed as the focal point between Airspace and ATM users, on one side, and consistent, common & harmonized, integrated & interoperable MET Information providers, on the other side.

This document describes the technical specifications of the MET systems used in the Sub-regional operational user environment as part of the Functional blocks referred to as Consolidation and Translation in P11.02.01-D33 (Technical Architecture Description). It is derived from MET requirements expressed in P11.02.01-D26 (DOD), D23 (OSED), D24 (SPR) and D25 (INTEROP).

This document is the final version and includes the verification status of the requirements developed in SESAR 1 Programme.

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Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground and EUMETNET Consortium background. The NWP models and meteorological information used to support the described 11.02 prototypes and validation/demonstration exercises belong to the respective National Meteorological Service.

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Executive summary

This document describes the technical specifications of the MET systems for Consolidation and Translation of MET information for Aviation usage used in a sub-regional operational user environment. It is derived from MET requirements expressed in P11.02.01-D23 (OSED) and D24 (SPR). The MET prototypes are developed as a joint effort of European National Meteorological Services members of EUMETNET EIG to provide airspace and ATM users with consistent, seamless, harmonised and interoperable MET information based on latest science & enhanced observation and forecasting capabilities, including management of the uncertainty.

This document describes the technical specifications (TS) of the Functional Blocks of the MET Domain System referred to as the 4DWxCube DS in the P11.02.01-D33 (Technical Architecture Description, TAD [6]) and it is focused on the Sub-regional (TMA and En-route) operational user environment (OUE).

MET requirements for operational services, their environment and use cases have been collected and analysed by P11.02.01 and summarised in 11.02.01 DOD, OSED and SPR. MET requirements and MET needs have been identified by the different operational projects and OFAs, namely for the Sub-regional environment OFA 03.03.01 & OFA 03.03.02 (Ground based Separation Provision in En Route and TMA), OFA 04.01.02 (Enhanced Arrival and Departure Management in TMA and En Route) and OFA 03.01.03 (Free Routing).

Interface requirement specifications (IRS) are based on 11.02.01-D25 (INTEROP) requirements and will be covered in detail in a separate document (P11.02.02-D42). This document gives an overview about the interfaces of the Consolidation and Translation Functional Blocks of the 4DWxCube and describes the internal interactions.

The TS requirements are traced to requirements of the listed OPS WPs and OFAs. In some cases when the MET needs are expressed without a formal requirement the TS requirements will be traced to the MET requirements which have been generated by P11.02.01 according to the communicated MET needs. The verification status of each requirement has been updated and included in this final version of the TS.

1 Introduction

1.1 Purpose of the document

The literature survey, the raising awareness workshops organised by P11.02.01 and the dialogue with OPS WPs and OFAs have demonstrated that most of the MET services both on observation and forecast fulfil the requirements of many operational services, although with slightly different SPR & INTEROP requirements. WP11.02 has therefore been designated as a Federating Project to collect all the OPS requirements and to develop a consistent and harmonised set of MET systems and MET services.

The high level concepts have been compiled in the 11.02.01-D26 (MET-DOD) and the requirements further developed in P11.02.01-D23 (OSED) , D24 (SPR) and D25 (INTEROP) (references [7] to [10]), with a mapping to the preliminary MET requirements identified by the different operational projects and OFAs, namely for the Sub-regional environment OFA 03.03.01 & OFA 03.03.02 (Ground based Separation Provision in En Route and TMA), OFA 04.01.02 (Enhanced Arrival and Departure Management in TMA and En Route) and OFA 03.01.03 (Free Routing). The technical architecture has been described in the 11.02.01-D31 (TAD) [6].

In WP11.2, the purpose of the TS deliverables is to define the technical specifications of the Functional Blocks (FB) constituting the MET Domain System (DS) also referred to as the 4DWxCube. Five FBs are devoted to “Consolidation” of MET Information, eight FBs to the “Translation” of MET Information for aviation, and the last two “4DwxCube Management” and the “MET information service Generation, ATM Tailoring and Exchange” (MET-GATE) describe the technical systems handling the MET information and products.

The background MET Information used to develop services is unique (observation and forecast), the technical requirements vary slightly among Operational User Environments (OUE). Therefore, three deliverables are produced to cover TS of the “Consolidation” and “Tailoring” FBs for the Local, Sub-regional, and Network OUEs, and an additional TS and IRS addresses the 4DWxCube as a whole with specifics on 4DWxCube Management and Met-GATE. **This document addresses the Sub-regional OUE TS**.

Figure 1 presents the TS within the hierarchy of the SESAR concept documents, together with the SESAR Projects responsible for their production and maintenance.

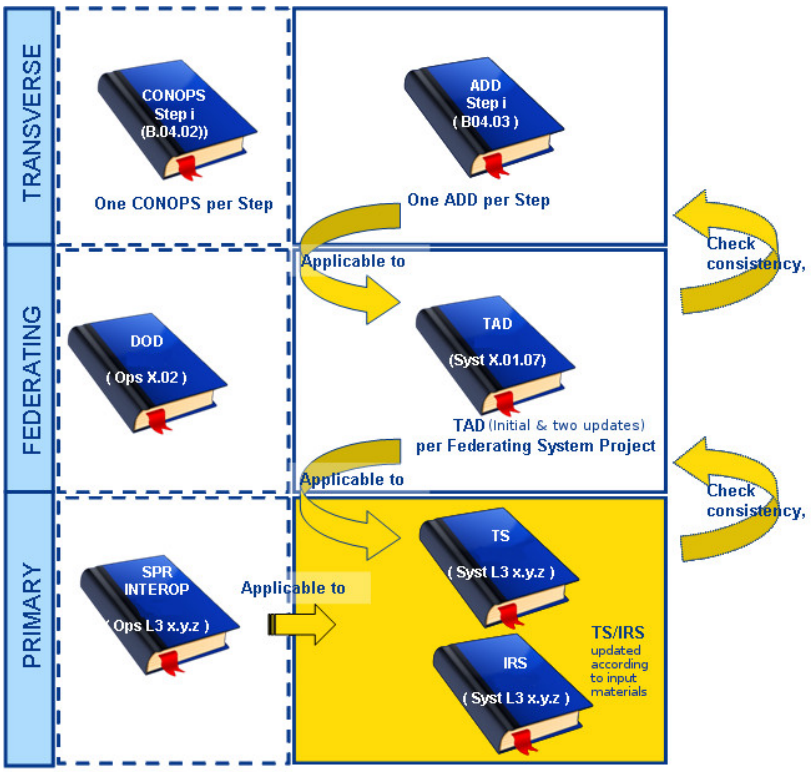

Figure 1: TS document with regards to the other SESAR deliverables

The MET TS will be traced to the OSED and SPR requirements of the Operational Projects and OFAs. However, their requirements have been composed by P11.02.01 in the MET DOD, OSED and SPR requirements which also include MET needs that have not been expressed in formal requirements but within their OSED or SPR deliverables. Therefore, the requirements are traced to OPS WPs whenever possible. However, a few traces are point to the P11.02.01 MET-OSED and MET-SPR deliverables. Interface Requirement Specifications are derived from the MET INTEROP requirements described in 11.02.01-D25. They are described in detail in a separate document (11.02.02-D42) [12].

This final version covers all information regarding current and future MET information and MET products for ATM and airspace users and the latest development status of enhanced MET systems.

1.2 Intended readership

The intended audience of this document is initially the WP11.2 projects to configure the architectural environment and to support suitable validation exercises. Furthermore P11.02.01 who has developed the MET requirements has an interest in this document for the MET Information Service systems gap analysis.

OFAs contributing to the Sub-regional OUE as well as their related technical projects needing MET Information in support of their architectural concepts are envisaged as intended audiences for this document as well. In particular, the following OFA and Projects are considered as the main audience:

- OFA 03.03.01 & OFA 03.03.02, its contributing operational projects 04.07.02, 04.07.03 and 05.07.02 and the mirror technical projects such as 10.04.01;
- OFA 04.01.02, its contributing operational projects 05.06.01, 05.06.04 and 05.06.07 and the related mirror technical projects and
- OFA 03.01.03 and their contributing operational projects 05.06.02, 05.06.03 & 05.07.04.

In addition, projects of WP08 are considered as audience, because their activity encompasses modelling MET information and developing MET and airport ATM Business Information Services, which will be based on MET information exchange requirements & services.

It is expected that the consolidated and translated Sub-regional MET products will arouse the interest of Airline Operators, ATM and Airspace Users who are involved in en-route and TMA procedures like En-route Control and Terminal Control and with pilots.

1.3 Inputs from other projects

The inputs for technical specifications of the MET systems are P11.02.01-D26 (DOD), D23-B (OSED-Sub-regional), D24-B (SPR-Sub-regional), D25 (INTEROP) and D33 (TAD) (references [6] to [10]).

1.4 Structure of the document

The document is structured as follows:

Chapter 1 introduces the document and describes the purpose of each functional block;
Chapter 2 provides a detailed description of each functional block, modes and states, capabilities, operational scenarios, functional decomposition & analysis and services;
Chapter 3 contains all the requirements;
Chapter 4 lists any assumptions.

This document describes the Technical Specifications of the “4DWxCube” DS that are specific to the Sub-regional OUE with a focus on the Consolidation and Translation FBs.

1.5 Requirements Definitions – General Guidance

The grouping of the requirements in chapter 3 and their breakdown structure is aligned with the template guidelines and includes section for the MET prototypes developed in WP11.2 and the general MET systems which includes available MET information from METSPs applicable for local OUE.

Table 1 : Requirements Breakdown Structure

- Capabilities
  - MET system for Regulatory MET information
  - MET system for Nominal MET information
    - Nominal Sub-regional MET Observations
      - X2.1 Mode S derived MET information
    - Nominal Sub-regional MET Forecast
    - Nominal Sub-regional MET Probabilistic Forecast
      - X1.3 Super-ensemble mesoscale forecast
      - X1.8 Support to 4D trajectory
  - MET system for Significant MET information
    - Significant Sub-regional MET Observations
      - X1.1 3D Radar Composite
    - Significant Sub-regional MET Forecast
      - X1.2 Nowcasting of Convection
      - X1.4 Icing forecast
      - X1.5 Turbulence forecast
    - Significant Sub-regional MET Probabilistic Forecast

- X1.3 Super-ensemble mesoscale forecast for convection
- Performance
  - MET system for Nominal MET information
  - MET system for Significant MET information
- Reliability
- Functional Block Internal Data
  - MET system for Nominal MET information
- Design and Construction Constraints
  - MET system for Nominal MET information
- Functional Block Interface Requirements
  (covered in 11.02.02-D42 IRS)

Requirements address successively the Capabilities, Performance, Reliability, Functional Block Internal Data, Design and Construction Constraints, and Interface Requirements though the latter in a separate document (11.02.02-D42) [12].

For Capabilities, Performance and Functional Block Internal data it is structured according to the developed MET systems, namely a split between WP11.2 developed MET prototypes and MET systems for Regulatory, Nominal and Significant MET information.

1.6 Functional block Purpose

Traditionally, there is an existing separation between providers of aeronautical meteorological information services and providers of air navigation services. The functions that belong to the domain of air navigation services are the 'ATM Impact Assessment for MET' and the 'ATM Decision'. The functions that belong to the aeronautical meteorological information services domain are 'MET Information' and 'MET translation' as depicted in the figure below:

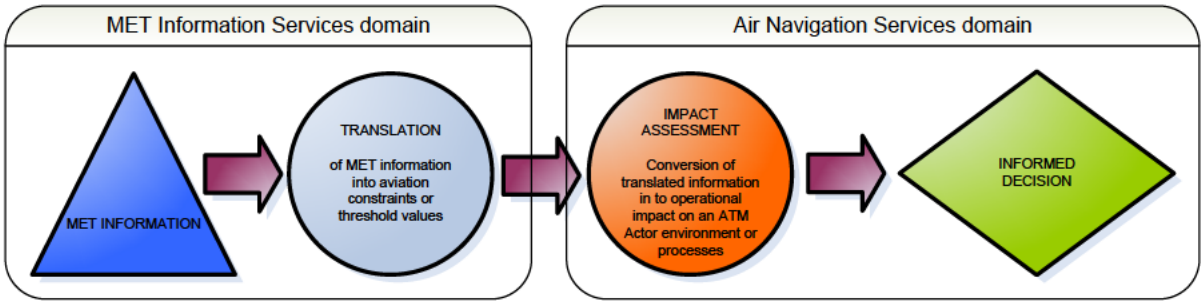

Figure 2 : Distribution of roles between MET and ATM

This segmentation provides the relevant framework for an allocation of functions and capabilities, with respect to the MET TAD, and to the ATM systems-related TADs. The following Figure 3 shows the technical architecture of the MET Information Services Domain and its interfaces with external systems and infrastructures.

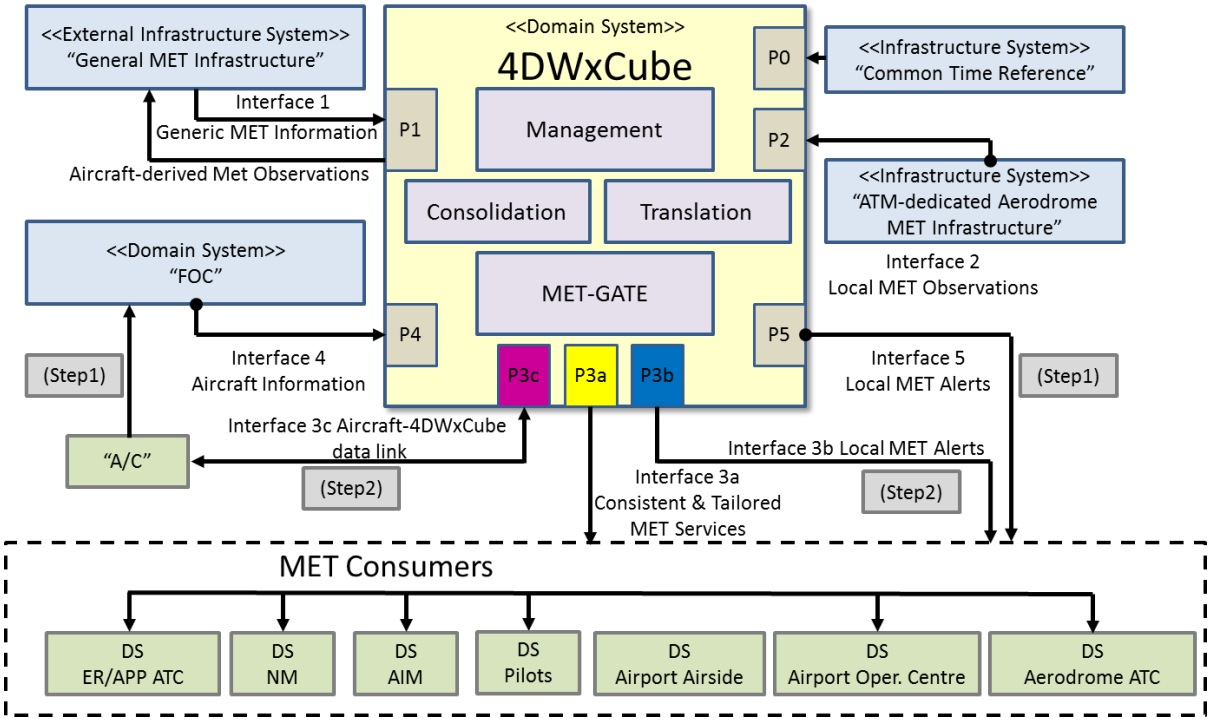

Figure 3: Technical Architecture of the MET Domain System 4DWxCube

The primary focus of the 4DWxCube Domain System is to deliver ATM focused MET Information to ATM Consumers through MET Services. The 4DWxCube shall enable ATM consumers to subscribe to MET-ATM SWIM services, offering access to tailored, high-level, user-oriented operational information, such as:

- "Gathering all relevant MET-ATM information along a 4D trajectory needed to plan a flight from the Airport of Departure (ADEP) to the Airport of Destination (ADES) scheduled at a given time/date ";
- "Gathering all relevant MET-ATM information needed to update a flight briefing on the terminal approach";
- "Gathering all relevant MET-ATM information needed to plan airport operations over the next 48 hours";
- "Gathering all relevant MET-ATM information needed to plan the MET impact on traffic flow over a Flight Information Region (FIR) during the next 12 hours";

To support this primary focus the 4DWxCube is also required to:-

- manage the delivery of meteorological information (observations and forecasts) from a variety of approved suppliers.
- consolidate the meteorological data to ensure that it is harmonised and presents a common MET view on a regional domain.
- translate the consolidated meteorological information into ATM specific MET Products.
- deliver the ATM specific MET Products in a tailored form according to ATM role needs (sub-setting, reformatting, etc.).

The 4DWxCube DS shown in Figure 3 collects

- generic MET Information from the "General MET Infrastructure" [Port 1].

- local MET Observations from the “ATM-dedicated Aerodrome MET Infrastructure” [Port 2].
- and Aircraft Information from Port 4, to supplement generic MET Information.
- Via Port 0 the 4DWxCube Management FB receives the time reference that is shared with all functional blocks.

The three categories of MET Information providers (blue triangle in Figure 2) are (i) Meteorological Service Providers (METSPs) with their observation infrastructure and numerical weather prediction capacities [Port 1], (ii) the local MET providers operating a dedicated MET observation infrastructure at the airport [Port 2], and (iii) the “aircraft” [Port 4] downlinking information to the ground that can further be processed to derive MET observations along the trajectory. Note also that Aircraft derived MET observations are made available to the General MET Infrastructure via Port 1 for MET SPs to improve the forecast.

Within the 4DWxCube DS, the first step is to manage the incoming MET information. The 4DWxCube Management FB sends on the received MET information if applicable to the Consolidation FBs. Most MET information are collected from a distributed infrastructure and needs to be consolidated first to provide aviation end users with information that is consistent in space over the regional domain and in time from execution to the longest lead time for planning. Consolidated but still generic MET Information shall then be translated to end users requirements (the light blue circle in Figure 2). Consolidated and Translated MET products are further processed into MET Services which are tailored according to user’s requests within the MET-GATE. The developed MET Services are distributed to aviation end users through the SWIM using either the Yellow [Port 3a], Blue [Port 3b] or Purple [Port 3c] profile. A direct link [Port 5] is also provisioned for Local MET warnings derived from the “ATM-dedicated Aerodrome MET Infrastructure” observations for the warnings to be transferred without undue delays to Local end users (e.g. TWR). Delivery via Port 3b using a blue profile could be an alternative option for such very short latency MET services.

This Technical Specification document is compliant with the high level architecture principles applied in SESAR and described in the MET TAD (reference [6]).

1.7 Functional block Overview

The functional blocks of the 4DWxCube DS are represented in Figure 4. This document as well as 11.02.02-D38 and –D40 for the Local and Network OUEs, respectively, address the MET systems Technical Specifications of the “Consolidation” and “Translation” Functional Blocks. The Specifications of the Management and the MET-GATE FBs are described in detail in the overview 4DWxCube documents 11.02.02-D41 for the Technical Specifications [11] and 11.02.02-D42 for the Interface Requirement Specifications [12].

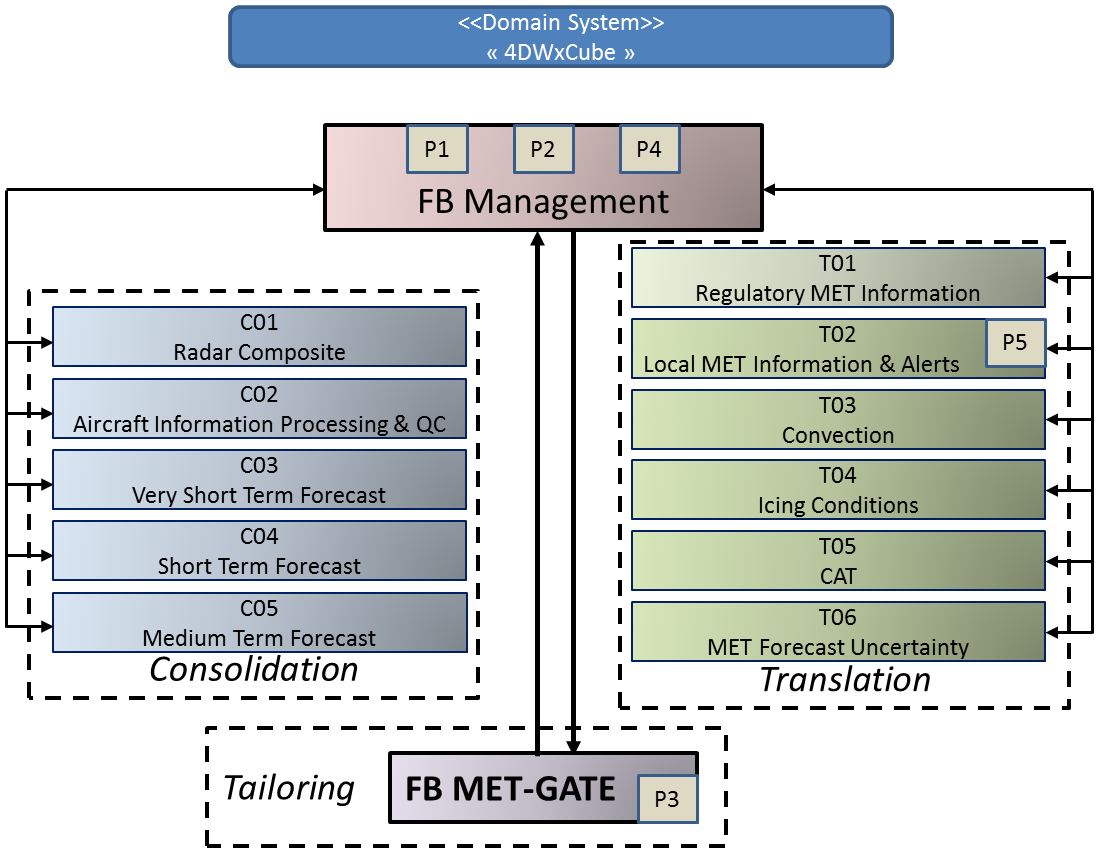

Figure 4: 4DWxCube DS Functional Breakdown

1.7.1.1 Consolidation Functional Block

This group of functional blocks aims at providing aviation with consistent, common, harmonized, and seamless, MET information at the European scale. In this FB category, functions entirely rely on MET Information. In the group, FBs are aligned with the MET scenarios per ATM phase and associated Use Cases (UC) as described in P11.02.01-D18 (DOD, Sec. 4.2), namely Execution, Short and Medium Term Planning.

Execution

- Consolidation of radar observations (*C01 : Radar Composite*) and of Aircraft derived MET Observations (*C02 : Aircraft Information Processing & QC*)
- *C03 : Very Short Term (VST) Forecast*

Short-Term Planning

- *C04 : Short Term (ST) Forecast*

Medium-Term Planning

- *C05 : Medium Term (MT) Forecast*

1.7.1.2 Translation Functional Blocks

This group of functional blocks encompasses all functions required to translate consolidated MET products into products translated to aviation end users requirements. In this FB category, functions rely on MET Information and Aviation end users specifications, such as extracting a suite of user-specified parameters from MET forecast fields; applying user specified thresholds to characterize severity of weather hazards; or the conversion of grids into objects with attributes that can be directly interpreted in terms of decision making, or be integrated into automated decision support tools.

In this group, FBs are not aligned with the MET scenarios per ATM phase since one key requirement is to provide the end user with a consistent vision of the MET regardless of the time horizon.

The first functional block (*T01: Regulatory MET Information*) includes functions required to produce ICAO Annex 3 Regulatory MET Information that cover nominal and significant weather, observation and forecast.

The second one (*T02: Local MET Information & Alerts*) is specifically dedicated to the “Local” OUE. Indeed, Airport and TMA MET requirements are particular in terms of vertical levels, down to the surface and even sub-surface for runway icing, and very short time steps (1s) for weather hazards such as cross wind gust, wake vortex, lightning and wind shear. In terms of MET infrastructures, that requires local observation systems, especially on high traffic platforms. The requirement for a very short latency in the transmission of MET alerts at the airport also calls for specific system interfaces. This is supported by the dedicated Port 5. An alternative approach could also be to use the “Blue” profile on the SWIM.

The following three FBs support diagnostics of significant weather for aviation with a focus on convection (*T03: Convection*), Icing Conditions (*T04: Icing Conditions*) and CAT (*T05: CAT*).

The last FB (T06: MET Forecast Uncertainty) supports user specified translation of ensemble MET forecast into a set of probabilities of occurrence of the phenomenon of interest. Functions can be very diverse (probability of snow at the airport, icing conditions, CAT or strong head wind en-route, probability of convection induced capacity reduction in the FIR, etc.). This FB supports both Short Term Planning and Medium Term Planning.

1.8 Glossary of terms

Table 2: List of Terms

Term	Definition	Source
Adverse weather conditions (airport)	Degraded weather condition: a condition which might have a significant negative impact on airport performance unless a proper response is organized (i.e. the selection of an airport operating mode to respond to given degraded conditions and eventually the use of additional airport resources such as de-icing/anti-icing services). This would be the case when visibility is poor and/or in case of freezing conditions, precipitations, etc.	ATM Lexicon
Domain System	Element of the technical architecture	WP11.02.02
Functional Block	Element which equal to or a part of a domain system	WP11.02.02
Meteorological forecast	Statement of expected meteorological conditions for a specified period and for a specific area or portion of air space	ICAO Annex 3 WMO N°182
Meteorological information	Meteorological report, analysis, forecast, and any other statement relating to existing or expected meteorological conditions. *Note: It is suggested by P11.02.01 to add 'data' in this definition*	ICAO Annex 3 ICAO Doc 9713 WMO N°182
Meteorological observation	Evaluation of one or more meteorological elements. *Note: An observation can be the result of amongst others a measurement, calculation or evaluation by human or automated means*	ICAO Annex 3 & WMO N°182
Meteorological report	Statement of observed meteorological conditions related to a specific time and location	ICAO Annex 3 WMO N°182
Meteorological services	Those facilities and services that furnish aviation with meteorological forecasts, briefings and observations as well as SIGMET information, VOLMET broadcasting material and any other meteorological data provided by States for aeronautical use *Note: in order to have a definition in line with SESAR terminology, the following new definition*	ICAO Doc 9713

Term	Definition	Source
	is suggested by P11.02.01: MET Service = Operational, application or information service in relation to the provision or use of MET information	*New*
Nominal weather conditions	Weather conditions which are the conditions in which the network operates in more than 90% of time and where the declared airport and airspace capacities for scheduling purposes is based on. Nominal conditions translate in excellent or good conditions such as an absence of any significant convective, wind, snow or visibility constraints.	Proposed by P11.02.01 (based on WPB.04.02 D65-011)
Nowcast	A description of current weather and a short-period (0-2hours) forecast *Note: It is suggested by P11.02.02 to modify this definition by adding 'specific methodology to perform a very-short term forecast' in this definition*	WMO N°182 *New*
Short term forecast	Forecast based on a description of the current weather situation for a short-period (2-24 hours) forecast Up to 36 hours to be aligned with TAF validity	P11.02.02 Proposed by ECA
Significant weather	Degraded, weather conditions, within the operational envelope of part of the network, which have a significant negative impact on operations unless an appropriate response is organized. This would be e.g. deep convective clouds, thunderstorms, turbulence or icing.	Proposed by P11.02.01 based on similar definition for airport
Tropical Cyclone Advisory Centre	A meteorological centre designated by regional and international air navigation agreement to provide advisory information to meteorological watch offices, area control centres, flight information centres, world area forecast centres and international OPMET databanks regarding the intensity, position and movement of tropical cyclones.	ICAO Annex 3
Volcanic Ash Advisory Centre	A Meteorological centre designated by regional air navigation agreement to provide advisory information to meteorological watch offices, area control centres, flight	ICAO Annex 3

Term	Definition	Source
	information centres, world area forecast centres and international OPMET databanks regarding the lateral and vertical extent and forecast movement of volcanic ash in the atmosphere following volcanic eruptions	
Very Short term forecast	Forecast based on a description of the current weather situation, Forecast of a period immediately after the current weather situation (0-2 hours)	

1.9 Acronyms and Terminology

Table 3: List of Acronyms

Term	Definition
ACC	Area Control Centre
AIRMET	Significant low-level en-route Meteorological Information
AMDAR	Aircraft Meteorological Data Relay
ATC	Air Traffic Control
ATM	Air Traffic Management
CAT	Clear Air Turbulence
DOD	Detailed Operational Description
DS	Domain System
DWD	Deutscher Wetterdienst (German Weather Service)
EASA	European Aviation Safety Agency
ECA	European Cockpit Association
ECAC	European Civil Aviation Conference
EUMETNET	European Meteorological Network
EX	Execution
FB	Functional Block
FIR	Flight Information Region
FMI	Finnish Meteorological Institute
FOC	Flight Operations Centre
HR	High Resolution
ICAO	International Civil Aviation Organisation
INTEROP	Interoperability Requirements
IRS	Interface Requirements Specification
IS	Industrial Support

Term	Definition
KNMI	Koninklijk Nederlands Meteorologisch Instituut
LA	Limited Area
LT	Long Term
MET	Meteorology or Meteorological
METAR	Routine Meteorological Aerodrome Report
MET-GATE	MET information services Generation, ATM Tailoring and Exchange
METSP	MET Service Provider
MR	Medium Resolution
MT	Medium Term
OFA	Operational Focus Area
OPS	Operational
OSED	Operational Service and Environment Definition
OUE	Operational User Environment
PIREP	Pilot Report
PO	Post Operations
QC	Quality Control
QNH	Barometric pressure adjusted to sea level
QoS	Quality of Service
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SIGMET	Significant en-route Meteorological Information
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SMHI	Swedish Meteorological and Hydrological Institute
SPR	Safety and Performance Requirements
ST	Short Term

Term	Definition
SWIM	System Wide Information Management
TAD	Technical Architecture Description
TAF	Terminal Aerodrome Forecast
TCAC	Tropical Cyclone Advisory Centre
TMA	Terminal Manoeuvring Area
TREND	Landing forecast valid for 2 hours and appended to the METAR
TS	Technical Specification
TWR	Aerodrome Control Tower
UC	Use Case
VAAC	Volcanic Ash Advisory Centre
VHR	Very High Resolution
VST	Very Short Term
WMO	World Meteorological Organization
WOC	Wing Operations Centre (military)
WP	Work package
Wx	Weather
4DWxCube	Four Dimensional Weather Cube

2 General Functional block Description

2.1 Context

The 4DWxCube DS (Figure 3) is constituted of four categories of Functional Blocks: “Consolidation” FBs, “Translation” FBs, 4DWxCube Management FB and MET-GATE FB.

The “Consolidation” FBs as well as the first “Translation” FB-T01 Regulatory MET Information collect Generic MET Information from the network of MET Service Providers, via Port 1 and Aircraft Information from Port 4. In the Local OUE, the specific Local “Translation” FB-T02 Local MET Information & Alerts also collects Local MET Observations from the Local Port 2.

Table 4 hereafter describes the main interfaces with the external systems

Table 4 : Interfaces of the 4DWxCube DS

Port	Interface	Origin	Destination	“Interaction”
1	Generic MET Information	General MET Infrastructure	4DWxCube DS	Observation & Forecast
	Aircraft-derived MET Observations	4DWxCube DS	General MET Infrastructure	Wind, Temperature, humidity, PIREPS
2	Local MET Observations	ATM-dedicated Aerodrome MET Infrastructure	4DWxCube DS	Local atmospheric state parameters and hazards
3a	SWIM Yellow Profile	4DWxCube DS	4DWxCube DS	MET Services
3b (Step 2)	SWIM Blue Profile	4DWxCube DS	4DWxCube DS	MET Alerts
3c (Step 2)	SWIM Purple Profile	A/C	4DWxCube DS	Aircraft information
4 (step1)	Aircraft information	FOC DS	4DWxCube DS	Aircraft information
5 (step1)	Local MET Alerts	4DWxCube DS	Aerodrome ATC DS	MET Alerts

2.2 Functional block Modes and States

Unlike the MET-GATE FB whose modes and states are determined by the end user communication modes, request/reply, subscription, or broadcast, the Management FB and therefore the “Consolidation” and “Translation” FBs behaviours are driven by the availability of generic MET Information that can be very diverse. For instance, Raw Radar Data collected on Port 1 is a

continuous high density data flow from the European radar network and processed in real-time in C01; in contrast, Ensemble Global Forecast is updated by a few MET providers (currently 4), four times a day. From this perspective, processing time for Consolidation of generic MET Information and Translation to assess significant weather occurrence can be critical when latency is important such as for the Radar Composite and the derived Convection Warnings.

Consolidated and Translated MET products are pushed to the MET-GATE FB via the Management FB as soon as it is available, or upon request.

2.3 Major Functional block Capabilities

The requirements are structured in alignment with the MET prototypes developed in WP11.2 and general MET systems not covered by WP11.2 developments but provided by the National Meteorological Services (NMSs), namely:

- MET system for Radar Composite for 3D convection information (X1.1 Prototype)
- MET system for Nowcasting of Convection information (X1.2 Prototype)
- MET system for Super-ensemble mesoscale forecast (X1.3 Prototype)
- MET system for Icing forecast information (X1.4 Prototype)
- MET system for Clear Air Turbulence forecast information (X1.5 Prototype)
- MET system for Winter weather information (X1.6 Prototype)
- MET system for MET information for Network capacity reduction due to weather across Europe (X1.7 Prototype)
- MET system for MET information to support to 4D trajectory planning (X1.8 Prototype)
- MET system for Mode-S enhanced forecast information (X2.1 Prototype)
- MET system for MET information with E-AMDAR information (X2.2 Prototype)
- MET system for Regulatory MET information
- MET system for Nominal MET information
- MET system for Significant MET information

The MET scenarios per ATM phase, namely Long (LT), Medium (MT) & Short Term (ST) Planning, Execution (EX), and Post Operation (PO) Phases require different technical specifications of the MET prototypes. Due to the lack of requirements for the LT Planning, the TS is focused on the MT Planning (although limited to a short time window from the day before operation to a week ahead), ST planning, EX and PO phases. MET prototypes technical specifications such as area coverage, time resolution (update rate and time steps of forecast) and spatial resolution vary with the lead time of the forecast (the longer the lead time the coarser the time and spatial resolutions, the higher the uncertainty). These specifications also depend on which model or observation system is used, but as a first guess, the following Table 5 provides coarse specification estimates of existing or quickly emerging MET information:

Table 5: Typical specifications of the existing or quickly emerging enhanced MET information

	Medium Term Forecast **(MT)**	Short Term Forecast **(ST)**	Very Short Term Forecast **(VST)**		Observation
Area coverage	Global & Regional	Sub-Regional	Sub-Regional	Local	Local
Validity time	3 h to 7 days	2h to 24 h	T0 to 2h	T0 to 2h	T0 to min
Time Steps	6h	1 h	15 min	15 min	min
Horizontal resolution	25 km **(MR)**	2 km **(HR)**	1 km **(HR)**	100 m **(VHR)**	m to 100 m

2.4 User Characteristics

The Sub-regional end users of the “4DWxCube” DS include ATM users and Airspace users.

ATM users: En-route control (ACC/UAC), ATC supervisor, Flight management, Network manager

Airspace users: FOC/WOC, Airlines; Pilots

From a system perspective, however, the user of the Consolidation and Translation FBs of the 4DWxCube DS is the Management FB and MET-GATE FB. The MET-GATE FB manages the end users requirements and delivers MET products via services to the ATM consumers. The Management FB collects and distributes information from and to the Consolidation and Translation FBs. Requirements include the scope of the MET Information, Nominal or Significant Weather, the addressed ATM Planning Phase, Medium Term, Short Term or Execution, the area of interest which in the Sub-regional OUE corresponds to the TMA & En-route. Based on performance requirements, the MET-GATE can eventually reduce the granularity, precision, coverage, etc. of the corresponding MET Information.

2.5 Operational Scenarios

The use cases in the Sub-regional OUE are related to all phases of operation. The MET DOD WP11.02.01 – D26 [7] identifies the following operational scenarios:

- Long term planning use cases (6 months to 30 years):
  - Determine climate change impacts (UC-MET-LT01)
  - Determine adverse weather occurrence frequency (UC-MET-LT02)
  - Forecast seasonal outlook (UC-MET-LT03)
- Medium term planning (day before operations to a 6 months ahead):
  - Provision of adverse weather information (UC-MET-MT01
  - Provision of nominal MET information (UC-MET-MT02

At this stage, however, due to the lack of requirements for the long term planning, this version of the TS is focused on the Medium Term Planning (although limited to a shorter time window from the day before operation to a week ahead), Short Term Planning, Execution and Post Operation phases.

- Short term planning (Day before operations and day of operations):
  - Provision of adverse weather information (UC-MET-ST01
  - Provision of nominal weather information (UC-MET-ST02)
- Execution phase (in-flight, near-real time planning and decision making):
  - Provision of forecast adverse weather information (UC-MET-EX01)
  - Provision of forecast nominal weather information (UC-MET-EX02)
  - Provision of observed MET information (UC-MET-EX03): no scenarios envisaged that use observations at the network level. Likely to come from the local domain, e.g. observations from airports to indicate local conditions that could impact on overall Network management by impacting on capacity.
- Post-operation use cases:
  - Verify quality of MET forecast information (UC-MET-PO01)
  - Assist ATM stakeholders in MET information assessment (UC-MET-PO02)

2.6 Functional

2.6.1.1 Functional decomposition

The MET OSED [8] describes the MET concepts in terms of relevant stakeholders and links to operational scenarios and use cases. Following this attempt the MET systems are divided into the two categories of nominal and significant weather information.
There are three higher level MET systems:

1) MET system for Nominal MET information
2) MET system for Significant MET information
3) MET system for Regulatory MET information

The MET system for Regulatory MET information represents the current portfolio of products available for the aviation community regulated by ICAO Annex 3 [5].

The MET prototypes developed in WP11.2 cover specific parts of either nominal or significant MET information and generate MET products with functions represented in the FB breakdown structure.

MET systems of Nominal MET information:

- X1.1 Radar Composite for 3D Convection Prototype
- X1.3 Super-ensemble mesoscale forecast Prototype
- X1.8 Support to 4D trajectory planning Prototype
- X2.1 Mode-S enhanced forecast
- X2.2 E-AMDAR case study

MET systems of Significant MET information:

- X1.2 Nowcasting of Convection prototype
- X1.4 Icing forecast prototype
- X1.5 Clear Air Turbulence forecast prototype
- X1.6 Winter weather prototype
- X1.7 MET support to network capacity reduction due to significant weather across Europe

The X1.7 prototype has been intended to support the prediction of network capacity reduction due to significant weather across Europe. This prototype was not represented in the user's requirements. Therefore the development work has been put on hold after the first preliminary prototype.

The X2.1 Mode-S enhanced forecast and the X2.2 E-AMDAR case study did not intend to develop a real prototype for validation or operational use. Scientific case studies have been performed to show the benefit of the implementation of aircraft derived observations and on-board measurements in numerical weather prediction systems for MET ATM products.

Table 6 summarises the links between general MET systems including MET prototypes developed by WP11.2 and the FBs participating to their production. It also covers the addressed ATM Planning Phase and the corresponding functions.

Table 6 : Functional blocks and functions

MET system of	FBs	ATM Planning Phase	Functions
Regulatory MET information	T01 – Regulatory MET Information	Covering all phases (Medium/Short Term planning, Very Short Term planning, Execution) One function per regulatory Service	Real-time measured and/or observed weather parameters Local routine & special reports METAR/SPECI TREND TAF Forecast for take-off Aerodrome warnings Wind shear warnings & alerts
Nominal MET information (X1.1 and X1.8 MET prototypes)	C05: Medium Term Forecast	Medium Term Planning	MR/MT, Nominal Weather MET Information –Forecast Grids : ● Deterministic ● Ensemble ● Probabilistic
	C04: Short Term Forecast	Short Term Planning	HR/ST, Nominal Weather MET Information–Forecast Grids : ● Deterministic ● Ensemble ● Probabilistic
	C01: Radar Composite C02: Aircraft Information Processing & QC C03: VST Forecast T02: Local MET Information & Alerts	Execution	VHR/VST Nominal Weather MET Information– Deterministic Forecast Grids Local MET Observations
Significant MET information (X1.2, X1.3, X1.4, X1.5 and X1.6 MET prototypes)	C05: Medium Term Forecast T02: Local MET Information & Alerts T03: Convection T06: MET Forecast Uncertainty	Medium Term Planning	MR/MT, Significant Weather Warnings –Forecast Grids ● Deterministic ● Ensemble ● Probabilistic Significant Weather
	C04: Short Term Forecast T02: Local MET Information & Alerts T03: Convection T04: Icing Conditions	Short Term Planning	HR/ST, Significant Weather Warnings –Forecast Grids ● Deterministic ● Ensemble ● Probabilistic Significant Weather

	T05: CAT		Warnings Objects
	C02: Aircraft Information Processing & QC C03: VST Forecast T02: Local MET Information & Alerts T03: Convection T04: Icing Conditions T05: CAT	Execution	VHR/VST, Significant Weather Warnings, Deterministic Forecast Grids VHR/VST, Significant Weather Warnings, Forecast Objects VHR, Significant Weather Observation VHR, Significant Weather Objects

2.6.1.2 Functional analysis

The following list encompasses the MET prototypes developed for the sub-regional OUE.

2.6.1.3 Radar Composite of 3D Radar (X1.1)

The X1.1 MET prototype ingests radar scans in from the Generic MET infrastructure and potentially also the ATM-dedicated Aerodrome infrastructure e.g. French and UK radar networks. It delivers consolidated 3D gridded multi radar reflectivity products for specific local areas e.g. TMA domains centred on London Heathrow and Paris-Charles-de-Gaulle airports. This X1.1 prototype MET products can be used by the MET system of Significant MET information to generate 2D from 3D products used to diagnose convection (FB T03).

2.6.1.4 Nowcasting of Convection (X1.2)

The X1.2 prototype ingests outputs of the nowcasting tools from the participating national weather services provided by the Generic MET infrastructure. In a second step the translated nowcasting of convection product will be based on consolidated generic MET information produced in the C03 Very Short Tem Forecast FB.

The X1.2 prototype generates one harmonized dataset of severity levels for convection based on user defined thresholds. The consolidated and translated Nowcasting of Convection product is based on mainly lightning, radar reflectivity, satellite data, NWP data and weather station data covering the overall geographical area covered by the input data.

2.6.1.5 Super-ensemble mesoscale forecast (X1.3)

The X1.3 prototype processes output from several contributing ensemble weather prediction systems and computes probability maps of weather events over the geographical area covered by the contributing systems. It exhibits no unphysical discontinuity at the model edges and produces a consolidated MET product in the very short and short term forecast range (C03 and C04). This prototype can be used to compute consolidated nominal MET products or to be used for consolidated translated MET products when the contributing systems provide relevant predictors of convective activity (e.g. upper-level microphysical parameters or simulated reflectivities).

2.6.1.6 Icing forecast (X1.4)

The X1.4 prototype generates one harmonized dataset of severity levels for icing forecast based on user defined thresholds. The consolidated and translated Icing Forecast product is based on mainly

NWP data and also radar and satellite data covering the overall geographical area covered by the input data.

This prototype ingests outputs of the icing forecast tools from the participating national weather services provided by the Generic MET infrastructure. In a second step the translated icing forecast product will be based on consolidated MET information produced in the Short Term Forecast FB (C03) or maybe even Medium Term Forecast (C05) and aircraft observations (C02).

2.6.1.7 Clear Air Turbulence forecast (X1.5)

The X1.5 prototype generates one harmonized dataset of severity levels for CAT forecast based on user defined thresholds. The consolidated and translated CAT forecast product is based on NWP output data covering the overall geographical area covered by the input data.

This prototype ingests outputs of the CAT forecasting tools from the participating national weather services provided by the Generic MET infrastructure. In a second step the translated CAT forecast product will be based on consolidated MET information produced in the Short Term Forecast FB (C03) or maybe even Medium Term Forecast (C05) and aircraft observations (C02).

2.6.1.8 MET support to 4D trajectory planning (X1.8)

The X1.8 prototype processes global ensemble forecast of winds and temperature and calculates e.g. flight time variability along a fixed route or a measure of flight time variability due to forecast uncertainty or a measure of route uncertainty due to forecast uncertainty. This prototype produces a translated product for nominal weather managing the MET Forecast Uncertainty (T06).

2.6.1.9 MODE-S enhanced forecast (X2.1)

Upper air wind is an important parameter when using data assimilation in Numerical Weather Prediction (NWP) with a rapid update cycle [15]. From downlinked Mode-S EHS data, which includes ground speed, magnetic heading, true airspeed, true track angle, and Mach number, wind information is inferred from the vector difference between the air vector (airspeed and heading) and the ground vector (ground speed and track angle). Temperature is calculated using the Mach number, and the observed airspeed (whose accuracy should be within 3%). If rapid availability of the Mode-S EHS data is ensured, the resulting numerical nowcast wind will be of better quality when compared to NWP, despite the fact that temperature information derived from Mode-S EHS may be of less quality.

2.6.1.10 E-AMDAR case study (X2.2)

The X2.2 E-AMDAR case study has been performed to show the benefit for MET forecast products by including on board humidity measurements in NWP models. Over a period of three month thousands of humidity data have been assimilated in a regional NWP model (exemplary number of AMDAR humidity measurements: 15,390 by 40 aircraft on 30th March). The implementation of humidity data has an impact on the forecast of the liquid water content of the atmosphere. Therefore, more accurate actual data will improve the icing forecast tools.

2.7 Service View

This section describes how FBs and functions participate in the constitution of each MET Service independent of the MET prototypes developed as a first approach within the SESAR WP11.2 development activities.

2.7.1 Nominal Weather Information

TMA & En-route Nominal MET Information Service (SVC-11.02.01-OSED-TER1.0002)

2.7.1.1 Medium Term Planning

FB C05 collects sets of “Ensemble Medium Term Forecast” from the “General MET Infrastructure” via Port 1 and the “4DWxCube Management” FB and constitutes a “Consolidated Super-Ensemble MT Forecast” that is processed by the FB T06 to assess MET uncertainty. Three options exist for the service (Figure 5).

(i) Super-ensemble forecast is delivered as such for ensemble impact assessment;
(ii) A specific member (e.g. the most probable) is provided as a deterministic forecast;
(iii) The ensemble forecast is processed in FB T06 using user specified MET parameters and thresholds to provide the end user with probabilities of occurrence of the phenomenon of interest.

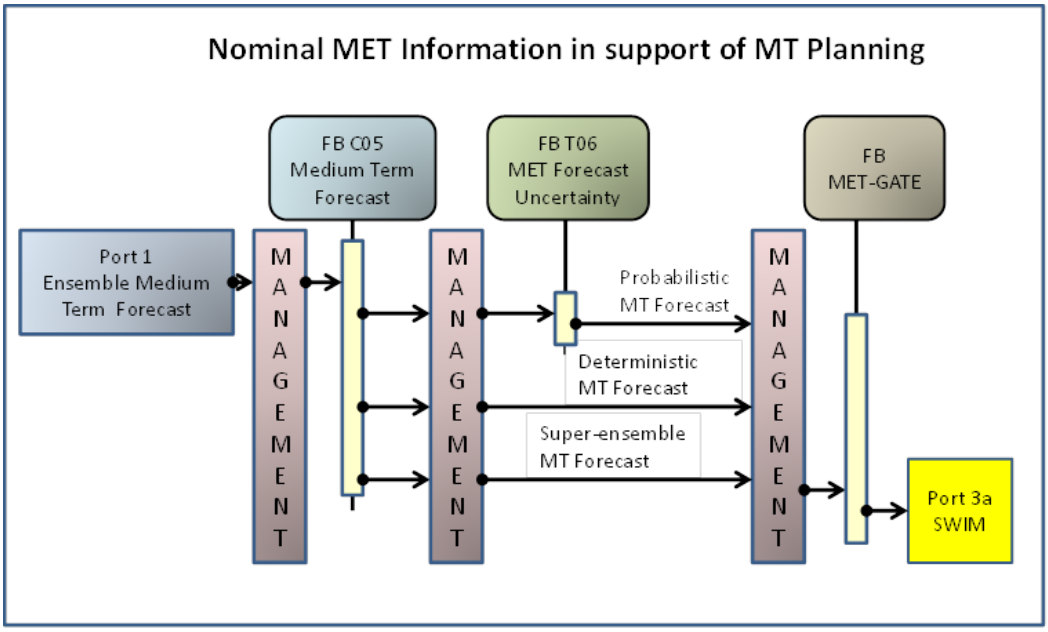

Figure 5 : Nominal MET Information in support of MT Planning

2.7.1.2 Short Term Planning

FB C05 collects sets of “Ensemble Short Term Forecast” from the “General MET Infrastructure” via Port 1 and the “4DWxCube Management” FB and constitutes a “Consolidated Super-Ensemble ST Forecast” that is processed by the FB T06 to assess MET uncertainty. Three options exist for the service (Figure 6).

(i) Super-ensemble forecast is delivered as such for ensemble impact assessment;
(ii) A specific member (e.g. the most probable) is provided as a deterministic forecast;
(iii) The ensemble forecast is processed in FB T06 using user specified MET parameters and thresholds to provide the end user with probabilities of occurrence of the phenomenon of interest.

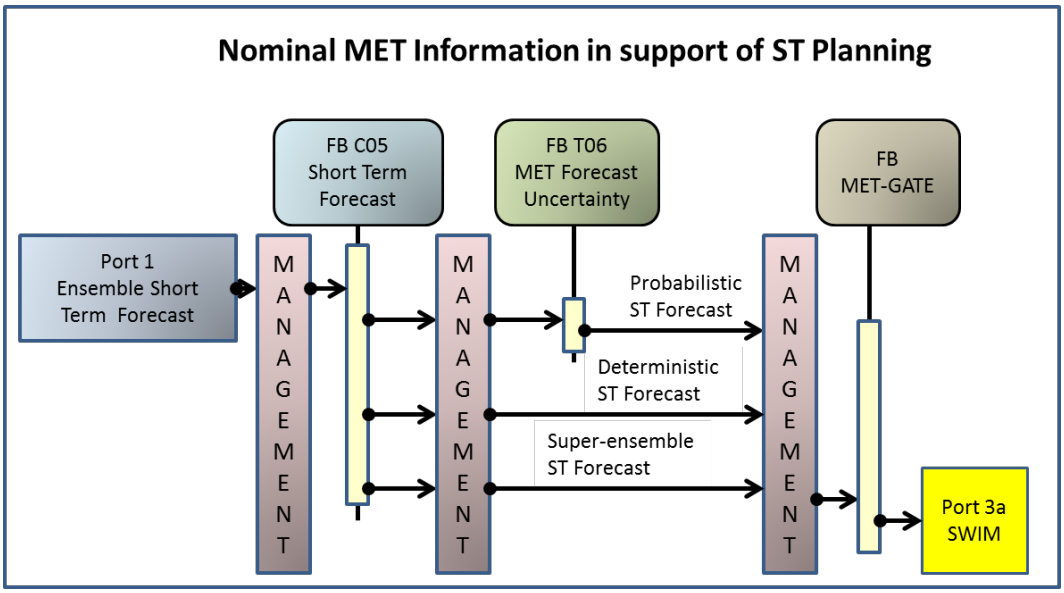

Figure 6 : Nominal MET information in support of Short-term planning

2.7.1.3 Execution

FB C05 collects sets of "Ensemble Very Short Term Forecast" from the General MET Infrastructure via Port 1 and the "4DWxCube Management" FB and constitutes a "Consolidated Super-Ensemble VST Forecast" that is processed by the FB T06 to assess MET uncertainty. Three options exist for the service (Figure 7).

(i) Super-ensemble forecast is delivered as such for ensemble impact assessment;
(ii) A specific member (e.g. the most probable) is provided as a deterministic forecast;
(iii) The ensemble forecast is processed in FB T06 using user specified MET parameters and thresholds to provide the end user with probabilities of occurrence of the phenomenon of interest.

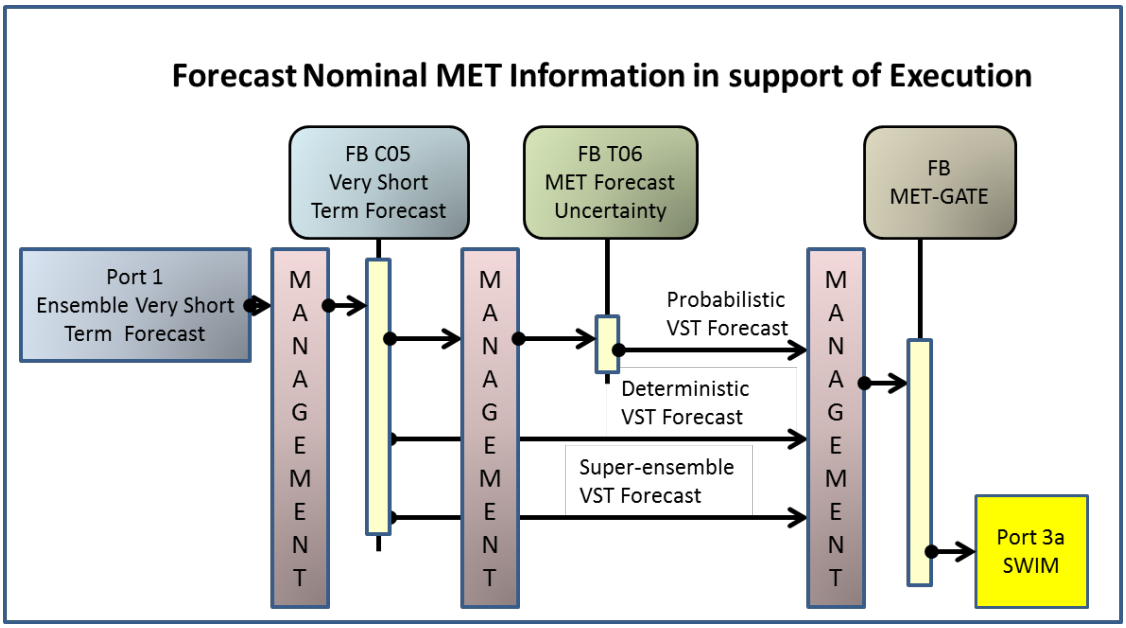

Figure 7 : Forecast Nominal MET Information in support of Execution

2.7.2 Significant Weather Information

TMA & En-Route Significant Weather Service (SVC-11.02.01-OSED-TER1.0003)

2.7.2.1 Medium Term Planning

FB C05 collects “Ensemble Medium Term Forecast” fields from the “General MET Infrastructure” via Port 1 and the “4DWxCube Management” FB and constitutes a “Consolidated Super-Ensemble MT Forecast”. The members of the Super-Ensemble forecast are analyzed to predict “Convection”, “Icing Conditions” and “CAT” hazards in FB T03, T04, and T05, respectively. FB MT06 collects the predictions of weather hazards to derive probabilistic predictions of the “Convection”, “Icing Conditions”, and “CAT” risks (Figure 8).

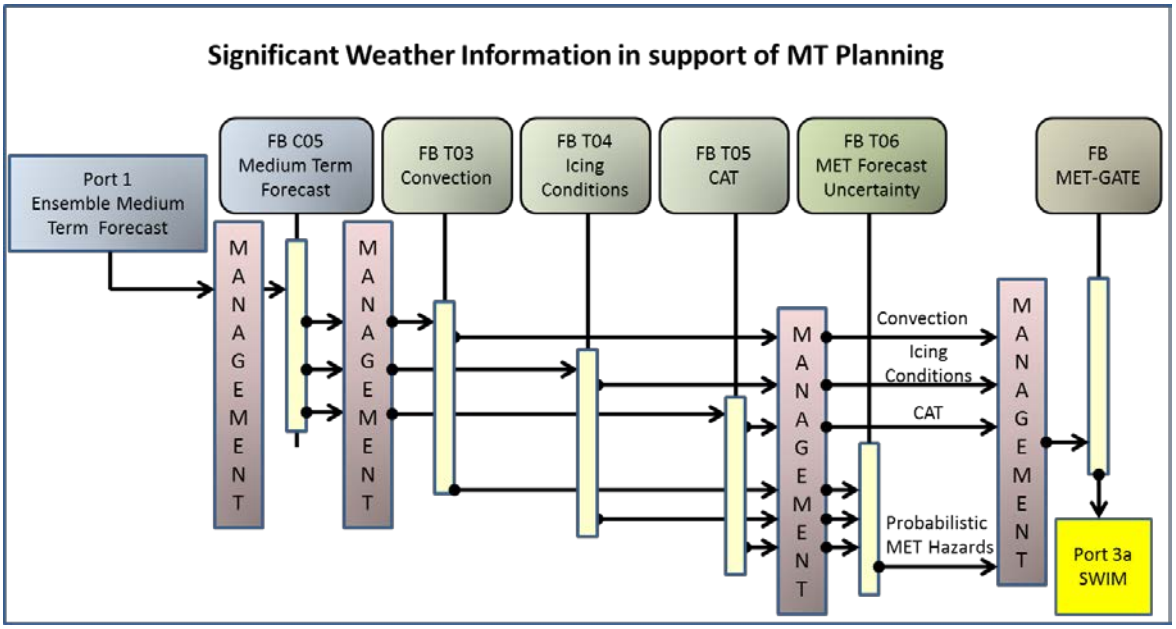

Figure 8 : Significant Weather Information in support of MT Planning

2.7.2.2 Short Term Planning

FB C04 collects “Ensemble Short Term Forecast” fields from the General MET Infrastructure via Port 1 and the “4DWxCube Management” FB and constitutes a “Consolidated Super- Ensemble ST Forecast”. The members of the Super-Ensemble forecast are analyzed to predict “Convection”, “Icing Conditions” and “CAT” hazards in FB T03, T04, and T05, respectively. FB MT06 collects the predictions of weather hazards to derive probabilistic predictions of the “Convection”, “Icing Conditions”, and “CAT” risks (Figure 9).

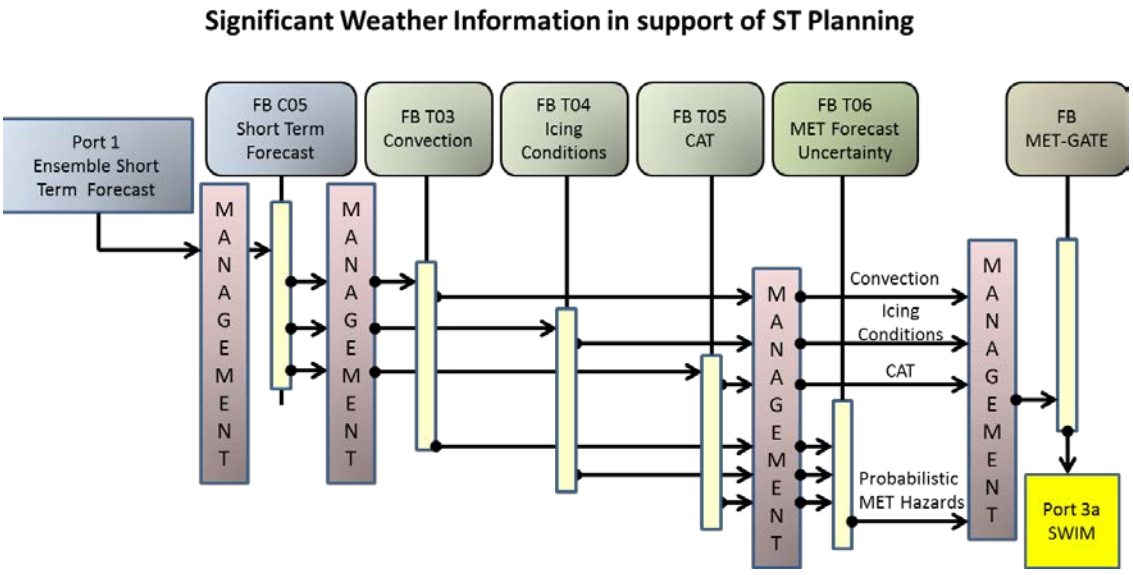

Figure 9 : Significant Weather Information in support of ST Planning

2.7.2.3 Execution

FB C03 collects “Ensemble Very Short Term Forecast” fields from the General MET Infrastructure via Port 1 and the “4DWxCube Management” FB and constitutes a “Consolidated Super-Ensemble VST Forecast”. The members of the Super-Ensemble forecast are analyzed to predict “Convection”, “Icing Conditions” and “CAT” hazards in FB T03, T04, and T05, respectively. FB MT06 collects the predictions of weather hazards to derive probabilistic predictions of “Convection”, “Icing Conditions”, and “CAT” risks. At the airport, FB T02 collects “Local Met Observations” from the “ATM-dedicated MET Infrastructure” via Port 2 and the “4DWxCube Management” FB and the “Consolidated VST Forecast” from FB C03 to develop VST forecast of “Local MET Information and Alerts” (Figure 10). “Local MET Alerts” are made available to end users via a short latency dedicated port (Port 5) in Step 1, and eventually in Step 2 via SWIM using the Blue Profile.

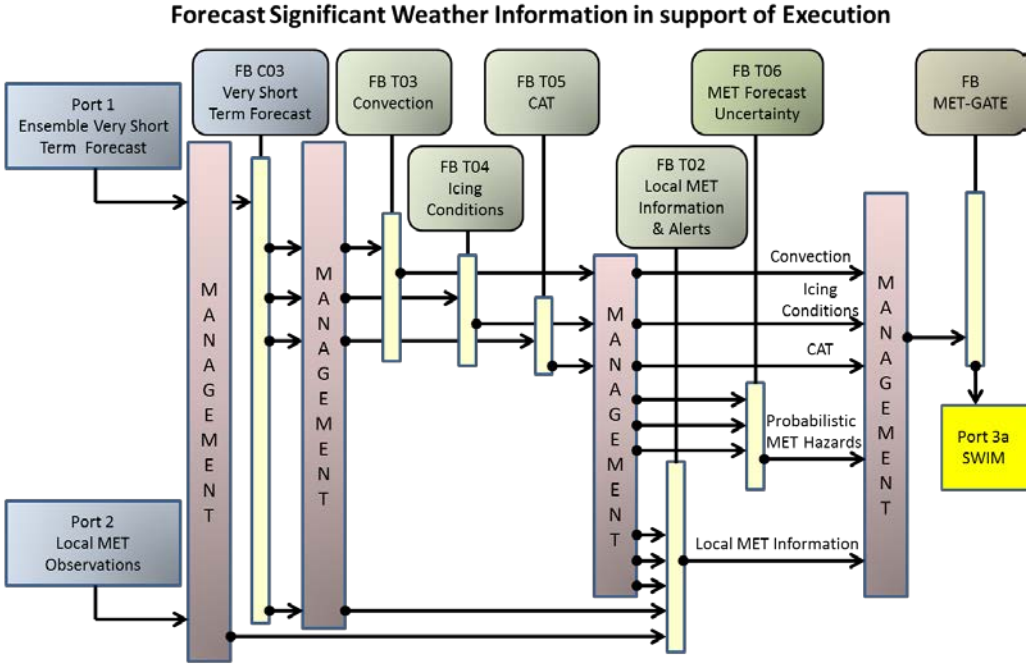

Figure 10 : VST Forecast Significant Weather Information in support of Execution

2.7.2.4 Observation

FB C01 and C02 contribute to the MET observations with the “Consolidated Radar Reflectivity” and the “Aircraft-derived MET Observations”, respectively. They supplement “Generic MET Observations” to support the assessment of “Convection”, “Icing Conditions”, and “CAT” in FB T03, T04 and T05, respectively. They are also used in combination with “Local MET Observations” collected from Port 2 to develop “Local MET Information & Alerts” in FB T02. Note that short latency local alerts can be delivered to end users directly via Port 5 (Step 1), or through the MET-GATE and the SWIM Port 4b using a Blue Profile in Step 2 (Figure 11).

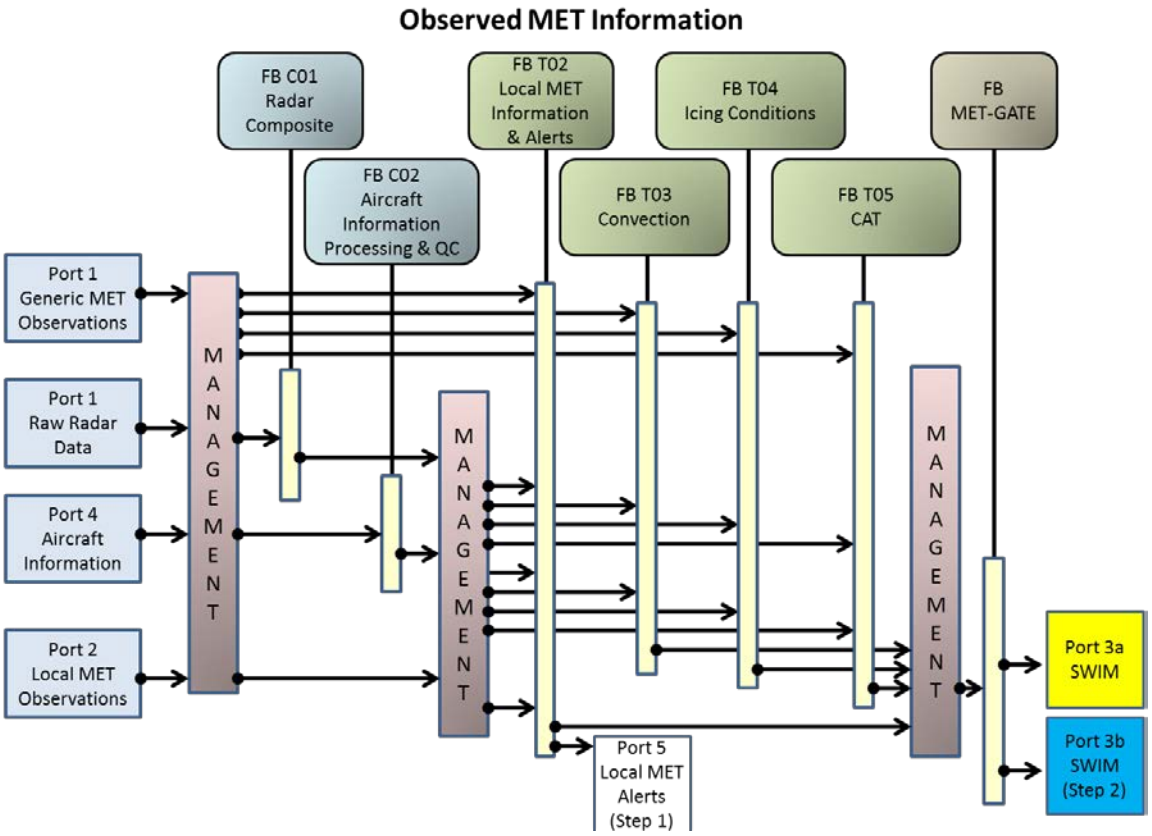

Figure 11 : Observed MET Information in support of Execution

3 Functional block Functional and non-Functional Requirements

In the following sections, the TS requirement identifiers are developed as follows:

MET TS document: REQ-11.02.02-TS-ABCD.XYZZ:

- ABC = LOC, TER or NET to indicate if the requirement is valid for the Local, Sub-regional or Network OUE ; hence in this MET-TS, ABC = TER
- D = indication of the development step: initial (D = 1) or updated (D = 2) requirement
- XYZZ = number unique for each ABCD combination with X indicating if the requirement is ICAO Annex 3 (0), Nominal MET (1), Significant MET (2), Safety (3) or general MET information (9) requirement and Y indicating if the requirement is of a general nature (0), an observation (1), deterministic (2) or probabilistic (3) forecast.

At the end of the SESAR 1 Programme the requirement status is selected to be either 'validated', 'deleted' or 'in progress'. System requirements have not been validated as operational requirements have been. Nevertheless, the status is named 'validated' if the system requirements have been verified successfully. The status of a requirement has been set on deleted for any requirement that has not been verified successfully due to the unavailability of input from the outside or other stakeholders. Requirements that have been partially verified successfully are marked as 'in progress' because some effort (e.g. implementation of functionalities in the prototypes) would have been needed to complete the verification process. Details of the verification results are reported in [14].

'Deleted' does not include 'not valid anymore', all requirements are evaluated as necessary and important.

3.1 Capabilities

3.1.1 Regulatory MET information

[REQ]

Identifier	REQ-11.02.02-TS-TER2.0001
Requirement	The MET system for Regulatory MET information shall produce - SIGMET - AIRMET - area forecasts for low level flights - METAR - TREND - SPECI - TAF - VAA - TCA - release of radioactive material - meteorological satellite images - ground-based radar images products according to ICAO Annex 3 templates (contents and if not otherwise specified accuracy) and ICAO Doc 7754 (issue time/update rate).
Title	Provision of ICAO Annex 3 products
Status	<Validated>
Rationale	ICAO Annex 3 regulated information are mandatory for aviation.

Category	<Functional>
Validation Method	
Verification Method	<Inspection>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.0002	<Partial>
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3.1.2 Nominal MET information

3.1.2.1 Nominal Sub-regional MET observations

[REQ]

Identifier	REQ-11.02.02-TS-TER2.1101
Requirement	The MET system for Nominal MET information shall produce observation products on - wind speed aloft - wind direction aloft - temperature aloft - air pressure (QNH) with instantaneous availability / update rate of 10 minutes (wind)
Title	Observation: wind, temperature and pressure products
Status	<Validated>
Rationale	Sub-regional stakeholders require observed wind speed aloft in support of their operations; wind aloft observations can be obtained via ground-based sensors such as LIDAR or via aircraft sensors.
Category	<Functional>
Validation Method	
Verification Method	<Inspection>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0002.4008	<Partial>
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<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0001.3008	<Partial>
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Mode-S derived MET information

[REQ]

Identifier	REQ-11.02.02-TS-TER2.1102
Requirement	The MET system for Mode-S derived information shall produce observation products for - wind speed aloft - wind direction aloft - headwind aloft - crosswind aloft - temperature for an area of minimum 10 NM around the airport extending from the surface up to 5000ft, with vertical resolution of 500ft up to 2000ft and 1000ft up to 5000ft, slant resolution of 0,5 NM and an update rate of 10 minutes.
Title	Mode-S derived MET information - observation
Status	<Validated>
Rationale	Sub-regional stakeholders require observed wind information in support of their operations.
Category	Functional
Validation Method	
Verification Method	Test

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET2.0022	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET2.0023	Partial
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<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-LOC1.2102	Partial
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<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-LOC2.2104	Partial
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<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-LOC1.2301	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-LOC1.2311	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-LOC1.2313	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-LOC1.2314	Partial

3.1.2.2 Nominal Sub-regional MET forecasts

[REQ]

Identifier	REQ-11.02.02-TS-TER2.1201

Requirement	The MET system for Nominal MET information shall produce deterministic forecast products on - wind speed aloft - wind direction aloft - temperature aloft - air pressure (QNH) with minimum time horizon as well as higher time resolution and update rate according to ICAO Annex 3 templates
Title	Forecast: wind, temperature and pressure products
Status	<Validated>
Rationale	Sub-regional stakeholders require forecast wind information in support of their operations
Category	<Functional>
Validation Method	
Verification Method	<Inspection>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0002.4008	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0001.3012	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0001.3015	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0001.3019	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0001.3008	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.1201	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.1202	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.1205	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.1206	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02-01-SPR-TER1.1301	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02-01-SPR-TER1.1302	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02-01-SPR-TER1.1303	<Partial>

[REQ]

Identifier	REQ-11.02.02-TS-TER2.1202
Requirement	The MET system for Nominal MET information shall produce forecast products for - wind speed aloft - wind direction aloft - headwind aloft - crosswind aloft - temperature for an area of minimum 10 NM around the airport extending from the surface up to 5000ft, with vertical resolution of 500ft up to 2000ft and 1000ft up to 5000ft, slant resolution of 0,5 NM and an update rate of 10 minutes.
Title	Mode-S derived information – deterministic forecast
Status	<Validated>
Rationale	Sub-regional stakeholders require forecast wind information in support of their operations.
Category	Functional
Validation Method	
Verification Method	Test

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance

<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET2.0022	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET2.0023	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET2.0024	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET2.0025	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET2.0026	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET2.0027	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.05.03-OSED-DCBS.0120	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.08.01-OSED-FUNC.0005	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.08.01-OSED-FUNC.0007	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.08.01-OSED-FUNC.0008	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.08.01-OSED-FUNC.0106	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.08.01-OSED-OPS1.0400	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-LOC1.2201	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-LOC1.2202	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-LOC1.2203	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-LOC2.2204	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-LOC1.2205	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-LOC1.2301	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-LOC1.2311	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-LOC1.2313	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-LOC1.2314	Partial

3.1.2.3 Nominal Sub-regional MET probabilistic forecasts

[REQ]

Identifier	REQ-11.02.02-TS-TER2.1301
Requirement	The MET system for Nominal MET information shall produce probability forecast products on - air pressure (QNH) with minimum time horizon as well as higher time resolution and update rate according to ICAO Annex 3 templates
Title	Probability: wind, temperature and pressure products
Status	<Validated>
Rationale	Sub-regional stakeholders require forecast wind information in support of their operations
Category	<Functional>
Validation Method	
Verification Method	<Inspection>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0002.4008	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0001.3012	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0001.3015	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0001.3019	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0001.3008	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.1201	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.1202	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.1205	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.1206	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02-01-SPR-TER1.1301	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02-01-SPR-TER1.1302	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02-01-SPR-TER1.1303	<Partial>

Super-ensemble mesoscale forecast information

[REQ]

Identifier	REQ-11.02.02-TS-TER2.1302
Requirement	The MET system for super-ensemble forecast shall produce a seamless prediction of ensemble forecast products for - 2m temperature - 2m relative humidity - 10m wind speed - 6hour precipitation accumulation In a high spatial and temporal resolution covering GER-FR-UK territory.
Title	X1.3 – nominal probabilistic forecast
Status	<Validated>
Rationale	Sub-regional stakeholders require probabilistic forecast information based on ensemble forecast data in support of their operations.
Category	<Functional>
Validation Method	
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
/	/	/	/

MET information to support to 4D trajectory

[REQ]

Identifier	REQ-11.02.02-TS-TER2.1303
Requirement	The MET system for MET information supporting to 4D trajectory shall produce ensemble forecast products for - wind speed aloft - wind direction aloft - temperature aloft probabilistic information in a high spatial and temporal resolution with a global coverage.
Title	X1.8 – global nominal probabilistic forecast
Status	<Validated>
Rationale	Sub-regional stakeholders require probabilistic forecast information based on ensemble forecast data in support of their operations.
Category	<Functional>
Validation Method	
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0002.4008	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0001.3012	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0001.3015	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0001.3019	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-04.07.02-OSED-0001.3008	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.1201	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.1202	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.1205	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.1206	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02-01-SPR-TER1.1301	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02-01-SPR-TER1.1302	<Partial>

<SATISFIES>	<ATMS Requirement>	REQ-11.02-01-SPR-TER1.1303	<Partial>

3.1.3 Significant MET information

3.1.3.1 Significant Sub-regional MET observations

[REQ]

Identifier	REQ-11.02.02-TS-TER2.2101
Requirement	The MET system for Significant MET information shall produce observation products on - significant weather - convective activity - turbulence - icing - wind shear with higher spatial and temporal resolution than in ICAO Annex 3.
Title	Observations related to significant weather phenomena
Status	<Validated>
Rationale	Sub-regional stakeholders require observed adverse weather information in support of their operations.
Category	<Functional>
Validation Method	
Verification Method	<Inspection>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.2101	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.3100	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.3102	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.3103	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3311	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3312	<Partial>

3D Radar composite MET information

[REQ]

Identifier	REQ-11.02.02-TS-TER2.2103
Requirement	The MET system for 3D radar information shall produce observation products for - convective activity information - lightning information for an area of minimum 120NM around the airport with an update frequency according the received information.
Title	X1.1 – convection & lightning observation
Status	<Validated>
Rationale	Sub-regional stakeholders require observed convective activity and lightning in support of safe operations.
Category	Functional
Validation Method	
Verification Method	Test

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET2.0065	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET3.0005	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET4.0005	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.05.03-OSED-PERF.0160	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-LOC1.3101	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-LOC1.3102	Partial

3.1.3.2 Significant Sub-regional MET forecasts

[REQ]

Identifier	REQ-11.02.02-TS-TER2.2201
Requirement	The MET system for Significant MET information shall produce deterministic products on significant weather with an accuracy at least as in and with higher spatial and time resolution than in ICAO Annex 3
Title	Deterministic forecasts related to significant weather phenomena
Status	<In Progress>
Rationale	Sub-regional stakeholders require forecast adverse weather information in support of their operations
Category	<Functional>
Validation Method	
Verification Method	<Inspection>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.3200	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3201	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3301	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3311	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3312	<Partial>

Nowcasting of Convection information

[REQ]

Identifier	REQ-11.02.02-TS-TER2.2202
Requirement	The MET system for Nowcasting of Convection information shall produce convective activity information forecast products for GER-FR-UK territories with an update frequency of 15 minutes.
Title	X1.2 - convection and lightning forecast (short term)
Status	<Validated>
Rationale	Sub-regional stakeholders require forecasts of convective activity and lightning in support of safe operations.
Category	Functional
Validation Method	
Verification Method	Test

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET1.0009	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET2.0065	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET2.0066	Partial

<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET1.0021	Partial
<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET4.0005	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-LOC1.3201	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-LOC1.3311	Partial

Icing forecast information

[REQ]

Identifier	REQ-11.02.02-TS-TER2.2203
Requirement	The MET system for Icing forecast information shall produce a seamless forecast of icing conditions in severity levels (no icing, light, moderate, severe) with higher spatial and temporal resolution than in ICAO Annex 3.
Title	Icing – deterministic forecast
Status	<Validated>
Rationale	Sub-regional stakeholders require forecast significant weather information in support of their operations
Category	<Functional>
Validation Method	
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.3203	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3201	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3301	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3311	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3312	<Partial>

Turbulence forecast information

[REQ]

Identifier	REQ-11.02.02-TS-TER2.2204
Requirement	The MET system for turbulence forecast information shall produce a seamless forecast of clear air turbulence in four severity levels (no turbulence, light, moderate, severe) with higher spatial and temporal resolution than in ICAO Annex 3.
Title	Turbulence – deterministic forecast
Status	<Validated>
Rationale	Sub-regional stakeholders require forecast significant weather information in support of their operations
Category	<Functional>
Validation Method	
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.3202	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3201	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3301	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3311	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3312	<Partial>

3.1.3.3 Significant Sub-regional MET probabilistic forecasts

[REQ]

Identifier	REQ-11.02.02-TS-TER2.2301
Requirement	The MET system for Significant MET information shall produce probabilistic products on - significant weather - turbulence - icing with accuracy at least as high as in and with higher spatial and time resolution than in ICAO Annex 3.
Title	Probabilistic forecasts related to significant weather phenomena
Status	<Validated>
Rationale	Sub-regional stakeholders require forecast adverse weather information in support of their operations
Category	<Functional>
Validation Method	
Verification Method	<Inspection>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.3200	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.3202	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.3203	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3201	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3301	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3311	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.3312	<Partial>

Super-ensemble mesoscale forecast for convection information

[REQ]

Identifier	REQ-11.02.02-TS-TER2.2302
Requirement	The MET system for super-ensemble mesoscale forecast for convection information shall produce a seamless ensemble forecast product for convective activity (depending on the received parameter) to enable probabilistic information in a high spatial and temporal resolution covering GER-FR-UK territory.
Title	Probabilistic forecast related to convective activity
Status	<Validated>
Rationale	Sub-regional stakeholders require forecast significant weather information in support of their operations
Category	<Functional>
Validation Method	
Verification Method	<Inspection>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
/	/	/	/

3.2 Adaptability

N/A

3.3 Performance

3.3.1.1 Nominal MET information

N/A

3.3.1.2 Significant MET information

[REQ]

Identifier	REQ-11.02.02-TS-TER2.2102
Requirement	The MET system for Significant MET information shall send on observed Information on observed significant weather conditions immediately after detection.
Title	Significant MET observations - latency
Status	<Validated>
Rationale	Latency of information on significant weather conditions shall be as low as possible.
Category	Performance
Validation Method	
Verification Method	Analysis

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-06.05.05-OSED-MET1.0009	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-LOC1.3303	Partial
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-LOC1.4303	Partial

3.4 Safety & Security

[REQ]

Identifier	REQ-11.02.02-TS-TER2.9004
Requirement	The products produced by the MET systems shall be approved by authorized organisation for aviation usage (e.g. by EASA).
Title	Certified MET products
Status	<Deleted>
Rationale	Legal regulations.
Category	<Security>
Validation Method	
Verification Method	<Inspection>

Not available for verification

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance

3.5 Maintainability

3.6 Reliability

[REQ]

Identifier	REQ-11.02.02-TS-TER2.9003
Requirement	The MET systems for Consolidation and Translation of MET information for Aviation use shall produce reliable (not corrupted) MET products.
Title	MET products - reliability
Status	<Validated>
Rationale	Only uncorrupted data is reliable and can be used for safe operations.
Category	<Reliability>
Validation Method	
Verification Method	<Inspection>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.9101	<Partial>

3.7 Functional Block Internal Data

3.7.1.1 Nominal MET information

[REQ]

Identifier	REQ-11.02.02-TS-TER2.1004
Requirement	The MET system for Nominal MET information shall produce statistical wind information on request of sub-regional stakeholder.
Title	Statistical wind on request
Status	<Validated>
Rationale	Stakeholders require statistical wind information in support of planning purposes (e.g. for optimizing route structures and procedures)
Category	<Functional>
Validation Method	
Verification Method	<Inspection>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-OSED-TER1.4003	<Partial>

[REQ]

Identifier	REQ-11.02.02-TS-TER2.1001
Requirement	The MET system for Nominal MET information shall produce individual - wind - temperature with accuracy better than 10kt / 10° and combined error less than 15kt (it is assumed that 1kt error = 1°error).
Title	Accuracy – wind and temperature
Status	<Validated>
Rationale	The MET information needs to be sufficiently accurate to support the

	operational processes.
Category	<Functional>
Validation Method	
Verification Method	<Inspection>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.1202	<Partial>

[REQ]

Identifier	REQ-11.02.02-TS-TER2.1002.
Requirement	The MET system for Nominal MET information shall use for MET observations aloft, the most accurate source (ground based observations, airborne observation or merge of ground based and airborne observations).
Title	Accuracy - most accurate source
Status	<Validated>
Rationale	The MET information needs to be sufficiently accurate to support the operational processes.
Category	<Functional>
Validation Method	
Verification Method	<Inspection>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.1203	<Partial>

3.8 Design and Construction Constraints

[REQ]

Identifier	REQ-11.02.02-TS-TER2.9001
Requirement	The MET systems for Consolidation and Translation of MET information for Aviation use shall produce MET products consistent in time and across the different Operational User environments.
Title	Consistency of MET information
Status	<Validated>
Rationale	Consistent MET information will avoid inconsistent situational awareness and inconsistent decision making
Category	<Design>
Validation Method	
Verification Method	<Review of Design>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-11.02-DOD-6100.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.1211	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-06.06.02-SPR-0001.0001	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-5.6.4-REQS-0028.1210	<Partial>

[REQ]

Identifier	REQ-11.02.02-TS-TER2.9002
Requirement	The MET systems for Consolidation and Translation of MET information for Aviation use shall produce MET products based on latest science in observation and forecasting techniques.
Title	Use of latest science
Status	<Validated>
Rationale	Latest forecasting techniques such as probabilistic forecasting and ensemble modelling will allow user to manage uncertainty. Latest forecasting techniques such as medium-range and seasonal forecasting will allow useful MET information available to users already in strategic planning phases. Latest science in nowcasting techniques will increase accuracy of forecasts in execution phase. Latest observation techniques will increase the quality of individual measurement and the integration of different measurements and post-processing will improve the overall quality and consistency of observations.
Category	<Design>
Validation Method	
Verification Method	<Review of Design>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-11.02-DOD-6100.0002	<Partial>

3.8.1.1 Nominal MET information

[REQ]

Identifier	REQ-11.02.02-TS-TER2.1003
Requirement	The MET system for Nominal MET information shall produce observation and forecast products in an area - at least 100-120 NM around the airport - or for trajectories with higher spatial and temporal resolution than in ICAO Annex 3.
Title	Coverage of the Nominal MET
Status	<Validated>
Rationale	Observed and forecast values need to be representative for the area of interest of the ATM stakeholders
Category	<Design>
Validation Method	
Verification Method	<Review of Design>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.1302	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.1312	<Partial>
<SATISFIES>	<ATMS Requirement>	REQ-11.02.01-SPR-TER1.1313	<Partial>

3.9 Functional Block Interface Requirements

See 11.02.02-D42 IRS deliverable [12]

4 Assumptions

N/A

5 References

[1] Template Toolbox 03.00.00
https://extranet.sesarju.eu/Programme%20Library/SESAR%20Template%20Toolbox.dot

[2] Requirements and V&V Guidelines 03.00.00
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5.1 Use of copyright / patent material /classified material

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