ICHASE D030
–
Final Report

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CHANGE RECORDS

ISSUE	DATE	§ CHANGE RECORDS	AUTHOR
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V 3.0	23/09/2022	- ICHASE-FR-RID-0017: ESSP removed from Figure 26. - ICHASE-FR-RID-0022: Accreditation labs added again. - ICHASE-FR-RID-0023 : Section 9 and 10 updated - ICHASE-FR-RID-0026: bullet numbers corrected - ICHASE-FR-RID-0027 : Section 10.4 added - ICHASE-FR-RID-0039: Section 1.4 updated with acronyms - ICHASE-FR-RID-044: correction of figure 14, and update of section 5.6. - ICHASE-FR-RID-051: summary of requirement definition methodology added in Section 5.2 - ICHASE-FR-RID-0075: reference added - ICHASE-FR-RID-0076: labelled changed - Arrows in integrity risk allocation tree corrected to be in the same direction, figure 19	TAS: Hanaa Al Bitar / Anne-Marie TOBIE / Rami Ali Ahmad

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1. EXECUTIVE SUMMARY

1.1. SCOPE OF THE PROJECT

Started in April 2021 with a duration of 15 months, ICHASE (standing for Integrity Complementing High Accuracy Service via EGNSS) aimed at providing inputs in relation to a possible future integrity service complementing EGNSS High Accuracy (HA). By EGNSS it is referred to the European GNSS ecosystem, including today Galileo and EGNOS systems). The ICHASE project is part of the roadmap that the EC is currently defining for the long-term evolution of the EGNSS (EGNOS and Galileo) programme, including new services and applications.

ICHASE focused on the deployment of autonomous cars operating at SAE Level 5/4 autonomy level, meaning that they have the capability of navigating autonomously on a road network without human dependency. In such conditions, a car needs precise and continuous position estimates to warrant their behaviour. A High Accuracy and Integrity Service (HAIS) that complements EGNSS HA signals is being considered for such future applications. ICHASE considers the 2030+ timeframe for the deployment of such new HAIS taking into account the alignment needs in terms of technological solutions, standards, legislation and market drivers.

1.2. FUNDING, CONSORTIUM AND EXPERTS SUPPORTING THE PROJECT

ICHASE was funded by the European Commission and technically managed by the EUSPA.

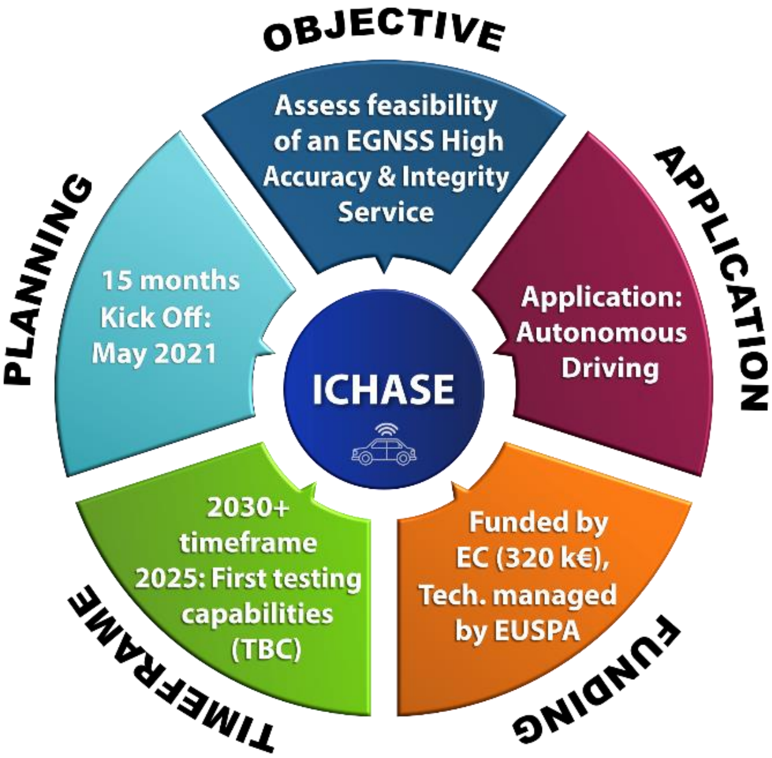

Figure 1 – ICHASE project meta data

ICHASE has been performed by an interdisciplinary team composed by Thales Alenia Space (prime), FDC and know.space, GEA Space and Université Gustave Eiffel. It involved also external experts in order to get inputs/feedbacks/validation at different moments/outcomes of the project. The panel of experts included representatives from key actors of the value chain and other stakeholders.

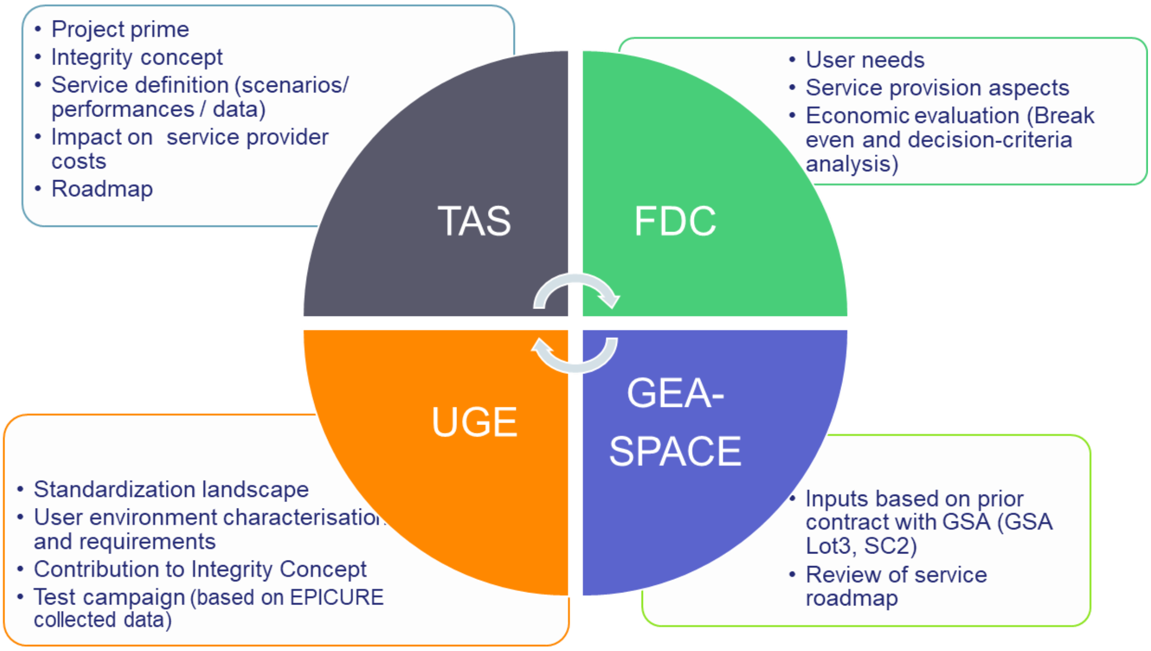

Figure 2 – ICHASE consortium and key roles

Three interactions with the experts were performed, namely for:

1. The formulation of the user needs and requirements of Autonomous Driving Systems;
2. The definition of the concepts/features that the future HAIS complementing EGNSS HA should have, and the potential service provision scheme;
3. The related decision making aspects and the elaboration of the associated roadmap for the HAIS introduction/adoption.

Know.Space has supported FDC in their activities, mainly on the decision criteria analysis.

1.3. STUDY LOGIC OF THE PROJECT

In order to fulfil the objectives of the ICHASE project, the consortium went through five different tasks, as illustrated in Figure 3.

- The first task consisted in a deep analysis of the autonomous driving needs. To state these needs is of prior importance since they drive all the integrity concept and service definition. These needs were derived based on a comprehensive analysis of the state of the art, as well as experts consultations. The consulted experts covered the whole autonomous domain chain: from OEM to Tier 1 and Tier 2 providers. These needs are detailed in [RD-1] and summarized in section 3.
- The second task consisted in the definition of the Autonomous Driving integrity concept at the user level. The design of such concept is itself split in 4 principal steps. The integrity concept final definition is the result of an iterative process over these different steps:
    - The definition of the Functional System Architecture,
    - The safety assessment
    - The design of the localization module
    - The definition of a 3 layer based integrity concept for the localization module

  These steps are described in details in [RD-2] and summarized in section 4.
- The third task focused on the integrity service definition which aims at defining the new service data content, the proposed high level architecture and the potential dissemination means. This is described in details in [RD-6] and summarized in section 5.
- Task 4 included activities related to the definition of the decision criteria. It consisted in the derivation of a set of key decision criteria for three stakeholder groups (Device Manufacturers; Users; and the Integrity service provider) that motivates their decision to provide/adopt the proposed service. This is described in details in [RD-7] and summarized in section 8.
- Finally, in Task 5, a roadmap for the HAIS implementation has been proposed as detailed in [RD-8] and summarized in section 9 of this Final Report.

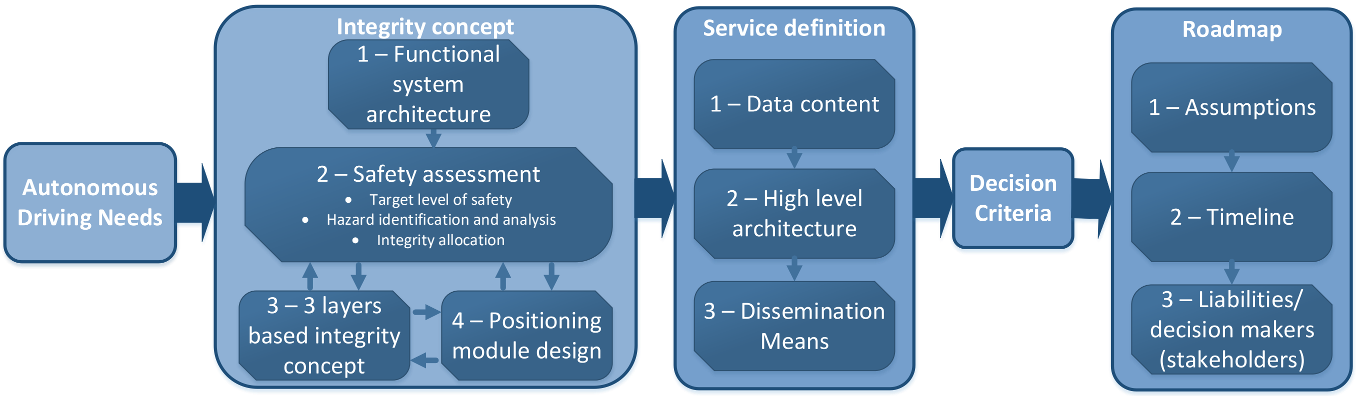

Figure 3 – Methodology of the ICHASE project

This methodology is associated to the deliverables illustrated in Figure 4 below.

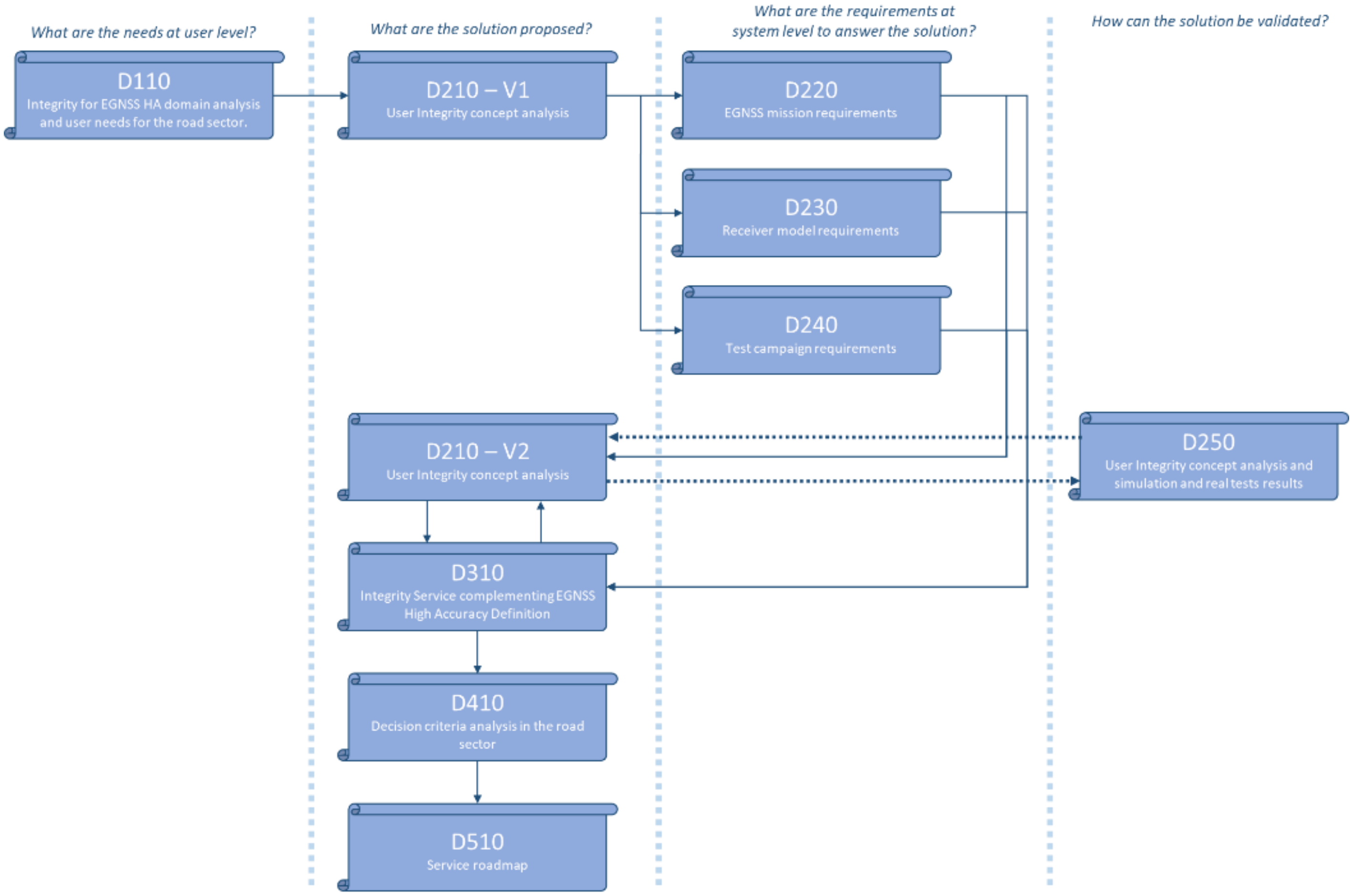

Figure 4 – Overview of the ICHASE deliverables

1.4. MAIN OUTCOMES

ICHASE addressed the challenging objective of computing a highly precise and reliable positioning for Autonomous Driving Level 4 and 5.

Why is positioning for AD applications challenging ?

When compared with other transports mode (like aviation, rail or road), the autonomous driving needs are more challenging. They combine the need for high accuracy, and continuity, with harsh and diverse operational domains. On top of this, safety is of utmost importance when it comes to such safety critical applications.

This means that, having technology ready for autonomous driving is not enough. One of the biggest drivers for a scaled adoption is the users acceptance, which is driven by Safety.

To this end, ICHASE developed a user centric End to End integrity concept that relies on two main parts:

- A user integrity concept building on sensor fusion architecture,
- A high precision and integrity service to be delivered by the EGNSS infrastructure.

In this case, the EGNSS systems provides monitoring of the GNSS based high precision service and related integrity data, and the user unit embeds the needed tools for local feared events monitoring and mitigation and thus computes the protection level of the high precision position.

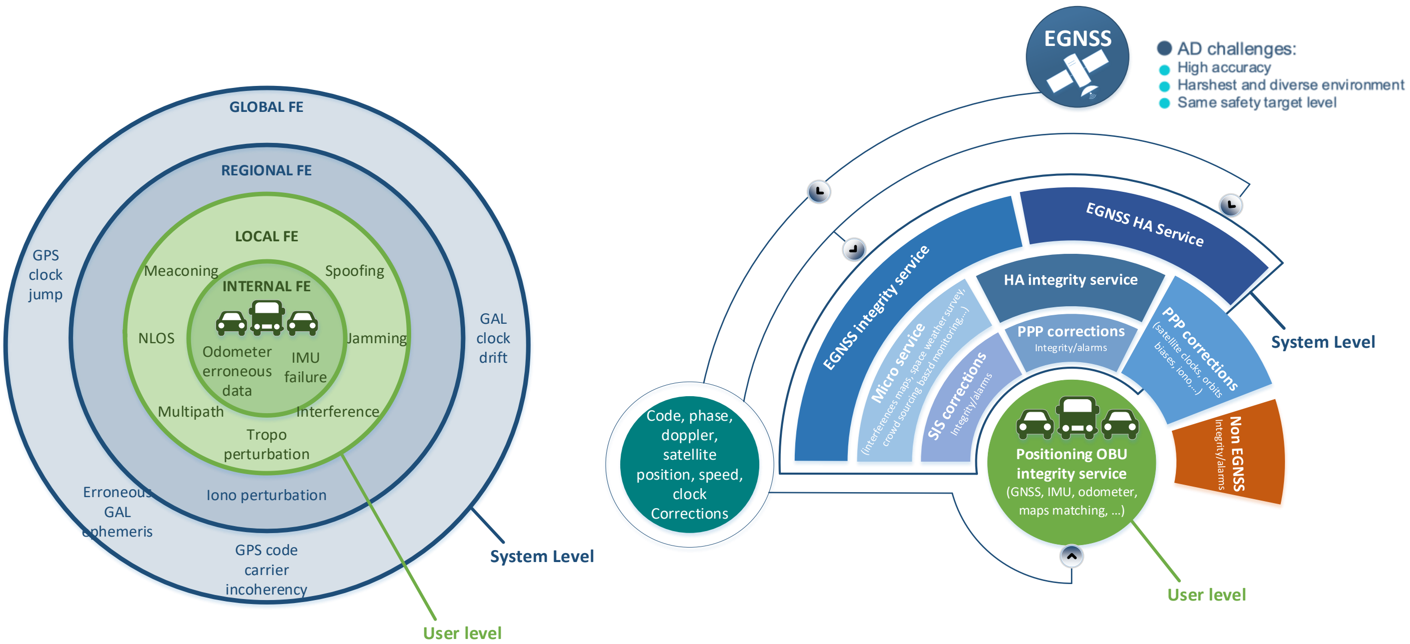

Figure 5 – End to End integrity concept to monitor local, regional & global Feared Events

Please note that, throughout this document, by On Board Unit (OBU) it is referred to the positioning module of the OBU.

The starting point for ICHASE was the user needs evaluated through several Key Performance Indicators (KPI), as captured in the next table. These user needs were based on state of the art review, as well as interviews of stakeholders from the Autonomous Driving value chain, and were finally validated by the experts reviewing the outputs of the ICHASE project.

KPI	Consolidated user Requirements
Position Accuracy	Horizontal : 20 cm | Vertical : 0.5-1 m at 95% AT : 20 cm, CT : 10 cm at 95%

Position Alert Limit	Horizontal : 1 m | Vertical : 2-3 m AT : 1 m, CT : 50 cm
Position Availability	99.9 % monthly
Position Continuity	10^{-5}/h
Position Integrity Risk	$2.5 * 10^{-7}$/h
TTA	< 1 second
TTFPF	< 60 seconds
Velocity Accuracy	3% of the vehicle velocity
Velocity Alert Limit	Proportional to Velocity Accuracy
Velocity Integrity Risk	$\mathbf{10^{-7}}$- $\mathbf{10^{-8}}$/h
Velocity Availability	99.9 % monthly
Heading accuracy	0.17° at 95%
Heading alert limit	0.5°

Table 1 – Reviewed user requirements – [RD-2]

ICHASE then proposed an OBU positioning module architecture (Figure 6) to meet these needs, building on a consistency check approach. This module leverages on a separation between two independent sub-modules, “doer” and “checker”, to compute a final accurate navigation solution and provides the corresponding integrity indicator.

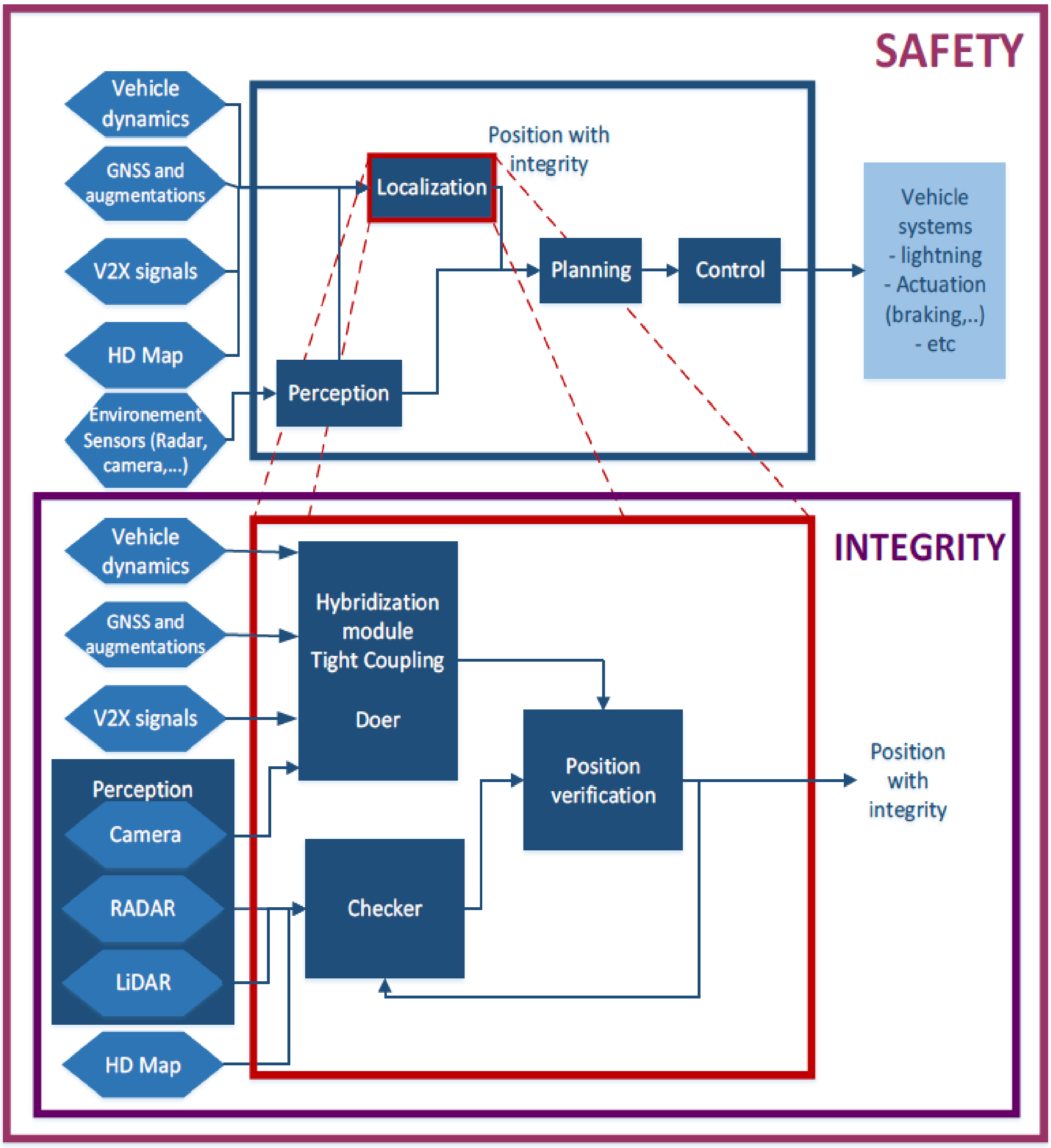

Figure 6 – Proposal 2: High level consistency-check architecture

This architecture was proved to be both "safe" and viable, through an extensive safety assessment on one side and a comprehensive decision criteria analysis on the other side.

- The safety assessment set the safety arguments to be fulfilled in order to reach the objective set in terms of number of fatal accidents per mile, and the associated verification methods (Figure 13), including a complete Failure Mode and Effect Analysis (FMEA) analysis (extract in Table 6). This safety assessment, has led to the allocation of a *Target Integrity Risk of 5.10^{-3}/h (*Figure 22*), and an ASIL A (*Figure 24*) safety level to the GNSS + HAIS service*. This is a very important conclusion which reduces the constraints / costs / certification and planning for the development of the system which would provide the HAIS service. The Top Down Safety analysis was completed by a Bottom-Up integrity tree, in order to assess the feasibility of the proposed approach based on known performances of each of the sensors used for the final fused solution. Further, the Doer hybridised architecture embeds an Advanced Receiver Autonomous Integrity Monitoring (ARAIM) inspired solution separation or majority vote based architecture which ensures both higher robustness and higher continuity of the solution, while keeping the computational load at acceptable levels.

- The main outcomes of the decision criteria analysis (section 8), also based on quantitative assessments and validation with key experts, highlighted the need for a timely implementation of the service, and the need for exploiting synergies with other applications thus ensuring wider adoption.

The Doer branch of this architecture, relies amongst others on the use of a Galileo High Accuracy Service augmented with Integrity data. it is naturally assumed that *hybrid terrestrial and satellite communication networks* and road-side units, and GNSS and non-GNSS dissemination means are needed in order to ensure compliance to the target service availability and continuity requirements. An E5b centred SiS is proposed for the dissemination of the HAIS service when disseminated through EGNOS GEOs (and potentially future IGSO / HEO satellites). ITS-G5 and 5G based telecom networks are proposed for terrestrial dissemination means. LEO constellations are proposed as an option. Road-side units part of C-ITS (Cooperative-Intelligent Transport Systems) infrastructures are also considered.

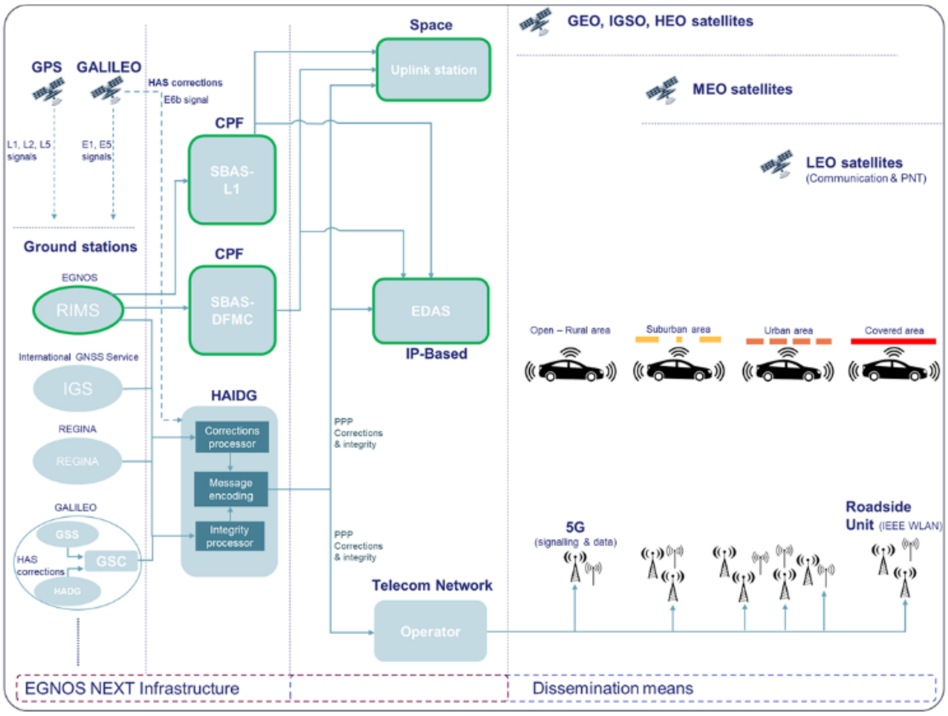

Figure 7 – HAIS service provision scheme

For the deployment of the HAIS service, the proposed roadmap (Figure 8) addresses both service level and system level activities, as long as related standardisation and certification processes. It is pointed out that this roadmap shall start by a first analysis step leveraging on synergies with other transport applications, namely rail and maritime, but also drones. This roadmap leads to first demonstration of service by 2025, declaration of Initial Services by 2027, and Full Operational Capabilities service by 2030. An important element of this roadmap on the system level is the coupling of the new uplink station (and more globally new HAIS infrastructure) with that of the EGNOS system.

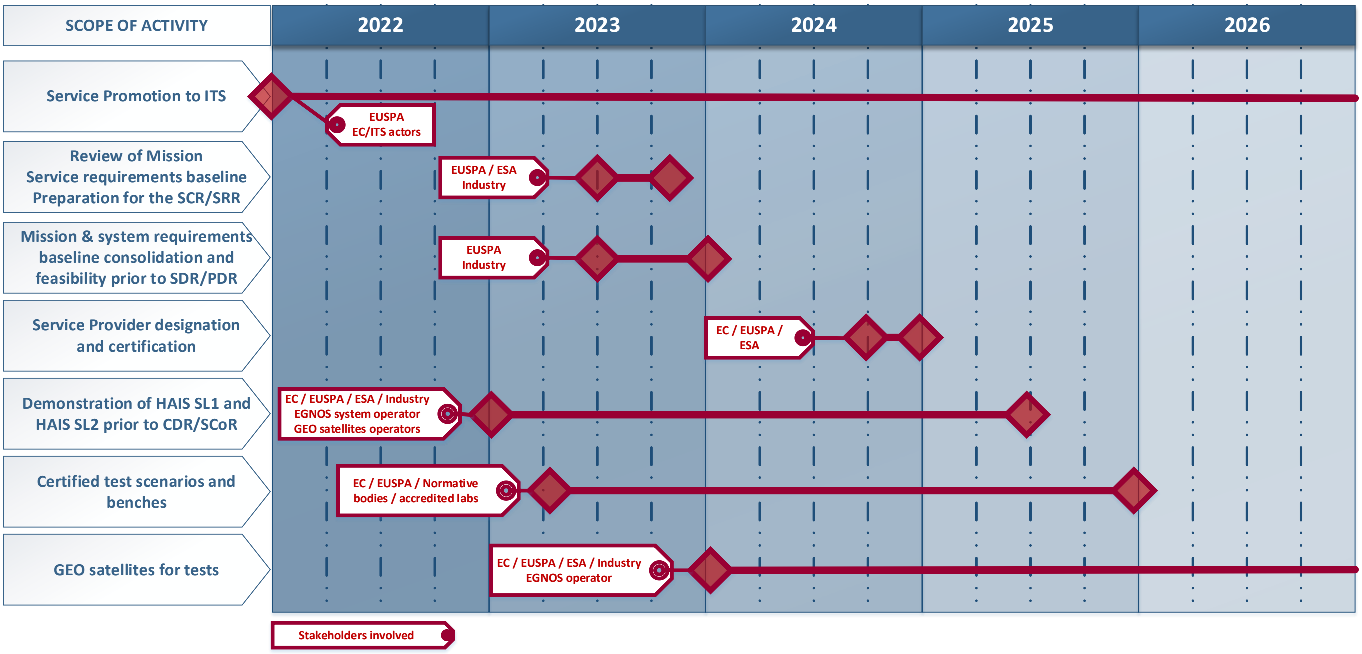

Figure 8 – EGNSS HAIS major activities timeline

1.5. Open points

Several points were raised throughout the ICHASE project that still need further consolidation or need to be addressed in subsequent related activities:

- On the user needs:
  - further consolidation is needed to confirm the proposed values for the velocity and heading availability, continuity and integrity budgets,
  - A cross validation of the user needs and solution amongst different transport modes is very relevant in order to increase the uptake of a new HAIS service.
- On the integrity concept:
  - The proposed integrity concept and safety assessment are rather position focused. A velocity focused integrity concept needs to be built in order to complete this work,
  - The target integrity risk needs to be validated through both simulations and real data. Extreme Value theory based validation process is proposed, and needs to be assessed further.
- All these activities need to rely of mature enough standards and regulations. The work done in ICHASE needs to be pushed to different standardisation and regulation groups.

2. INTRODUCTION

2.1. SCOPE AND PURPOSE OF THE DOCUMENT

This document is the Final Report of the ICHASE (Integrity Complementing High Accuracy Service via EGNSS) project, launched by EUSPA through the European Commission's H2020 funds.

The project results represent the views of the users and the consortium. They do not necessarily represent the views of the European Commission and they do not commit the Commission to implementing the results.

2.2. PROJECT SUMMARY

With the advent of new positioning-based applications, and most importantly, new safety critical and precise positioning applications (like autonomous transport), the European Commission (EC) is assessing the possible evolutions of the EGNSS to introduce new services. One of these evolutions could be an integrity service complementing the EGNSS High Accuracy (HA) in the 2030+ timeframe to meet the needs (e.g., in terms of precision, integrity, availability and continuity) in autonomous transport. Indeed, autonomous transportation applications drive the need for enhanced precision, high availability and continuity, low Time To First Fix (TTFF), low latency, and most importantly, reliability, and integrity for Safety of Life applications.

The ICHASE project assessed the feasibility and added-value for EGNSS systems and services evolutions to meet the target performances for road autonomous vehicles.

A twofold objectives is pursued with the ICHASE project. First, an integrity concept customised to autonomous vehicle for road, in particular considering the various constrained environments applicable to these applications (e.g., urban environments) has been defined. Second, EGNSS service(s) in the 2030+ timeframe which efficiently supports these applications has been defined, providing the necessary commitments on EGNSS HAIS new messages used in such an integrity concept.

All of the ICHASE developments are built on the use of GNSS combined with other positioning methods in order to cope with the needs raised by autonomous vehicles.

2.3. APPLICABLE DOCUMENTS

The following list presents the applicable documents.

Internal code / DRL	Title
[AD1]	Tender specifications, No DEFIS/2020/OP/0005
[AD2]	Service Contract, No DEFIS/2020/OP/0005
[AD3]	Technical proposal, No DEFIS/2020/OP/0005

[AD4]	Directive 95/46/EC of the European Parliament and of the Council of 24 October 1995 on the protection of individuals with regard to the processing of personal data and on the free movement of such data
[AD5]	Directive 2002/58/EC of the European Parliament and of the Council of 12 July 2002 concerning the processing of personal data and the protection of privacy in the electronic communications sector (Directive on privacy and electronic communications)
[AD6]	REGULATION (EU) 2016/679 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation)

Table 2 – Applicable documents

2.4. REFERENCE DOCUMENTS

The following list presents the reference documents.

Internal code / DRL	Reference	Title
[RD-1]	ICHASE D110	Integrity for EGNSS high accuracy domain analysis and user needs for the road sector
[RD-2]	ICHASE D210	User integrity concept analysis
[RD-3]	ICHASE D220	EGNSS mission requirements
[RD-4]	ICHASE D230	Receiver model requirements
[RD-5]	ICHASE D240	Test Campaign requirements
[RD-6]	ICHASE D310	Integrity service complementing EGNSS high accuracy definition
[RD-7]	ICHASE D410	D410 Decision Criteria analysis in the road sector for: device manufacturers, users, HAIS service provider
[RD-8]	ICHASE D510	HAIS service roadmap
[RD-9]	EGNOSHA D210	EGNOS HIGH ACCURACY SERVICE DEFINITION, D210. V3.1, 30/09/2019.
[RD-10]		De Jong Yeong, Gustavo Velasco-Hernandez, Dr. John Barry and Prof. Joseph Walsh, “Sensor and Sensor Fusion Technology in Autonomous Vehicles: A Review”. www.preprints.org.
[RD-11]		User report for road, EUSPA
[RD-12]		“NLES-NG : Augmenting EGNOS with an E5b Channel”, 6th European workshop on GNSS signals and signals processing, Munich,

		December 2013, H. Al Bitar, M. Raimondi, Thales Alenia Space France, L. Ries, CNES
[RD-13]		Lorenzo Ortega, “Signal Optimization for Galileo Evolution”, Lorenzo Ortega, PhD thesis report, 2019.
[RD-14]		L. Ortega, C. Poulliat, ML. Boucheret, M. Aubault, H. Al Bitar, “New multiplexing method to add a new signal in the Galileo E1 band”, IET Radar, Sonar & Navigation journal, September 2020
[RD-15]		Understanding 3GPP basics – Qualcomm https://www.qualcomm.com/news/onq/2017/08/understanding-3gpp-starting-basics
[RD-16]		Tyler G. R. Reid, Sarah E. Houts, Robert Cammarata, Graham Mills, Siddharth Agarwal, Ankit Vora, and Gaurav Pandey, “Localization Requirements for Autonomous Vehicles”, 2019

Table 3 – Reference documents

2.5. DEFINITIONS AND ACRONYMS

Acronym	Description
ACTE	ACross Track Error
AD	Autonomous Driving
ADAS	Advanced Driver Assistance System
AIS	Automatic Identification System
AIV	Assembly Integration and Validation
ASIL	Automotive Safety Integrity Level
AT	Along Track
ATC	Automatic Train Control
AV	Autonomous Vehicle
BEA	Break-Even Analysis
CENELEC	European Committee for Electro-technical Standardization
CER	Community of European Railway
C-ITS	Cooperative Intelligent Transport System
CPF	Central Processing Facility
CT	Cross Track

DFMC	Dual Frequency Multi Constellation
DFRE	Dual-frequency range error
EC	European Commission
ECA	Error Characterization Approach
EDAS	EGNOS Data Access Service
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European Global Navigation Satellite System
EMRF	European Maritime Radio navigation Forum
ERA	European Railway Agency
ERTMS	European Rail Traffic Management System
ESSP	European Satellite Services Provider
EU	European Union
EUG	ERTMS User Group
EUSPA	European Union Agency for the Space Programme
FDE	Fault Detection and Exclusion
FMEA	Failure Mode and Effect Analysis
FQR	Factory Qualification Review
GEO	Geostationary Orbit
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSS	Galileo Sensors Stations
HA	High Accuracy
HADG	High Accuracy Data Generator
HAIDG	High Accuracy & Integrity Data Generator
HAIS	High Accuracy and Integrity Service
HAS	High Accuracy Service
HD	High Definition
HDOP	Horizontal Dilution Of Precision
HEO	High Elliptical Orbit
HNSE	Horizontal Navigation System Error
HPA	High Power Amplifier
HR	Hazard Rate
IALA	International Association of the Marine Aids to Navigation and Lighthouse Authorities
ICHASE	Integrity Complementing High Accuracy Service via EGNSS
IGS	International GNSS Service

IGSO	Inclined Geosynchronous orbit
IMO	International Maritime Organization
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
IOV	In-Orbit Validation
IR	Integrity Risk
KPI	Key Performance Indicators
KFMI	Kalman Filter Measurement Innovation
LEO	Low Earth Orbit
LIDAR	Light Detection And Ranging
MEO	Medium Earth Orbit
MRA	Measurement Rejection Approach
NLOS	Non Line Of Sight
NLES	Navigation Land Earth Station
NRE	Non-Recurrent Equipment cost
OBU	On-Board Unit
ODTS	Orbit Determination and Time Synchronisation
OEM	Original Equipment Manufacturer
PDR	Preliminary Design Review
PL	Protection Level
PNT	Position Navigation and Timing
PPP	Precise Point Positioning
PRN	Pseudo Range Number
PVT	Position Velocity and Timing
RADAR	Radio Detection And Ranging
RAIM	Receiver Autonomous Integrity Monitoring
RF	Radio Frequency
RIMS	Ranging and Integrity Monitoring Stations
RTCM	Radio Technical Commission for Maritime
RF	Radio Frequency
Rx	Receiver
SAE	Society of Automotive Engineers
SBAS	Satellite Based Augmentation System
SIL	Safety Integrity Level
SIS	Signal In Space
SL	Service Level

SoS	System of Systems
SOTIF	Safety Of The Intended Functionality
SPS	Service Performance Standards
TBC	To Be Confirmed
TBD	To Be Defined
TTA	Time To Alarm
TTFF	Time To First Fix
TTFPF	Time To First Precise Fix
UNISIG	UNion Industry of SIGnalling
V2X	Vehicle To Everything

Table 4 – Acronyms

2.6. DOCUMENT OUTLINE

Section 1 provides an executive summary for this document.

Section 2 describes the purpose, scope and application field of this document. In addition, it gives useful information for a better understanding of the document such as applicable documents, reference documents, specific definitions used or refer to in the document and at least the list of acronyms used. A brief presentation of its content completes this section.

Section 3 describes the user positioning needs of the Autonomous Vehicle.

Section 4 describes the End-to-End integrity concept at user level designed in the ICHASE project.

Section 5 defines the Integrity Service complementing the EGNSS High Accuracy Service.

Section 6 details the suitability of the proposed integrity concept and service definition for rail.

Section 7 details the suitability of the proposed integrity concept and service definition for maritime.

Section 8 details the decision criteria analysis in the road sector for device manufacturers, users and HAIS service provider.

Section 9 describes the service implementation roadmap.

Section 10 proposes a focus on the certification and standardization aspect.

Section 11 summarizes the main challenges and recommendations raised along the ICHASE project.

3. USER POSITIONING NEEDS OF THE AUTONOMOUS VEHICLE

As a first step, the ICHASE consortium has defined the user needs in terms of final positioning performances for Autonomous Driving Level 5. The starting point for these user needs was based on existing state-of the Art desk research, [RD-1].

The results of this desk research were further consolidated by experts from the different value chain elements of the Autonomous Driving ecosystem: Tier 2 (GNSS Rx manufacturers), Tier 1, OEM (car manufacturer), certification labs.

The consolidated user requirements are as reported in Table 5 below, [RD-2].

KPI	Consolidated user Requirements
Position Accuracy	Horizontal : 20 cm | Vertical : 0.5-1 m at 95% AT : 20 cm, CT : 10 cm at 95%
Position Alert Limit	Horizontal : 1 m | Vertical : 2-3 m AT : 1 m, CT : 50 cm
Position Availability	99.9 % monthly
Position Continuity	10^{-5}/h
Position Integrity Risk	$2.5 * 10^{-7}$/h
TTA	< 1 second
TTFPF	< 60 seconds
Velocity Accuracy	3% of the vehicle velocity
Velocity Alert Limit	Proportional to Velocity Accuracy

Velocity Integrity Risk	$\mathbf{10^{-7}}$- $\mathbf{10^{-8}}$/h
Velocity Availability	99.9 % monthly
Heading accuracy	0.17° at 95%
Heading alert limit	0.5°

Table 5 – Reviewed user requirements – [RD-2]

From these requirements, the most challenging are the target accuracy in considered harsh environments, and the integrity risk requirement for both the position and the velocity especially when considering the need for high continuity and availability. As detailed in [RD-5], the amount of data to reach such requirements is extremely high: as a reminder for validation of the integrity risk $\boldsymbol{IR} = \mathbf{10^{-7}}/\boldsymbol{h}$ with a risk $\boldsymbol{\alpha} = \mathbf{5}\%$ the amount of data shall be of $10^9 h$ for the Binomial Proportion Confidence Interval validation tool and of $10^5 h$ for the Extreme Value Theory validation tool.

Regarding the operation duration, note that in aviation the performances (integrity, continuity) are expressed on a typical time interval for the targeted operations (e.g. /150s for integrity and /15s for continuity for Approaches with Vertical Guidance - APV-I service , /hour for both integrity and continuity for Non-Precision Approach, En-Route, Terminal approach services).

In the road context, a time interval of one hour was assumed, for the following reasons:

- The integrity and continuity requirements were expressed per hour by the stakeholders,
- It is unclear whether the duration to be considered should for a whole ride or for single driving tasks (lane keeping, in turn, cross-road…), and what are the typical durations,
- No consistent answer was provided along the several expert consultations performed,
- The equipment failure rates are usually expressed per hour. The conversion of failure rates per hour to/from other interval lengths is an approximation which would need to be validated in the context of automotive transports.
- In EN16803-1 standard the following definition is mentioned: "In the automotive domain it is hard to identify specific phases of driving which are significantly more critical than others, but it is usual to assume that the average trip lasts for about one hour, so T = 1h is often considered as suitable characteristic time length".

It is worth noting that the velocity and heading continuity, availability and target integrity risk requirements need to be further consolidated (these are tagged by the red line in the previous table).

4. END TO END INTEGRITY CONCEPT AT USER LEVEL

Based on these consolidated user requirements, the second task of the ICHASE project consisted in the design of an integrity concept at the user level.

4.1. USER INTEGRITY CONCEPT DEVELOPMENT METHODOLOGY

Based on the user requirements and on a thorough analysis of the threats impacting the Autonomous Vehicle navigation solution, the ICHASE project has proposed an overall methodology for the definition of the autonomous cars integrity concept, consisting in four steps analysis, illustrated in Figure 9:

- The first step of this methodology consisted in the definition of the Functional System Architecture, which is the definition of the system architecture at the vehicle level where several modules as perception, localization, planning and control interact to ensure the functions of the automated driver.
- The definition of the Functional System Architecture allowed to perform the safety analysis. Based on a final Target Level of Safety and the different hazards that could occur, an integrity allocation could be done for the different blocks of the system including the localization module.
- The third step has consisted in the design of the localization module. The requirements defined for the localization module are used as input for the design of this module. Based on these requirements, a set of sensors as well as the system architecture and the multi-sensor fusion algorithm has been proposed in order to be able to meet these requirements.
- Finally, the integrity concept for the localization module has been proposed. The proposed sensors and the architecture of the localization module as well as the requirements from the safety analysis are used for the final step which is the definition of the integrity concept. An integrity allocation for the different sensors has been done and different techniques/solutions has been proposed at several levels (GNSS signals pre-processing, error characterization, Fault Detection and Exclusion, Protection Level computation) in order to meet the requirements on the integrity and other KPIs.

As illustrated in Figure 9, these steps do not follow a linear progression. Several iterations have been performed to best fit the final integrity concept to the requirements expressed in section 3.

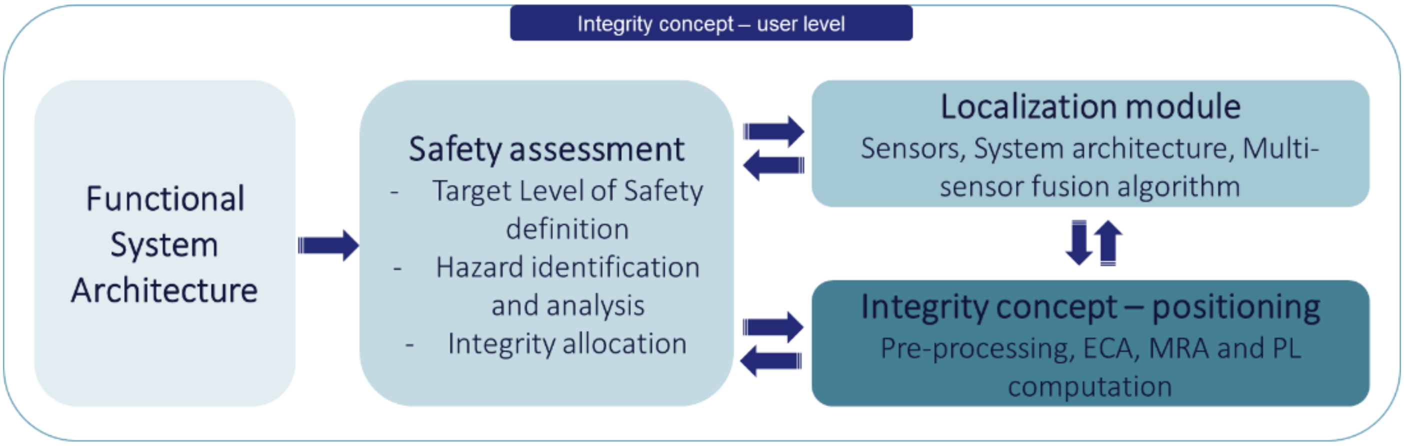

Figure 9 – User integrity concept development methodology

The high level functional architecture that was considered for the analysis is provided in Figure 11 below.

4.2. SAFETY ASSESSMENT

The safety assessment took as baseline a commonly adopted high level functional architecture for autonomous driving (as in [RD-16] for instance), and represented in Figure 11 below.

Before getting to the details and outputs of the Safety assessment, please recall that by definition, a safety case is a structured argument, supported by evidence, intended to justify that a system is acceptably safe for a specific application in a specific operating environment.

The Safety assessment main objective is to ensure acceptably safe operation of Autonomous Driving applications. It considered two main applicable standards : "ISO 26262: Road vehicles — Functional safety - Part 3: Concept phase", and "Road Vehicles – SOTIF – Safety Of The Intended Functionality (ref. DS/ISO/PAS 21448:2019)".

This Safety assessment claim is supported by a number of arguments as described in Figure 10.

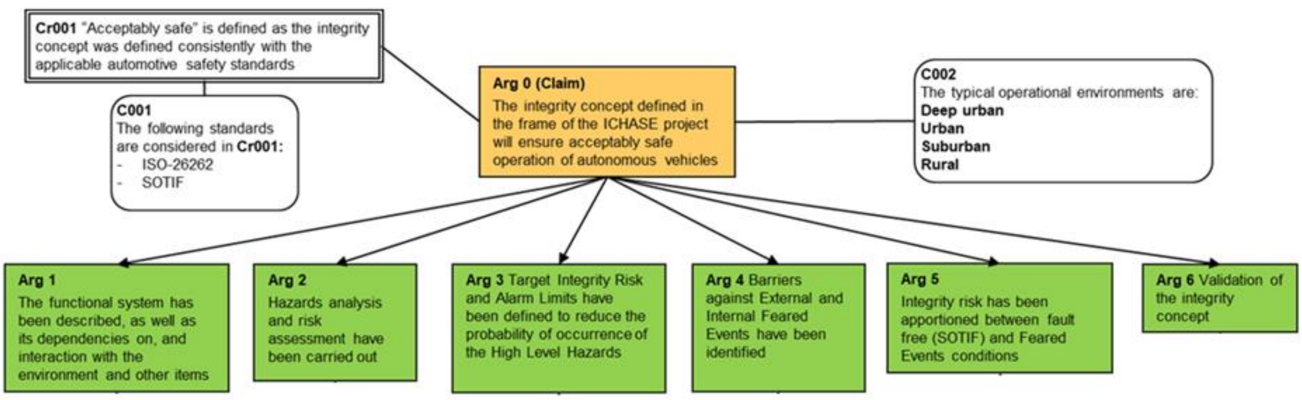

Figure 10 – The ICHASE Safety Case Claim

These arguments were mapped on the high level functional architecture (Figure 11).

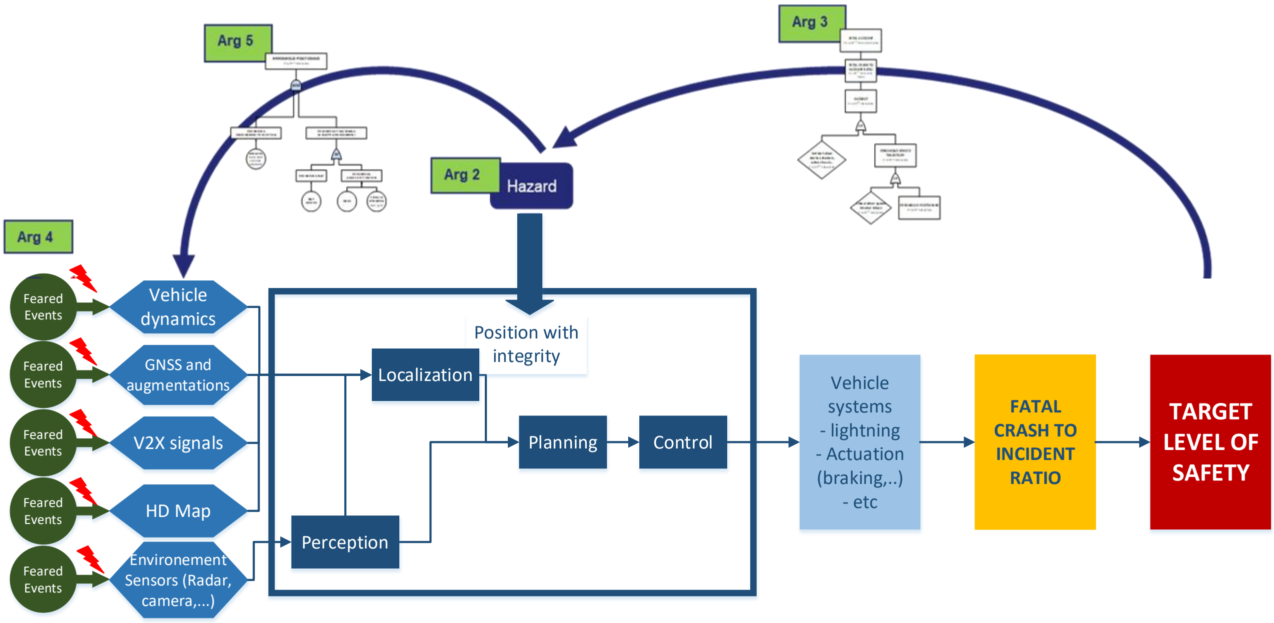

Figure 11 – ICHASE safety approach

An important assumption here is that emergency obstacle avoidance safety function is considered as independent from the localization function. It is assumed that the Planning function is able to issue an emergency obstacle avoidance command even though the vehicle absolute position provided by the Localization function is incorrect or unavailable. In the high level functional architecture as depicted in Figure 11, the perception module directly provides information to the trajectory planning module for emergency obstacle avoidance, based on the inputs from environment sensors (e.g. radar, LiDAR, cameras…). These relative position information are used differently for emergency obstacle avoidance than for absolute positioning.

Accordingly, the analysis of the concept of independence of the information used by these two functions concluded to the fact that although the same environment sensors are used for absolute positioning by the Localization function and for Emergency obstacle avoidance by the Planning function, Emergency obstacle avoidance can be considered as an effective mitigation means, as:

- A relative measurement error (e.g. 11m instead of 10m) doesn't not necessarily imply an absolute position error (e.g. position determined based on a 2m displacement).

- The diversity of sensors and technologies used to provide measurements to both Localization and Planning functions offers a great robustness to possible failure conditions affecting one sensor (analysed through the FMEA).

- The Localization and Planning function algorithms are independent. A measurement error will be processed differently in the Localization function (e.g. through Fault Detection and Exclusion) and in the Planning function (mechanism to be defined outside of the ICHASE project scope).

This assumption of independence is critical to the following safety aspects:

- Target Integrity Risk quantitative allocation between Absolute positioning and Emergency avoidance functions

- ASIL allocation between Absolute positioning and Emergency avoidance functions

Once the safety arguments were defined, their required justification may or may not depend on the localization module architecture. Namely arguments 1, 2 and 3 are independent from this architecture.

Safety Argument 2 was justified through an extensive hazard analysis and risk assessment.

Safety Argument 3 was justified through top-down integrity and continuity risk apportionment as per the following tree.

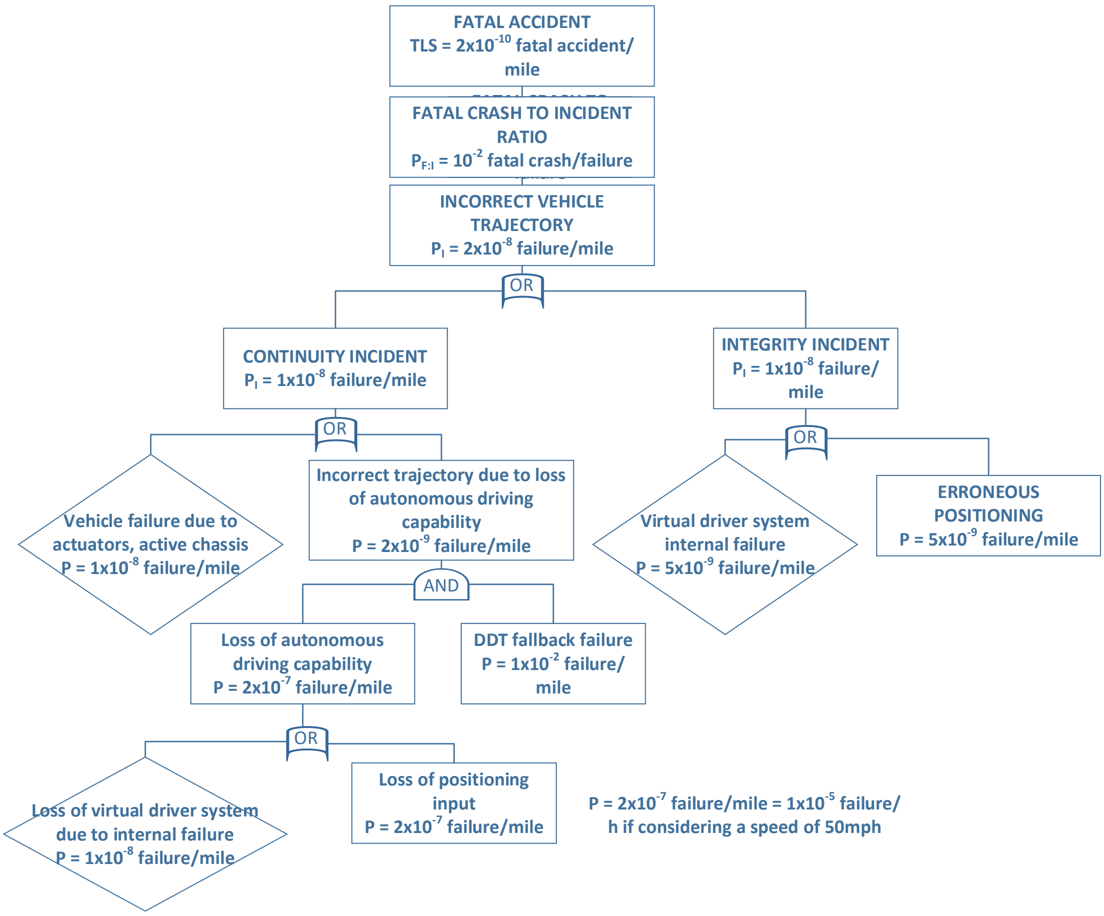

Figure 12 – Target Level of Safety apportionment

This safety assessment was completed by a bottom up integrity risk and ASIL level apportionment, based on the considered high level architecture of the OBU as described in the next section. This architecture also served as the basis for the justification of safety arguments 4, 5 and 6 which are tightly coupled to the underlying architecture. This process is illustrated in Figure 13. Note that an exception is made here with the particular case of the TTA, as the target TTA cannot be reached at the system level.

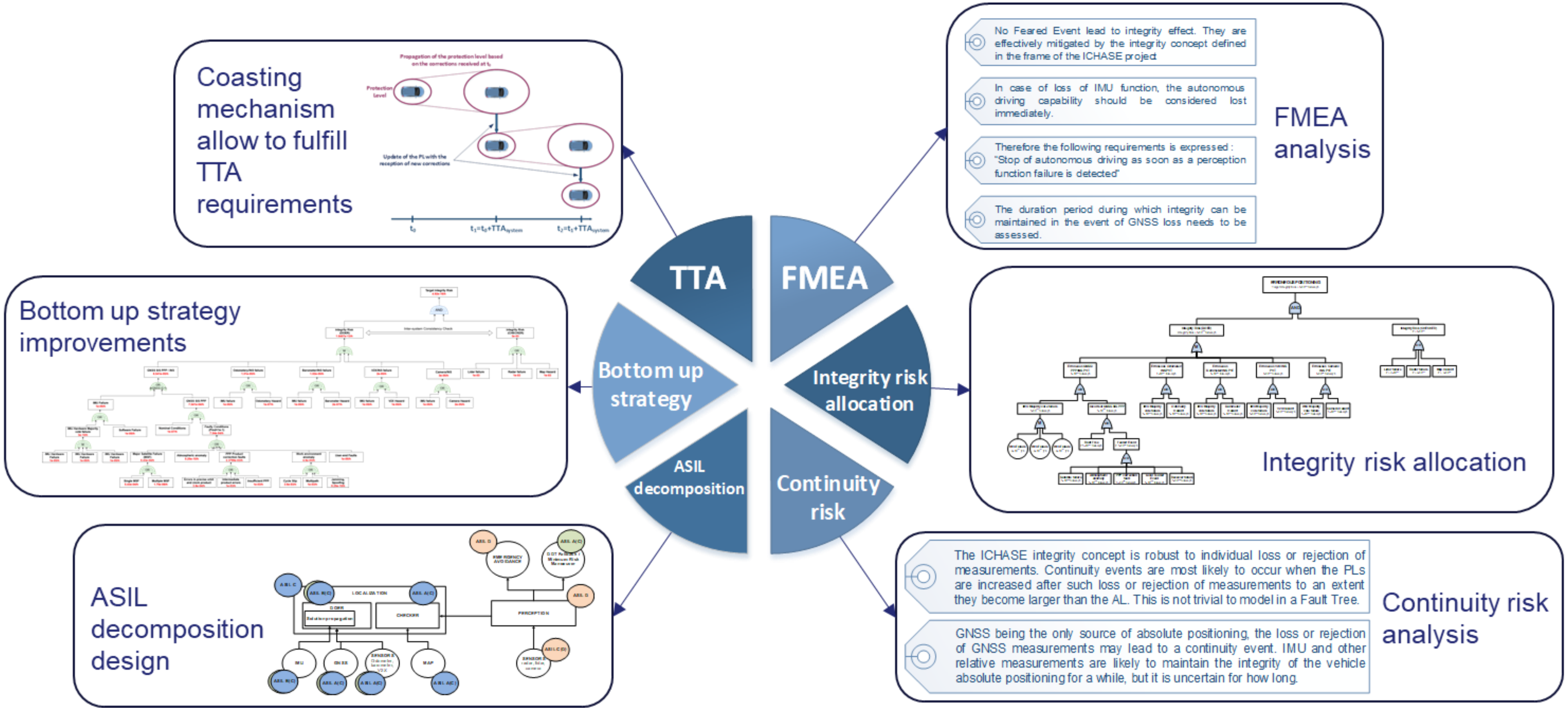

Figure 13 – Validation steps

4.3. MULTI-LAYER INTEGRITY CONCEPT DEFINITION

The Integrity Concept is based on 3 main pillars as per the next figure :

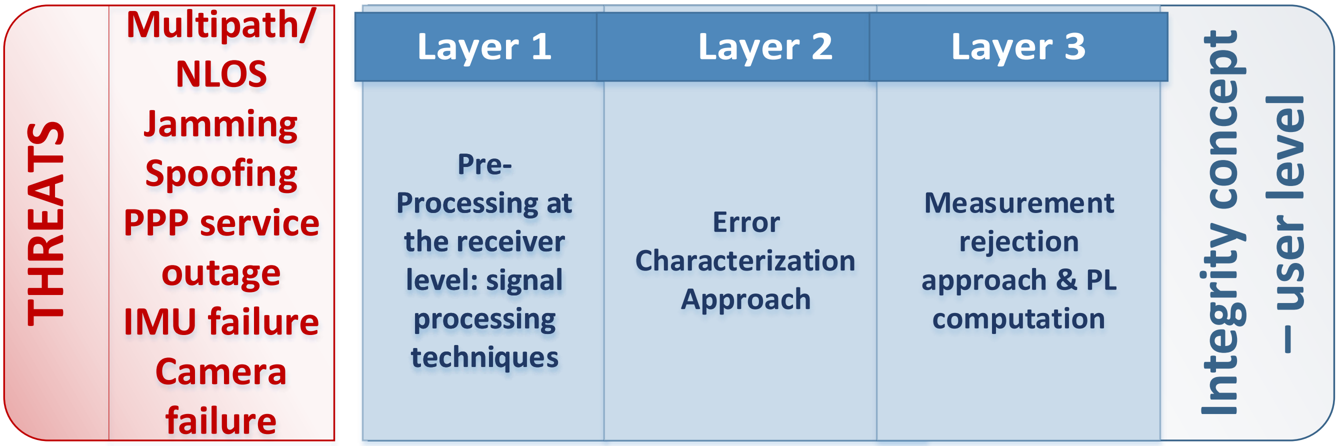

Figure 14 – Three main layers of the proposed integrity concept

As illustrated it is based on 3 main layers:

- Layer 1: Pre-processing at the receiver level

  Several detection and mitigation methods can be applied in the different stage of a GNSS receiver. The reasoning is as follows: the reliability of the GNSS solution (same reasoning for non-GNSS solution) stands on the capability of the GNSS receiver to provide signal quality indicators at different stages of the GNSS signal processing chain and to use all these indicators in the final solution computation to either select or overweight the contribution of GNSS measurements into the final solution.

  As an example, monitoring and mitigation of interference will be better handled at the RF/pre-correlation stage than at the PVT computation stage. Similarly, multipath errors can be better monitored and mitigated in the correlation domain, rather than in the final PVT solution computation.

- Layer 2: Error Characterization Approach (ECA)

  In an urban environment, GNSS measurements are affected by frequent errors, due to complex surroundings such as high buildings and numerous obstacles, that causes multipath and NLOS reception. These errors are not deterministic and they depend on the travelled environments as well as the relative satellite-receiver motion. Thus, they are extremely difficult to model accurately. The aim of the ECA is to assess a statistical model of the measurement errors.

- Layer 3: Measurement Rejection Approach (MRA) and Protection level (PL) computation

The last layer of the integrity concept relies on the application of MRA which aim, by definition, at rejecting measurement that are deemed erroneous. As an example, a well-known MRA method, for being widely used in the civil aviation domain, is the RAIM algorithms. Receiver Autonomous Integrity Monitoring (RAIM) is a class of algorithms that monitor erroneous measurements at user level, taking as input a measurement noise model, and alternative threat models.

Based on the techniques and solutions presented above, several possibilities and combinations were considered at different stages of the user level integrity concept. As shown in Figure 15, to meet the performance requirements of the localization module two main categories of architectures are possible. The first one does not consider the concept of consistency check, where the measurements of all used sensors are fused together to provide a single navigation solution. The second one is based on the consistency check between the solutions of two independent algorithms, where two independent subsets of the considered sensors are used by both algorithms (the solution is available when difference between both solutions do not exceed a given threshold). Multi-sensor fusion algorithms based on tight or loose coupling could be used with either consistency check or no-check architectures. The same for the error characterization models (Gaussian and non-Gaussian) and the measurement rejection approaches (Solution Separation, measurement innovation based techniques, etc.).

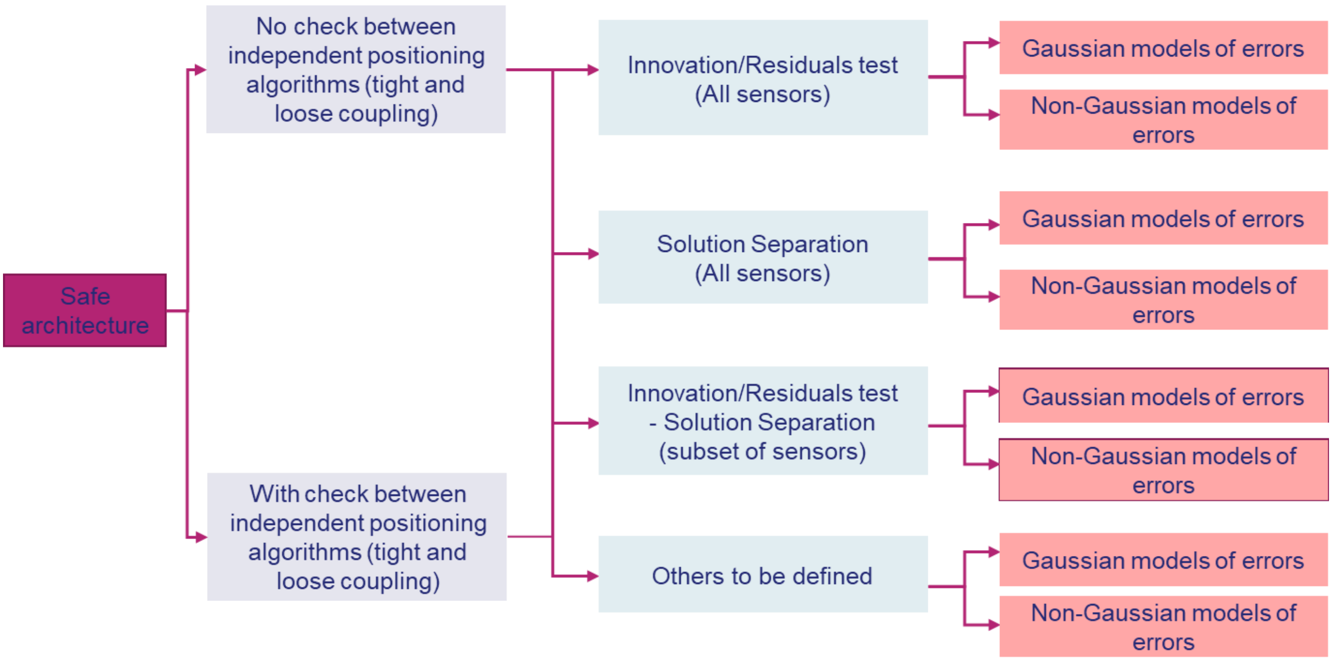

Figure 15 – Several possible combinations of techniques for the definition of the integrity concept

The experts consultation on the integrity concept led to the adoption of the consistency-check based architecture as shown below.

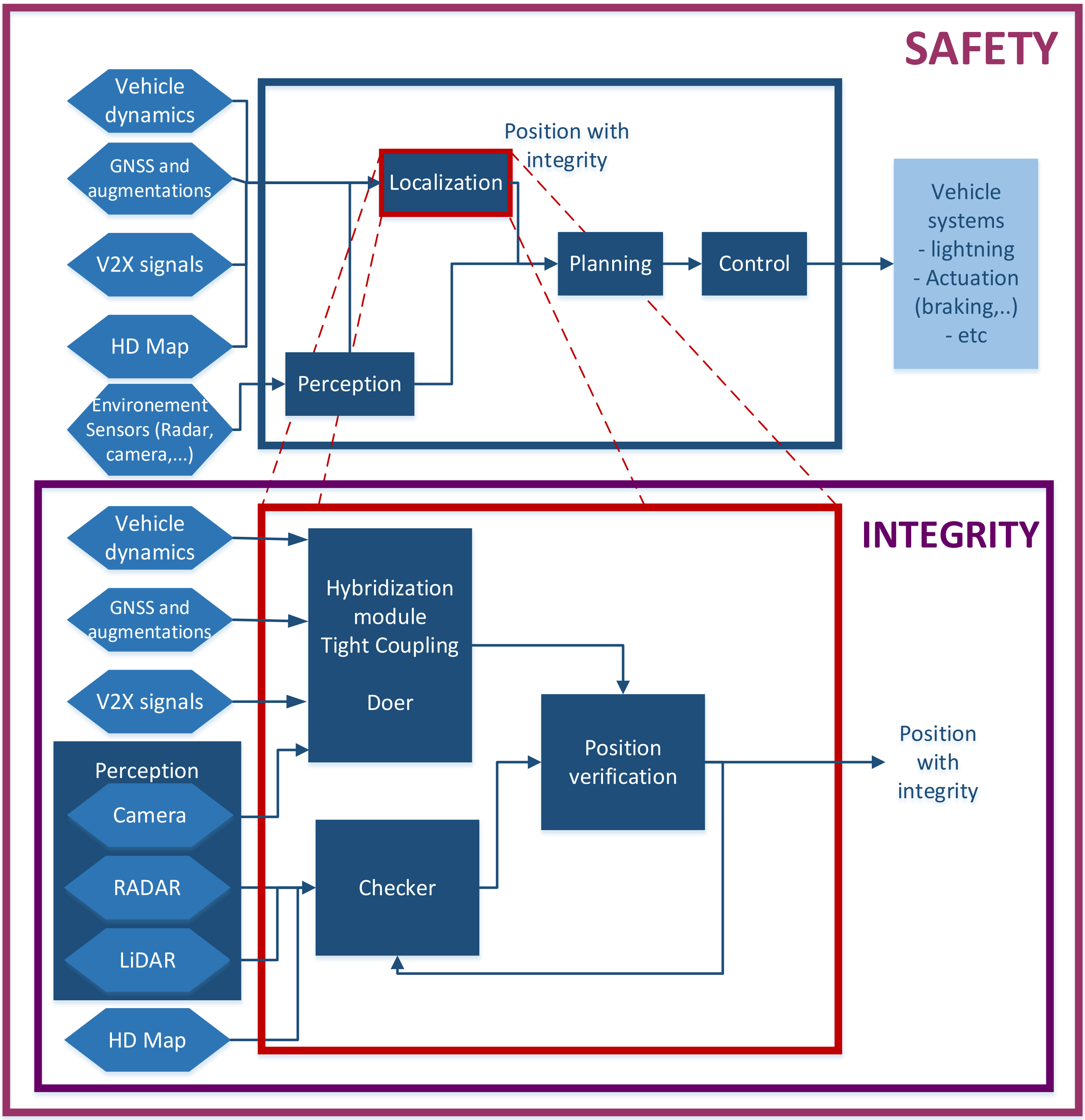

Figure 16 – Proposal 2: High level consistency-check architecture

Basically, the Hybrid navigation filter is a Tight coupling Kalman Filter using the vehicle sensors and the perception sensors delegated to the processing set. The navigation solution at the output of the hybrid navigation filter goes through the Fault Detection and Exclusion (FDE) processing which will identify and exclude the faulty measurements as illustrated in Figure 17.

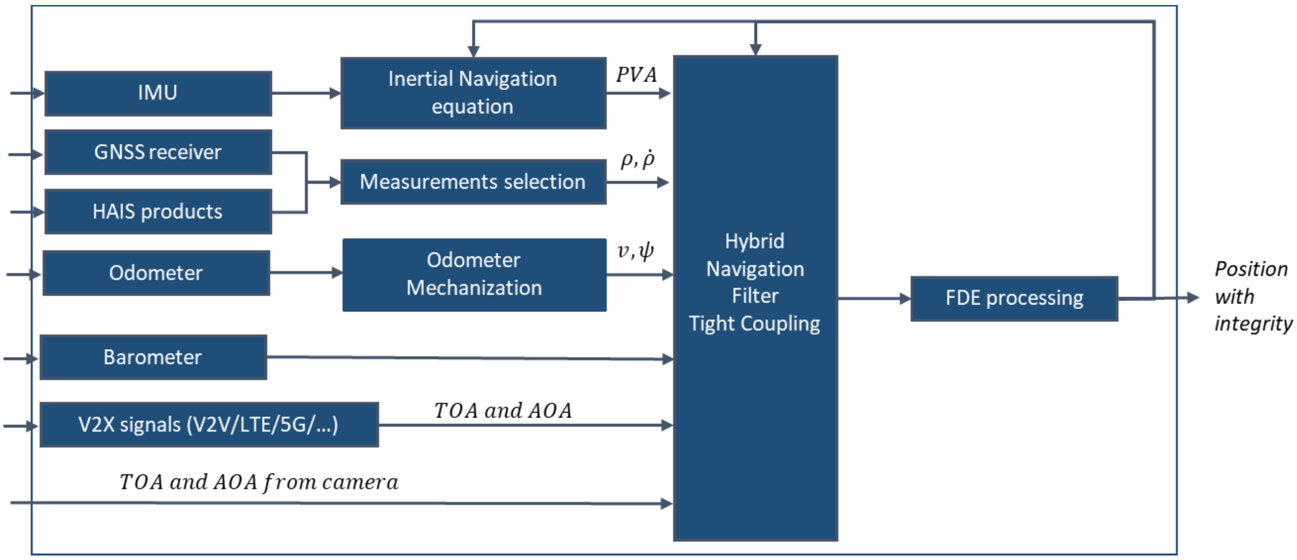

Figure 17 – Hybrid navigation filter

Based on this architecture, Figure 18 proposes the corresponding integrity tree. As it can be seen, there are two branches, one linked to the processing set or doer and one to the check set or checker. With a conservative approach, OR gate is considered between the different sensors.

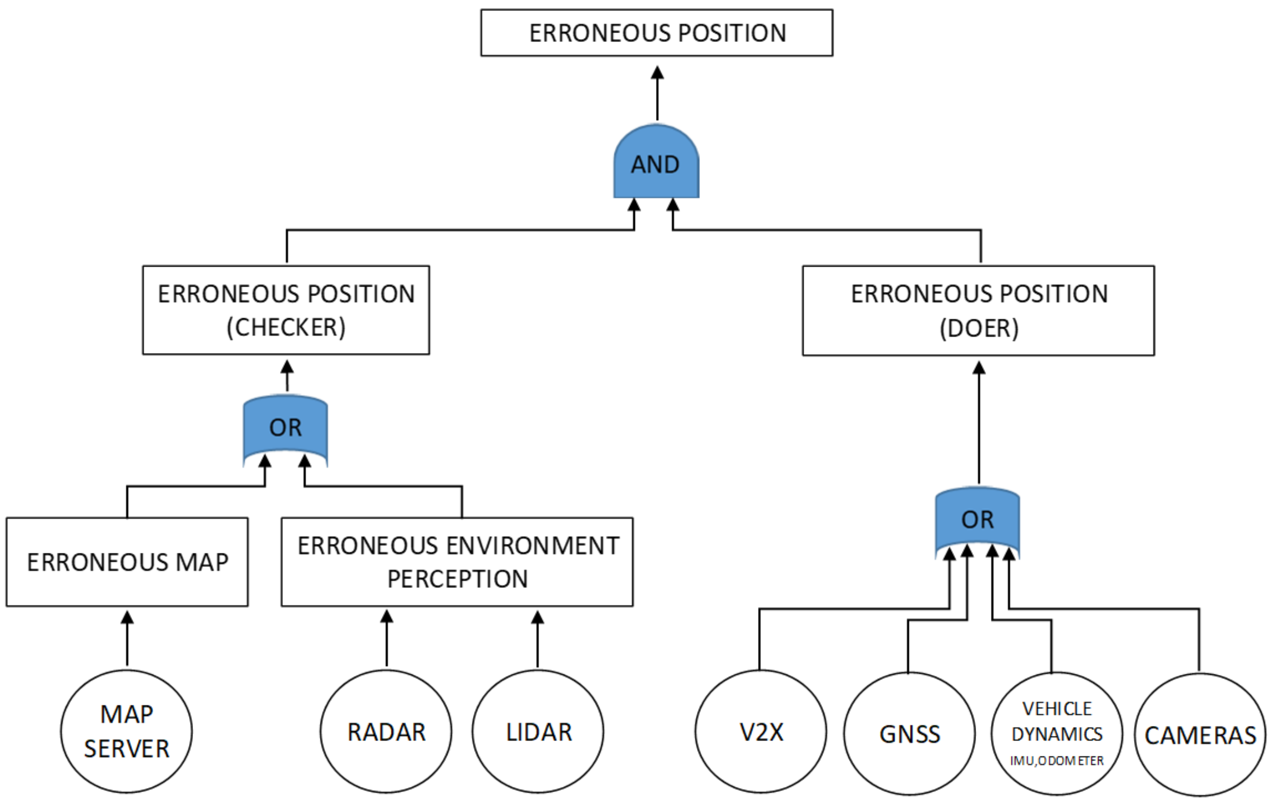

Figure 18 – Integrity tree overview

4.4. LOCALIZATION MODULE ARCHITECTURE AND INTEGRITY CONCEPT

The analysis performed in the frame of the ICHASE project concluded to two main outcomes:

- The OBU positioning module architecture shall include at least two independent positioning channels (so-called consistency-check architecture). The consistency check concept is recommended when high integrity risks for SoL applications are needed. EGNOS SoL is based on this architecture at the system level where the so called "Processing Set" and "Check Set" are used to compute and verify EGNOS corrections by processing measurements provided by independent RIMS. This architecture allows to divide the required integrity risk between these two sets due to the independency between them and thus reduce the complexity of the system validation and qualification process. An integrity risk of 10^{-4} is allocated for the Processing Set and an integrity risk of 10^{-3} is allocated for the Check Set (PMD). This leads to a final integrity risk of $10^{-7}/h$.

- Within each positioning channel (or branch), consistency check between the different redundant sensors shall also be managed. A tight coupling scheme was considered in ICHASE, which fosters the implementation of solution separation or majority vote architectures taking into account the measurements of the different sensors (per branch).

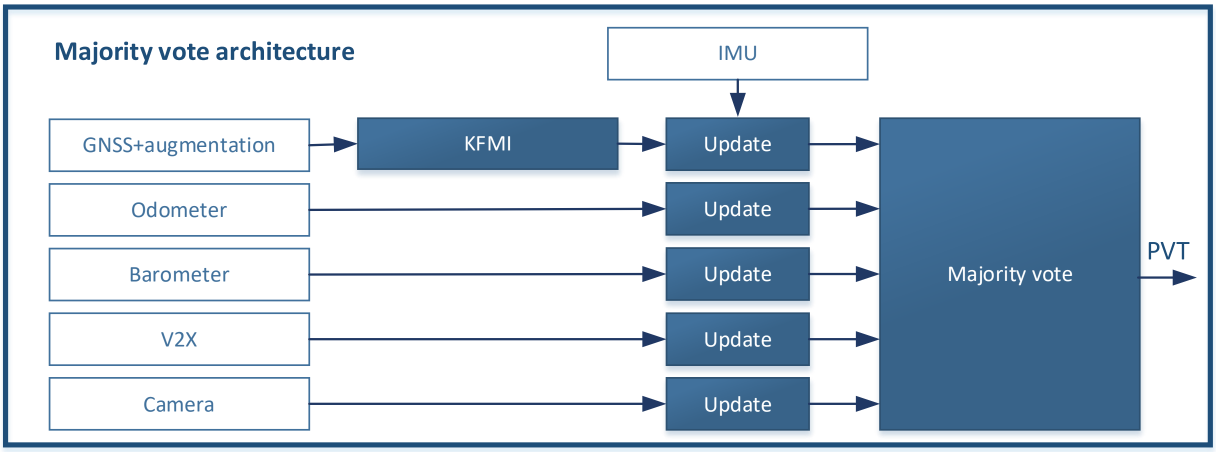

Figure 19 – Localisation module architecture 1 : Majority Vote based

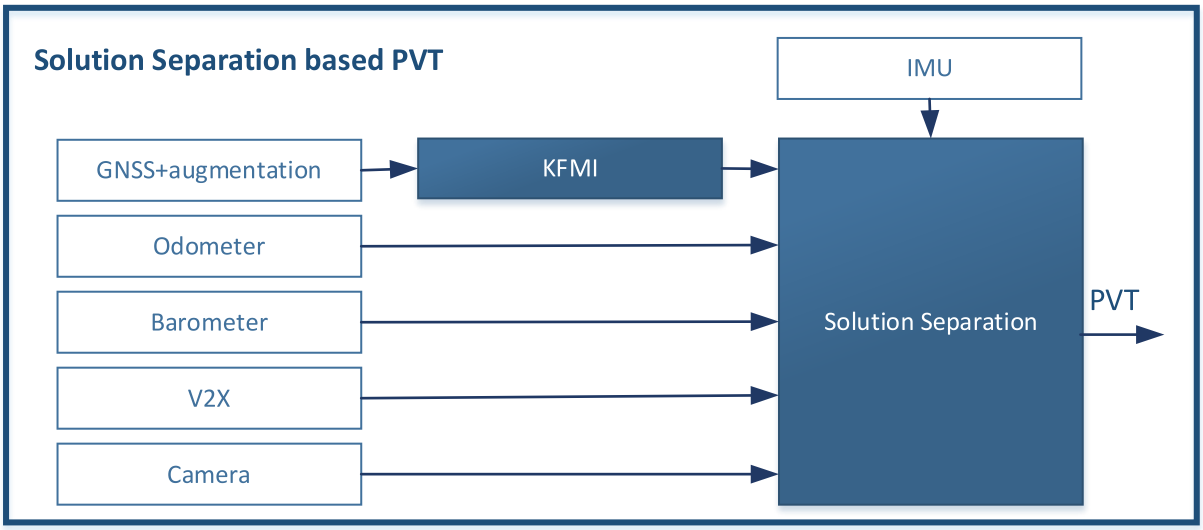

Figure 20 – Localisation module architecture 2 : Solution Separation based PVT method

Based on these architectures, Safety argument 4 was justified through a complete Failure Mode Effect Analysis (FMEA). A brief excerpt of this FMEA is proposed in Table 6.

Feared Event		GNSS receiver & signal processing algorithms	Augmentation system	Vehicle dynamics	Perception for localization	Effect at vehicle level (without mitigation)	Localization algorithms	Effect at the output of the Localization module (after mitigation)	Perception for emergency manoeuver	Effect at vehicle level (after mitigation)
Atmospheric propagation	**Ionosphere effects**	Ionospheric propagation induces a delay in the code PR, and an equal advance in phase PR. Uncorrected, this delay induces positioning errors at localization level. Ionospheric scintillation can affect the acquisition of a signal, resulting in noise in the GNSS measurement. Depending on the type of scintillation, the code or the phase can be affected more. Mitigation : - Scintillation indicators can be implemented at pseudorange preprocessing level	Mitigation : - Regional ionospheric corrections can be broadcast by a system based on a network of local stations (EGNOS)	Not impacted	Not impacted	Undetected ionospheric scintillation could contribute to integrity risk. Impact on position availability ; the convergence time of PPP is longer due to the presence of ionospheric delay in the measurements. HAZARDS: - Incorrect vehicle trajectory due to erroneous positioning (INT#1) - Localization service unavailability	Uncorrected delay induces bias in the pseudoranges, thus erroneous positions. Mitigation : - The iono-free combination removes the contribution of ionospheric delay - Residual ionospheric delay can be estimated at PPP algorithm level - FDE techniques can help detecting lines of sight impacted by scintillation	Mitigation techniques within the localization algorithms are deemed efficient against ionopsheric delay. Ionopsheric delays do not directly lead to integrity events in the considered architecture. Impact on position availability : the convergence time of PPP is longer due to the presence of ionospheric delay in the measurements.	Perception of obstacles is possible through information provided by sensors not impacted by ionospheric delays.	No effect at vehicle level.

Table 6 – FMEA Excerpt

In this table, the following interpretation is associated to each colour:

- Text in red shows how the different elements (sensors or functional blocks) are negatively impacted by the Feared Event,

- Text in green shows how the different elements (sensors or functional blocks) can help mitigate the Feared Event,

- Text is in black when the Feared Event has a neutral impact on the element. Note that sometimes a sensor is neither negatively impacted by a Feared Event, neither directly provides a mitigation against this Feared Event, but its presence allows a mitigation of the Feared Event through the integrity algorithms defined as part of the ICHASE project within functional modules.

The main conclusions from the FMEA analysis are :

- No Feared Event (except Failure of the perception function) lead to integrity effect. They are effectively mitigated by the integrity concept defined in the frame of the ICHASE project (diversity of sensors, algorithm mechanisms implemented in the Localization module, emergency obstacle avoidance).

- Failure of the perception function providing measurements from environment sensors (radar, LiDAR, camera), could lead to a crash, as these information are used for emergency avoidance and are the only ones able to detect pedestrians.

  Therefore the following requirement is expressed :
  "Stop of autonomous driving as soon as a perception function failure is detected"

- In case of loss of IMU function, the autonomous driving capability should be considered as lost immediately.

- The duration of time where integrity can be maintained in the event of GNSS loss (e.g. in an urban environment) needs to be assessed.

- The diversity of environment sensors makes the perception function robust to meteorological adverse conditions (see [RD-10]). In particular, Figure 21 below recalls the performances of camera, LiDAR and radar including when in degraded meteorological conditions.

Table 6. A comparison of the commonly employed sensors in self-driving cars; camera, LiDAR, and radar, based on technical characteristics and other external factors. The "✓" symbol indicates that the sensor operates competently under the specific factor. The "~" symbol indicates that the sensor performs reasonably well under the specific factor. The "×" symbol indicates that the sensor does not operate well under the specific factor relative to the other sensors.

Factors	Camera	LiDAR	Radar	Fusion
Range	~	~	✓	✓
Resolution	✓	~	×	✓
Distance Accuracy	~	✓	✓	✓
Velocity	~	×	✓	✓
Color Perception, e.g. traffic lights	✓	×	×	✓
Object Detection	~	✓	✓	✓
Object Classification	✓	~	×	✓
Lane Detection	✓	×	×	✓
Obstacle Edge Detection	✓	✓	×	✓
Illumination Conditions	×	✓	✓	✓
Weather Conditions	×	~	✓	✓

Figure 21 – Performances of Camera, Lidar and Radar [RD-10]

Safety arguments 5 and 6 were justified through the Integrity Risk allocation (Figure 22) and the Bottom-Up approach (Figure 23) for integrity fault tree design.

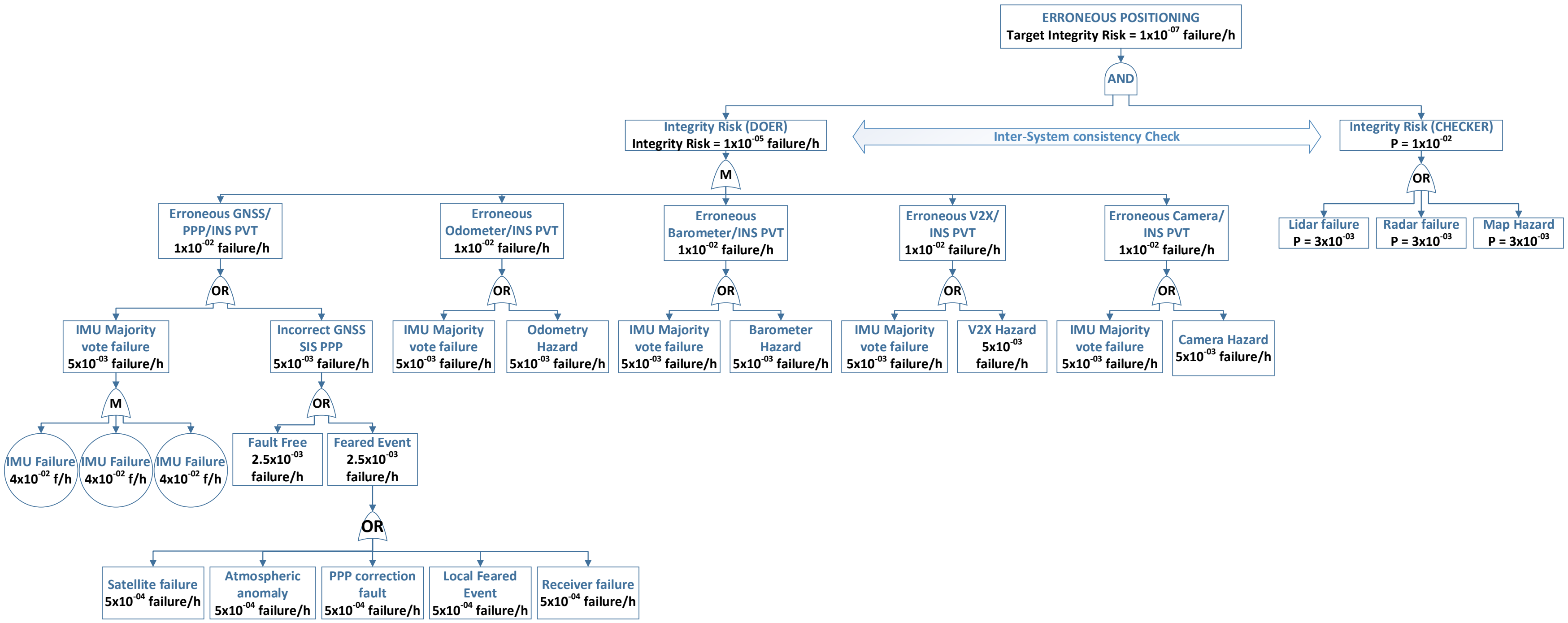

Figure 22 – Integrity Risk Allocation

The integrity risk allocation takes advantage of the following concepts:

- A Doer/Checker architecture, allowing to split the risk between these two sub-functions based on measurements from different and independent sets of sensors.
- A Majority voting algorithm ("M" gates), modelling the Fault detection and Exclusion (FDE) mechanism between, GNSS/PPP/INS PVT, Odometer/INS PVT, Barometer/INS PVT and Camera/INS PVT.
- kGNSS, a GNSS environment related coefficient introduced in the bottom up integrity tree, modelling the KFMI mechanism between IMU and GNSS/PPP
- Majority voting between the 3 IMU considered in the architecture. IMU is considered a major function to ensure the TTA of 1s.

Note: These integrity mechanisms are modelled under the form of gates in the Fault Tree. However, it must be recognized that some of these mechanisms have their own performances and error rates, which have not been taken into account in this Integrity Risk Allocation. No information regarding their respective performances is available for the time being, but this should be evaluated as part of future activities. This is deemed acceptable as the integrity risk budget shows significant margins once compared with real life sensors failure rates.

Indeed, the resulting quantitative requirements on the different elements on the system should be easily achievable. This is demonstrated through a bottom up analysis based on realistic failure rates.

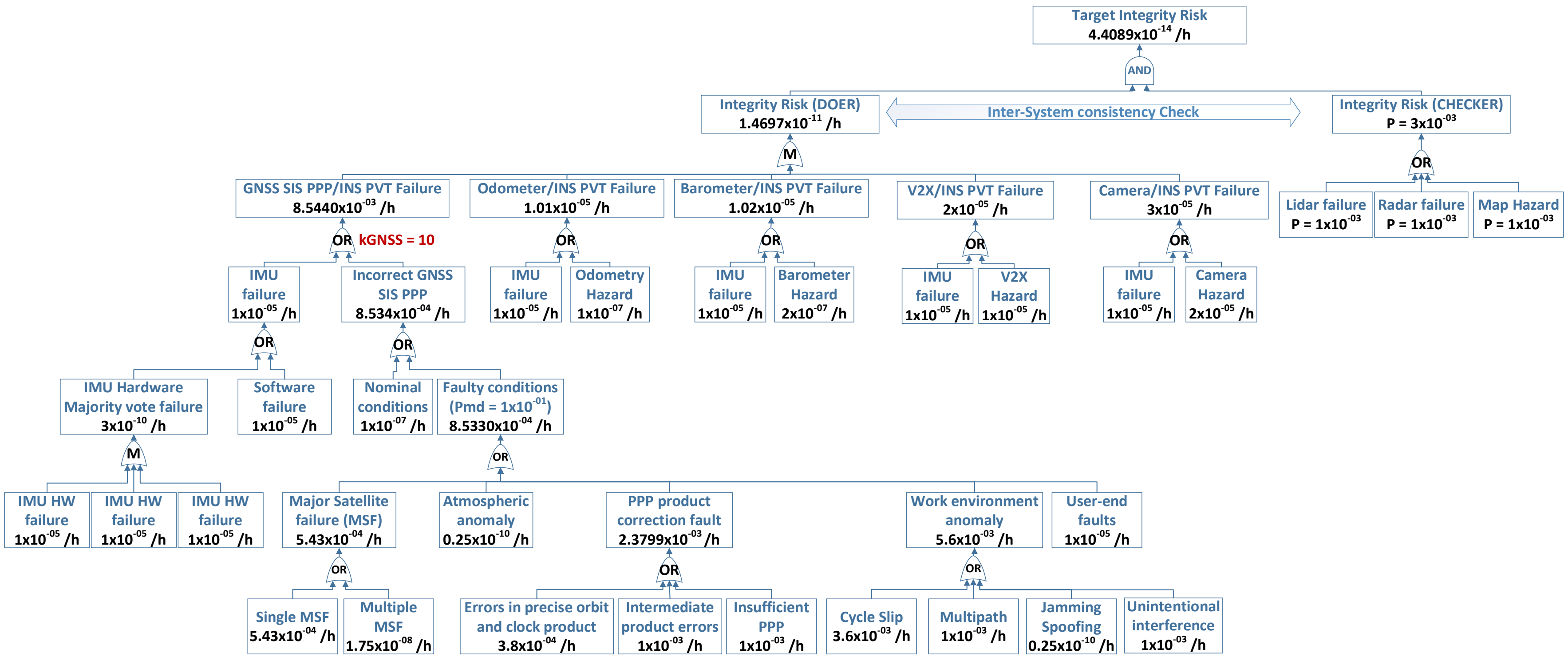

Figure 23 – Integrity Fault Tree constructed in a bottom-up approach for the complete system with $P_{md} = 10^{-1}$ in GNSS-denied environment

Based on the considered functional architecture, an ASIL decomposition for hazards INT#1 ("Incorrect vehicle trajectory due to erroneous positioning") and CONT#1 ("Loss of autonomous driving capability") was further provided, as per the following figure :

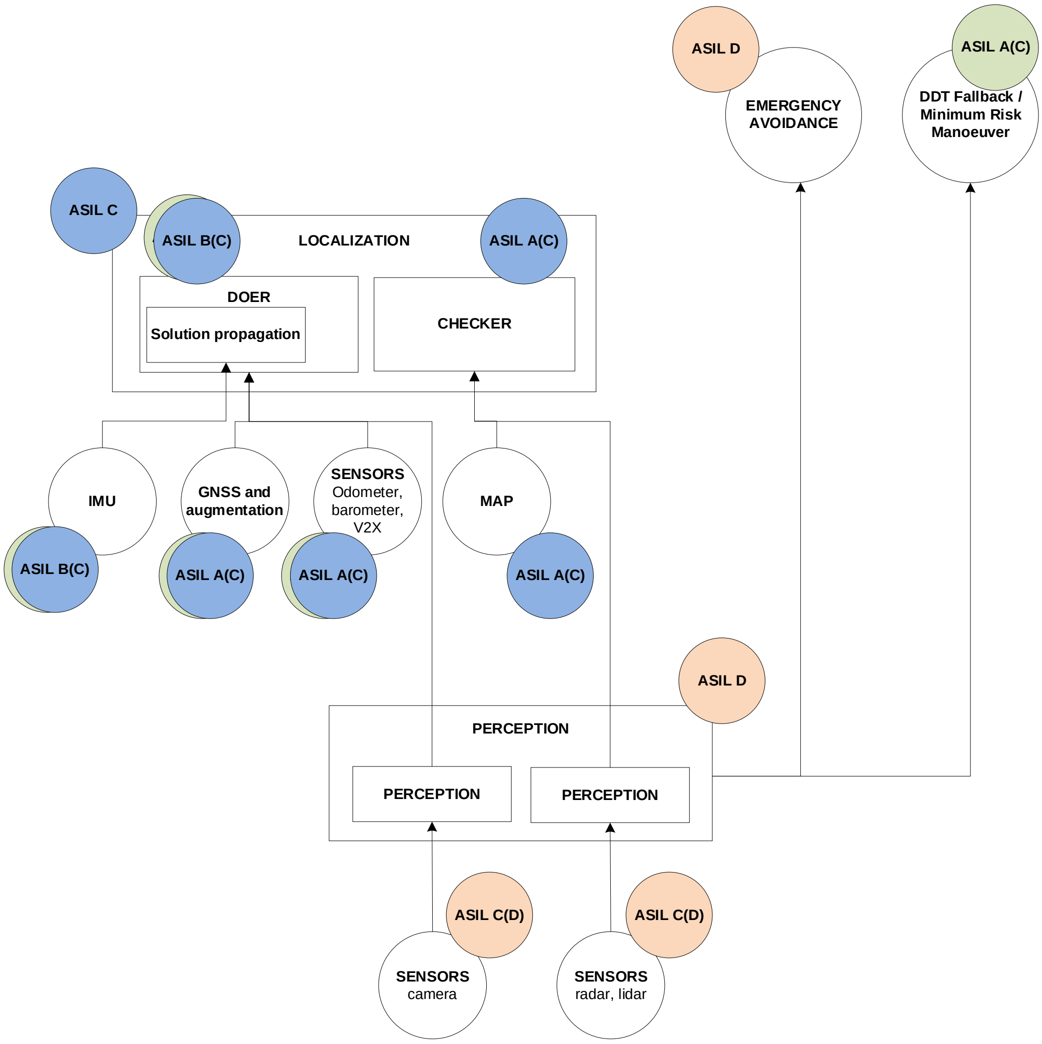

Figure 24 – Consolidation of ASIL levels

This ASIL decomposition shows the allocation of Level A to the EGNSS system providing the potential future High Accuracy and Integrity Service.

Note that one of the main outcomes of this analysis is that the computational burden is not a major driver for the design of the solution. Indeed, next generation cars are expected to be compatible with Artificial Intelligence and Machine Learning methods which are already complex enough.

Finally, the ICHASE integrity concept suitability to the rail and maritime domains was analysed. The comparison between the different transport domains considered the embedded sensors in the localisation architecture, the use case and operational environment, the user requirements for positioning system, and the regulations and standardisation contexts. The main outcomes of the analysis are in section 6 for the rail domain and in section 7 for the maritime domain.

5. INTEGRITY SERVICE DEFINITION

5.1. HAIS DATA CONTENT

For the user performance requirements to be reached, the user needs to have a high level of accuracy associated with a high reliability when computing the theoretical measurements. The components that the user needs for achieving high precision are the GNSS satellite position and clock offset at transmission time.

The intrinsic precision of the GNSS navigation message is not enough to provide a user accuracy below the meter level. To reach the accuracy requirements for the user, the EGNSS High Accuracy and Integrity service must transmit orbit and clock corrections to be applied to the GNSS navigation message.

From the stringent accuracy requirements at user level, and the fast convergence time, we can deduce that the user will need to use the phase measurements, and estimate integer ambiguities. This means the EGNSS High Accuracy and Integrity service needs also to transmit code and phase biases for the different frequencies the user might use.

Finally, if the user does not only use ionofree measurements but uncombined measurements, it will have to evaluate the ionospheric delay on his lines of sight. Therefore the EGNSS HAIS service will have to transmit ionospheric corrections as well. The user is then expected to use this information as a priori values in his filter to re-estimate the actual values on his lines of sight.

According to the analysis done in ICHASE, the data to be transmitted by the EGNSS High Accuracy and Integrity service are given in the summarized below:

Transmitted parameters	Comment
Orbit and clock corrections	
Orbit corrections	broadcast as 3 parameters ΔR (radial correction with respect to the position given by the GNSS navigation message), ΔT (tangential, or along-track correction) and ΔN (normal or cross-track)
Clock corrections	broadcast as 1 parameter Δh
Code biases	1 for each considered frequency (L1/L2/L5, E1/E5a/E5b). The code bias must be applied to the satellite clock in the pseudo-range measurements on the corresponding frequency
Phase biases	1 for each considered frequency (L1/L2/L5, E1/E5a/E5b). The phase bias must be applied to the satellite clock in the phase measurements on the corresponding frequency

Orbit and clock covariance	4x4 Covariance matrix giving the structure of errors of the orbit and clock corrections. The user will use this matrix to compute the level of orbit and clock error on his line of sight The matrix can be calculated by the formula: $P = \sigma_{DFRE}^2 \cdot 2^{e-5} \cdot \begin{pmatrix} E_{11} & 0 & 0 & 0 \\ E_{12} & E_{22} & 0 & 0 \\ E_{13} & E_{23} & E_{33} & 0 \\ E_{14} & E_{24} & E_{34} & E_{44} \end{pmatrix} \begin{pmatrix} E_{11} & E_{12} & E_{13} & E_{14} \\ 0 & E_{22} & E_{23} & E_{24} \\ 0 & 0 & E_{33} & E_{34} \\ 0 & 0 & 0 & E_{44} \end{pmatrix}$ The broadcast parameters are σ_{DFRE}, e, and the E_{ij}
Code biases error	confidence level for each code bias
Phase biases error	confidence level for each phase bias
Correlation time of residual errors	Gives the level of time correlation between residuals on a line of sight. This information is useful for a user implementing a Kalman filter to take into account the temporal correlation of residual errors
Sigma residual	Gives the amplitude of residual errors. This information is useful for a user implementing a Kalman filter to take into account the temporal correlation of residual errors
Atmospheric corrections	
Ionospheric delays	Gives the vertical TEC on a two-layer grid of IGP points. The user can interpolate the grid to retrieve the ionospheric delay on his lines of sight.
Confidence level of the ionospheric delay	Gives the confidence level of the vertical TEC on a two-layer grid of IGP points. The user can interpolate the grid to retrieve the confidence level of the ionospheric delay on his lines of sight.

Table 7 – EGNSS HAIS data type

5.2. SERVICE PERFORMANCE REQUIREMENTS

The HAIS performance requirements are provided in Table 8 below.

Requirement ID	Requirement description
Orbital error	The orbital error projected on the line of sight shall be less than 8 cm (@ 95%).
Satellite clock error	The satellite clock error shall be less than 10 cm (@95%)

Requirement ID	Requirement description
Code phase bias error	The code phase bias error shall be less than 4 cm (@95%)
Carrier phase bias error	The carrier phase bias error shall be less than 4 cm (@95%)
Ionospheric correction error	The ionospheric vertical delay error shall be below 0.7 TECU
Availability	The availability at pseudorange level shall be better than 99%
Continuity	The continuity at pseudorange level shall be better than $10^{-5}/h$
Integrity	The integrity at pseudorange level shall be better than $2 \cdot 10^{-3}/h$. Pseudorange integrity is defined as : $SRE < k \cdot \sigma_{ODTS}$ $GIVD - TEC_{ref}\| < k \cdot \sigma_{GIVE}$ With k the normal law quantile associated to $2 \cdot 10^{-3}/h$.
Time-To-Alert	The TTA at system level shall be 6 seconds

Table 8 – HAIS Service Performance Requirements

The HAIS accuracy requirements for the orbit and clocks have been defined with a methodology fully described in [RD-3], and summed up here:

- A conservative model of the final user is defined: we assume it is calculating its position with a snapshot algorithm, using only GNSS measurements.
- The accuracy requirements at user level are taken as input for the calculation: a standard deviation of 10 cm of the user error is taken on the 3 coordinates (up, north, east).
- Considering a single constellation of 24 Galileo satellites, a simulation allows to calculate for a grid of users on Earth the positioning problem to be solved:

  $$A\ \delta X = b$$

  Where A is the design matrix, δX is the user error, and b the pseudorange error.
- Knowing the distribution of δX (standard deviation of 10cm on all 3 coordinates), the distribution of b is calculated with the above formula.
- The results of the simulation thus indicate a distribution of the pseudorange errors having a standard deviation of 7.5 cm.

- These 7.5 cm are then decomposed in orbit, clock and biases components, giving the requirements in the above table.

For the ionospheric corrections accuracy requirements, the value is taken from [RD-9] of EGNOSHA project. It must be noted that this value is very conservative, as the ionospheric correction accuracy is not as important as the orbit/clock accuracy, since the final user re-estimates the ionospheric delays on its lines of sight. The ionospheric corrections are however essential for a quick convergence. What accuracy level allows a quick convergence will have to be refined with experimentations. For now, the value from EGNOSHA is considered.

5.3. SERVICE LEVELS AND COVERAGE

The service levels and coverage are assumed to stick to the definitions of service level and coverage of the Galileo HAS. ***This applies to both the integrity data complementing the Galileo HAS, and to the High Accuracy data that would be computed in contingency cases***.

Accordingly, it is proposed to keep the separation in two service levels (SL1 and SL2) for the HAIS as for the HAS of Galileo. SL1 has a global coverage area and aims at providing corrections and integrity data for clocks, orbits and biases (for code and phase) in addition to integrity flags. SL2 has a regional coverage (European Coverage Area) and aims at providing the same data as SL1 in addition to corrections and integrity data for ionosphere.

Service Level	Coverage Area	Data
SL1	Global	Corrections and integrity data for : 1. Clocks and orbits 2. Code and Phase Biases
SL2	European	Corrections and integrity data for : 1. Clocks and orbits 2. Code and Phase Biases 3. Ionosphere delays

Table 9 – HAIS service levels

HAIS SL1 service shall be complemented by an ionospheric model in order to ensure convergence time in compliance with the specification (<1 min).

5.4. PROCESSING FACILITY ARCHITECTURE

In order to compute the integrity data of HAIS, several solutions concerning the processing facility have been studied. The following possibilities with their pros and cons was analysed :

1. Correction dissemination and integrity monitoring as one system: the HAIS does not use the Galileo HAS corrections and computes its own corrections and the associated integrity data independently from the Galileo HAS infrastructure,

2. Correction dissemination and integrity monitoring as two systems: the HAIS is an independent system which makes use of the HAS corrections and measurements from stations to compute the integrity data associated to the HAS corrections,

3. Hybrid solution : the HAIS makes use of the HAS corrections and stations measurements to compute the integrity data and its own corrections as well. The HAIS provides messages for corrections and integrity data.

The trade-off of these solutions has led to the adoption of the hybrid solution where the HAIS broadcasts the HAS corrections in nominal cases but it may also compute its own corrections in contingency cases.

Figure 25 presents the proposed architecture of the hybrid solution for the HAIS.

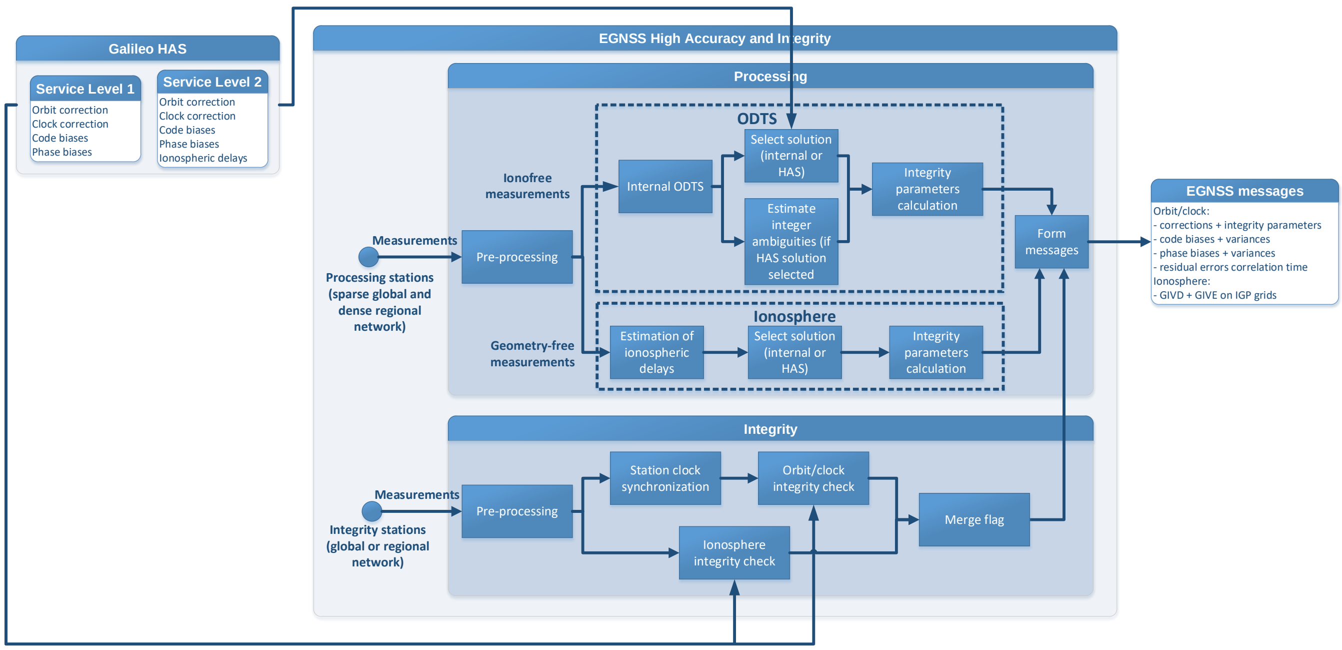

Figure 25 – High Accuracy and Integrity architecture in case of hybrid system

5.5. GROUND STATIONS NETWORK

As mentioned above, the HAIS would make use of measurements from ground stations to compute corrections and integrity data.

For the global integrity service (SL1), the GSS stations of Galileo are mainly used in addition to other stations around the world . A simulation of these stations is presented in Figure 26. A total of 32 stations will be needed for this level of service.

For the SL2 of HAIS, 44 additional RIMS are needed to compute the ionosphere data in Europe. The total network gathering all the needed stations (SL1 and SL2) is shown in Figure 27.

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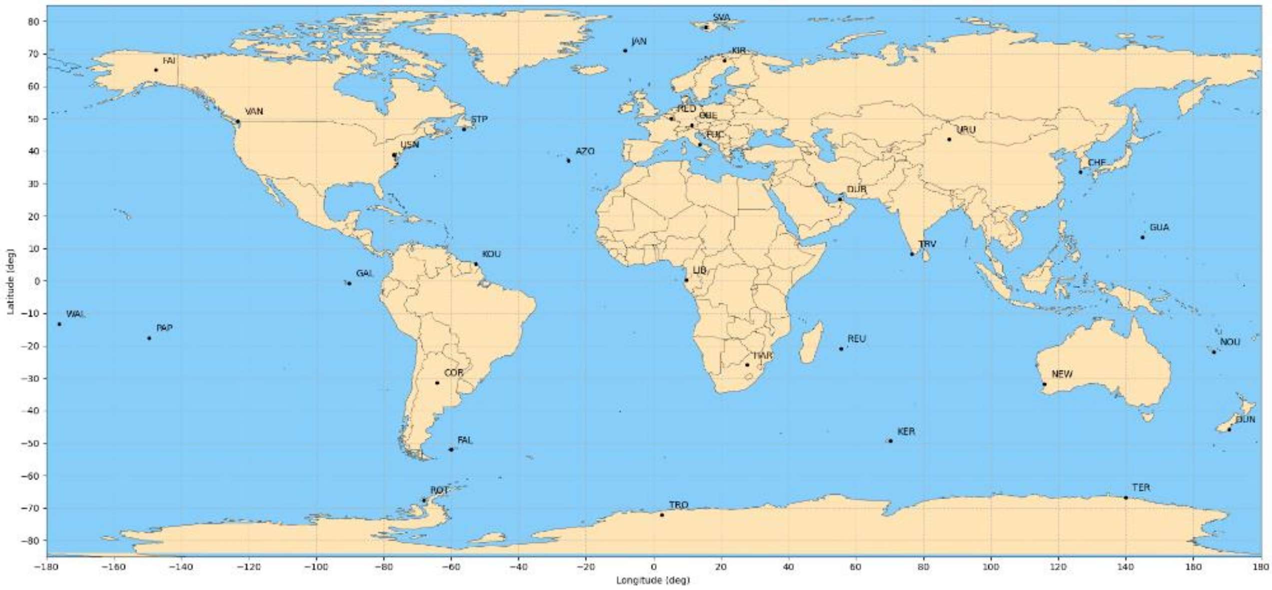

Figure 26 – Network of stations for the global orbit/clock/bias integrity service (GSS + 18 other stations – typically IGS)

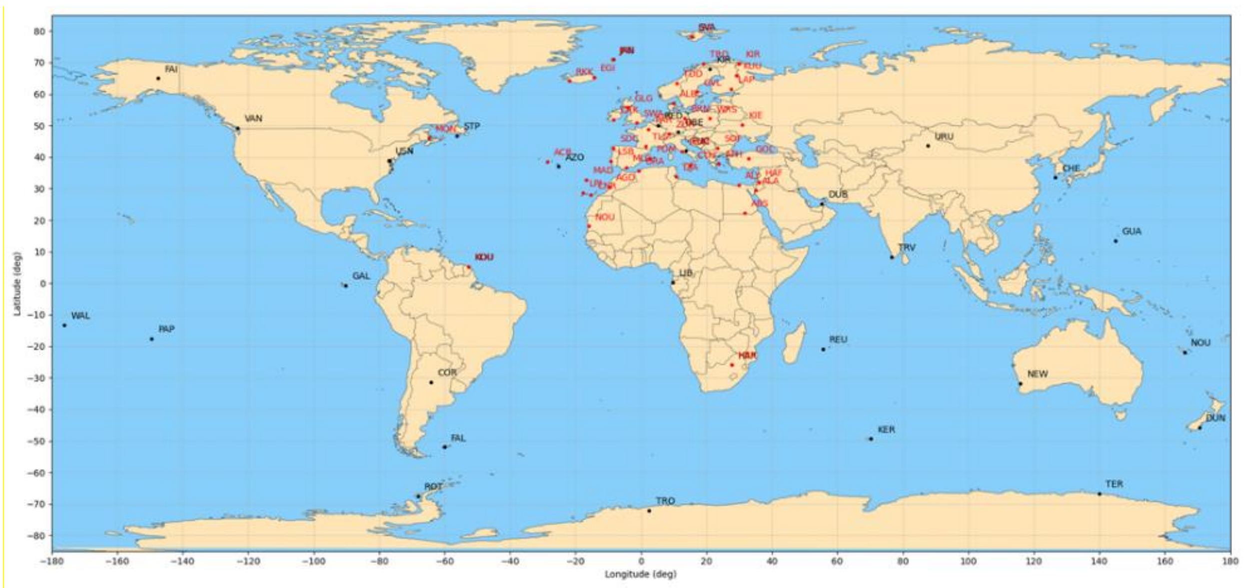

Figure 27 – Network of stations for the global orbit/clock/bias integrity service, and ionosphere in Europe (GSS + RIMS + 18 other stations – typically IGS)

5.6. DISSEMINATION MEANS AND SERVICE PROVISION SCHEME

Several dissemination means were analysed with their pros and cons in order to define the most promising hybrid dissemination architecture to ensure a global coverage of the HAIS in different operational scenarios. Obviously, both satellite and terrestrial links are needed to meet the requirements on the service especially when it comes to the service availability at the user level.

Figure 28 below shows the proposed service provision scheme where the new proposed Central Processing Facility (CPF) called High Accuracy and Integrity Data Generator (HAIDG) would be integrated in a future evolution of EGNOS. This is in line with the current system analysis being addressed in the frame of the EGNOS Next project (H2020-044), where the future EGNOS versions would be integrated in a "System of Systems" vision.

As can be seen in this figure, satellites on different orbits are considered for the dissemination of the SiS and Cooperative-ITS (C-ITS) and 5G networks are proposed for the terrestrial means.

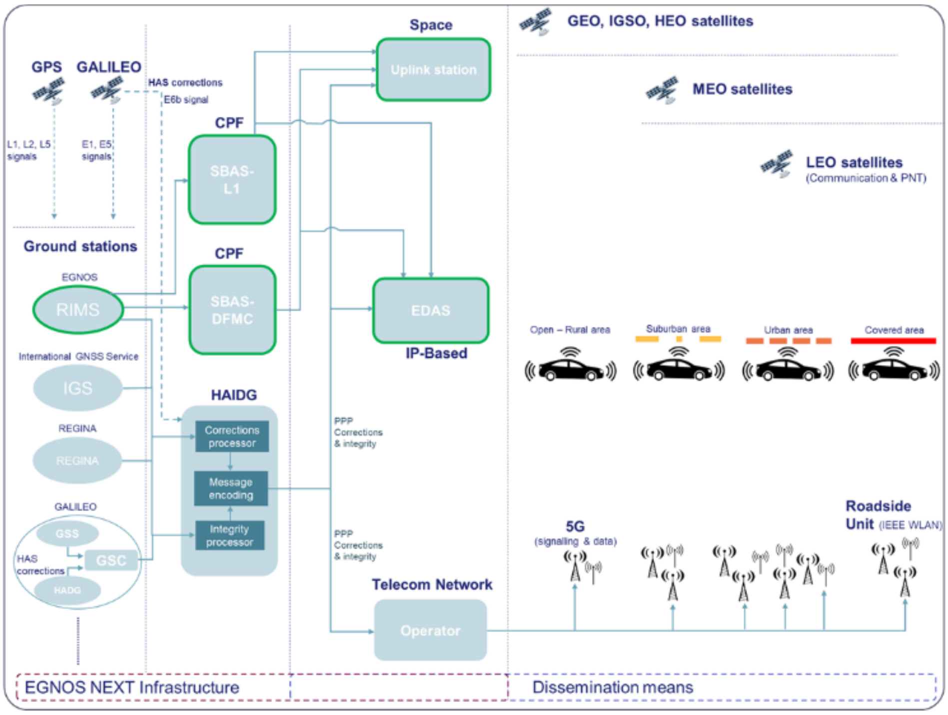

Figure 28 – HAIS service provision scheme

It is clear from this figure that the EGNSS HAIS service on both the Galileo and the EGNOS infrastructures to deliver this high accuracy and integrity service. More particularly, the EGNOS infrastructure plays two main roles in the provision of the HAIS:
1 – The use of the RIMS network measurements for the computation of ionospheric corrections,
2 – The use of the EGNOS dissemination means (EDAS, and SiS).

The EGNOS infrastructure may also be used to host the new HAIDG, but this needs to be addressed in a system level study.

6. SUITABILITY OF THE PROPOSED INTEGRITY CONCEPT AND SERVICE DEFINITION FOR RAIL

6.1. SUITABILITY OF THE PROPOSED INTEGRITY CONCEPT FOR RAIL

The suitability of the proposed integrity monitoring concept of ICHASE project for rail application is analysed respectively from the following four aspects:

- Embedded sensors of the positioning system for rail applications,
- Rail use cases and operational environments,
- Rail user requirements for the positioning system,
- Rail regulations and standards for positioning systems.

6.1.1. Embedded sensors of the positioning system for rail applications

Typical railway positioning sensors include Doppler radar, wheel sensors (tachometers/odometers), Eddy current sensor (a non-contacting position sensor used for measuring the change of position of a specified target), IMU, GNSS as well as the trackside equipment such as the balise transponder.

ICHASE project has proposed several positioning system architectures including the following sensors: GNSS, IMU, odometer, barometer, Lidar, Radar, Camera and HD map. From the hardware point of view, all these sensors proposed by ICHASE for autonomous vehicles could be embedded on the train in order to provide absolute positioning information with high accuracy and integrity especially for the safety-critical applications.

GNSS is already being introduced into the rail applications aiming at replacing the physical balises to increase railway network capacity, decrease operational and maintenance costs as well as foster new train operations. In recent years, in parallel to the introduction of GNSS into rail activities, the rail community is focusing also on the use of perception sensors, such as cameras, Lidar and Radar, to overcome the limitations of the GNSS-based positioning for certain rail applications. The use of these perception sensors for railway obstacle detection and distance estimation is still under research. The main challenge of the railway compared to autonomous vehicles regarding obstacle detection is that train collision avoidance is only possible if the detection distance exceeds the train's stopping distance, which depends on many factors (e.g., mass distribution, speed, achievable deceleration rate, brake delay time, track gradient etc.). For example, according to national regulations in most EU countries, the stopping distance of a freight train pulling 2000 t of cargo at 80 km/h is approximately 700 m. This long-range stopping distance is specifically challenging for obstacle detection using perception sensors compared to road vehicles.

It shall be added also that, in rail the use of precise maps is also an added value and reliable maps can help fulfil the required performance.

6.1.2. Rail use cases and operational environments

Rail applications can be classified into safety-critical ones and non-safety-critical ones. [RD-2] extracts the safety-critical rail applications such as ERTMS positioning, autonomous train control and signalling as well as traffic management.

The environmental impacts for trains are at the same level as the autonomous vehicles when the trains travel in or near the city centre (urban or sub-urban). One specific critical environment affecting GNSS signal reception for rail, compared to autonomous vehicles, is the forest scenario. There exist some rail tracks especially in mountains, which are surrounded or even covered by trees. Thus, the sky visibility is very limited in the forest scenario with high HDOP and the Hazard Rate (HR).

6.1.3. Rail user requirements for the positioning system;

Different rail user requirements exist, which are summarized in [RD-2]. Table 10 summarizes the comparison of the ICHASE consolidated user requirements with the most stringent rail requirements. Conclusions are also drawn concerning whether the ICHASE user requirements can cover the rail user requirements for positioning systems.

KPI	ICHASE Consolidated user requirements [ICHASE D210]	Rail most stringent requirements	Does ICHASE req. cover rail req. ?
Position Accuracy	Horizontal : 20 cm | Vertical : 0.5-1 m at 95% AT : 20 cm, CT : 10 cm at 95%	2-sigma Horizontal Navigation System Error (HNSE) < 1m Or ACTE < 1.9 m	Yes for the majority of the safety-critical applications; TBC for certain applications (e.g., cold movement detection, track identification)
Position Availability	99.9 % monthly	> 99.99% (SIL 4)	Yes for SIL 0 – 2; No for SIL 3 - 4
Position Continuity	$1 \cdot 10^{-5}\ /\ h$	>99.98%	Yes (assuming average rail mission time = 1h)
Position Integrity	$2.5 \cdot 10^{-7}\ /\ h$	$\geq \mathbf{10^{-9}}$ to $<\mathbf{10^{-8}}$ (SIL 4)	Yes for SIL 0 – 2; No for SIL 3 - 4
Alert Limit	Horizontal : 1 m | Vertical : 2-3 m AT: 1 m, CT: 50 cm	2.5 m to 50 m (depending on use case)	Yes for the majority of the safety-critical applications; TBC for ATC
TTA	< 1 second	<1 s to 30 s	
TTFPF	< 60 seconds	TBD	-
Velocity Accuracy	3% of the vehicle velocity	± 2 km/h for speed lower than 30 km/h, then	The ICHASE's preliminary proposition can cover the requirements for low-speed

		increasing linearly up to ± 12 km/h at 500 km/h.	rail lines but not the high-speed ones.
Velocity Alert Limit	Proportional to Velocity Accuracy	TBD	-
Velocity Integrity Risk	10^{-7}- 10^{-8}/h	TBD	-
Velocity Availability	99.9 % monthly	TBD	-

Table 10 – Summary of the suitability analysis of ICHASE user requirements for rail

6.1.4. Rail regulations and standards for positioning systems

The main policy and regulatory European stakeholders involved in the user requirement definition process are the European Railway Agency (ERA) and the UNion Industry of SIGnalling (UNISIG). Besides, the Community of European Railway (CER) and the ERTMS User Group (EUG) are also involved in the user regulations and requirements definition.

Some railway safety standards exist such as EN 50126, EN 50128 and EN 50129, which have been developed by CENELEC (European Committee for Electro-technical Standardization). [RD-2] has made a summary of some technical railway standards concerning functional safety.

6.2. SUITABILITY OF THE PROPOSED INTEGRITY SERVICE FOR RAIL

[RD-6] has discussed the suitability of HAS service enhanced by ICHASE (HAIS) for rail applications. The suitability is analysed from the two following aspects: service coverage and the dissemination means of the service.

In terms of coverage, the HAIS service proposed by ICHASE is suitable for rail applications. As a terrestrial transport mode, the railway has similar service coverage requirements as the ones for autonomous vehicles. In particular, for the trains which travel out of the European area, the HAIS-SL2 is not available.

In terms of dissemination means, the satellite links are more suitable, especially in favourable coverage conditions. The terrestrial links can further enhance the service dissemination when the trains travel near cities where the terrestrial infrastructures (telecom networks and other roadside units) for HAIS dissemination are available. Moreover, some rail-specific transmission systems can also be considered as dissemination means for HAIS service especially for rail applications. In this way, it can minimize the modifications to be done (hardware or software) for the railway community to benefit from the proposed HAIS service.

7. SUITABILITY OF THE PROPOSED INTEGRITY CONCEPT AND SERVICE DEFINITION FOR MARITIME

7.1. SUITABILITY OF THE PROPOSED INTEGRITY CONCEPT FOR MARITIME

The analysis of the suitability of the proposed integrity concept for maritime follows the same structure as for the rail in the previous section.

7.1.1. Embedded sensors of the positioning systems for maritime applications

Commonly-used sensors for maritime navigation and positioning include on-board equipment such as GNSS-based systems, IMU, Lidar-based systems, sonar / multi-beam sonar, visual systems, speedometer, compass, sextant and structure equipment such as transponder, reflector as well as radio beacons.

Compared to road navigation, maritime navigation has to deal with a moving environment, i.e., ocean currents and winds. A speedometer (log) could be similar to an odometer in a road context, except that the former gives information relative to the water (which is a moving environment), where the latter gives information relative to the road (static environment). Finally, GNSS technology is widely used in the maritime domain Automatic Identification System (AIS), providing a very valuable and scalable absolute position over the whole world.

From the hardware point of view, all the sensors proposed by ICHASE for autonomous vehicles could be embedded on vessels in order to provide absolute positioning information with high accuracy and integrity, especially for safety-critical applications.

7.1.2. Maritime use cases and operational environments

Different categories of safety-critical maritime applications exist such as SOLAS and search and rescue (Category 1), Coastal, Port approach and entrances, automatic collision and avoidance and track control (Category 1+) etc. [RD-2] made a summary about all these applications as well as their categories. Thus it definitively makes sense to use the outcomes of ICHASE project. Maritime context has a list of “safety-critical” applications from relaxed ones up to the more stringent ones that could benefit from the integrity concept developed in the scope of ICHASE.

In terms of maritime operation environments, conditions can be considered easier than road context, but harder than aviation domain. According to the PROSBAS project, except for the “Multipath condition” which is classified as “can be high” or “medium” for both open sea and coastal waters, harbour entrances and approach environments, all other criteria (such as elevation mask, attenuation, interference and user dynamic) are low. In conclusion, the maritime environment doesn’t present any serious difficulties to the extrapolation of the ICHASE integrity concept to the maritime context.

7.1.3. Maritime user requirements for the positioning system;

Different maritime user requirements exist, which are summarized in [RD-2]. Table 11 summarizes the comparison of the ICHASE consolidated user requirements with the most stringent maritime requirements.

KPI	ICHASE From D110	Maritime most stringent requirements between IMO and FRP	Does ICHASE req. cover maritime req. ?
Position Accuracy	Horizontal :20 cm Vertical :0.5-1 m at 95%	Horizontal:1m Vertical: -	YES
Position Availability	99.9 % monthly	99.9% monthly	YES
Position Continuity	99.999% / 1h	99.97% / 15 min	YES (if homogeneous discontinuity)
Position Integrity	$2.5 \cdot 10^{-7} / h$	$1 \cdot 10^{-5} / 3h$	YES
Alert Limit	Horizontal: 1m Vertical: 2-3m	Horizontal: 2.5 m Vertical: -	YES
TTA	<1s	10 s	YES
TTFPF	<60s	-	N/A
Velocity Accuracy	3% of the velocity	-	N/A

Table 11 – Summary of the suitability analysis of ICHASE user requirements for maritime

The most stringent requirements for maritime deal with two specific phases of navigation "Port" and "Inland waterways", where accuracy has to be very small with a high degree of availability, continuity and integrity. Even in that context, we can observe that ICHASE requirements are still more stringent; meaning that ICHASE requirements fully cover maritime needs.

7.1.4. Maritime regulations and standards for positioning systems

Maritime domain is a very standardized and regulated world due to its nature: ships evolving over the whole world, need to be compliant with the regulations of many different countries. The most representative organizations responsible for regulation, standardization and certification within the Maritime community are listed in [RD-2], such as IMO (International Maritime Organization, Belongs to United Nations), IALA (International Association of the Marine Aids to Navigation and Lighthouse Authorities), EMRF (European Maritime Radio navigation Forum), RTCM (Radio Technical Commission for Maritime Services), etc.

The following documents are identified as ones among the most important in the maritime world:

- SOLAS convention is an international treaty under which all IMO resolutions are provided (in particular IMO resolutions A.915 (22) and A.1046 (27))
- 61108 series written in the frame of IEC TC80 aims at defining GNSS requirements for each known constellation or service

Because the maritime domain is very regulated, it may be difficult to address ICHASE integrity concept from road to maritime context. But on the other hand, standards for autonomous vessels have just begun to be tackled. This can be considered as an opportunity for ICHASE outcomes.

7.2. SUITABILITY OF THE PROPOSED INTEGRITY SERVICE FOR MARITIME

The analysis of the suitability of the proposed integrity service for maritime follows the same structure as for the rail applications in the previous section. That is to say, the service coverage and the dissemination means of the ICHASE service are analyzed.

The main difference of the Maritime context compared to the ICHASE one is "Ocean navigation" applications where services could be less dense, and communication means are not so easy with the absence of terrestrial cellular communication means. Concerning Inland Waterways, we assume the service will be suitable for European usage like for the nominal Galileo HAS. In conclusion, we can conclude that HAIS service will be suitable for all maritime applications, except Service Level 2 (Regional coverage availability: centred over the European Coverage Area) when vessels evolve outside of the Europe Coverage Area.

In terms of dissemination means of the proposed service, the ones proposed by ICHASE are achievable for coastal or inland waterways. For ocean maritime applications, EGNOS E5B has been identified as the best dissemination means in terms of cost and availability. Similarly, if the maritime-specific transmission means are included as HAIS service dissemination means, it will facilitate the adoption procedures.

7.3. SUMMARY OF THE SUITABILITY OF THE PROPOSED INTEGRITY CONCEPT AND SERVICE TO RAIL AND MARITIME

Both following tables summarises the sections 6 and 7.

	For Rail	For maritime
Embedded positioning sensors	All the sensors proposed by ICHASE could be embedded on the train; The use of perception sensors for obstacle/rail track detection and distance estimation is still under research due to the challenging stopping distance of the train.	All sensors used for ICHASE could be used and deployed for maritime applications Special attention for extrapolation of odometer to speedometer (movement of water over ground)

Use case and operational environments	Safety-critical applications requiring high accuracy & integrity The environmental impacts are at the same level as the autonomous vehicles when the trains travel in or near the city center.	Safety-critical maritime use cases (all categories) could benefit from ICHASE integrity concept. Operational environments are less stringent in MARITIME than ROAD (except for static): ICHASE is almost 100% suitable
User requirements for positioning system	Most stringent safety-critical apps in the rail domain require HNSE <1m, TTA <1 s, integrity risk SIL 4 (≥ 10-9 to <10-8). SIL classification [EN 50129]: target performances of ICHASE requirements can achieve SIL 0-2 but not SIL 3&4	Could differ from one standard to another: e.g., for "Ocean" IMO-Acc_min = 10m / FRP-Acc_min=1800m Most stringent requirements (IMO&FRP) are covered by ICHASE requirements: ICHASE is suitable
Regulation and standards	Main stakeholders: European Railway Agency (ERA), UNion Industry of SIGnalling (UNISIG), Community of European Railway (CER) and the ERTMS User Group (EUG) … Existing standards: EN 50126, 50128 and 50129	Very standardized domain by nature: IMO / IALA / CIRM / EMRF / IMPA / RTCM / ITU / IEC / … Among the most important standards: SOLAS convention (IMO A.915 (22) & A.1046 (27)) / IEC61108 (GNSS std)

Table 12 – Summary of the suitability of the proposed integrity concept for rail and maritime

	For Rail	For Maritime
Coverage	HAIS service suitable for rail applications As a terrestrial transport mode, the railway has similar service coverage requirements as the ones for autonomous vehicles. In particular, for the trains which travel out of the European area, the HAIS-SL2 is not available.	The main difference of the Maritime context is "Ocean navigation" applications where services could be less dense, and communication means are not so easy with the absence of terrestrial cellular communication means. Concerning Inland Waterways, the service will be suitable for European usage like for the nominal Galileo HAS.

Dissemination means	The satellite links are more suitable, especially in favourable coverage conditions. The terrestrial links can further enhance the service dissemination when the trains travel near cities where the terrestrial infrastructures (telecom networks and other roadside units) for HAIS dissemination are available. Moreover, some rail-specific transmission systems can also be considered as dissemination means for HAIS service especially for rail applications.	Dissemination means are achievable for coastal or inland waterways. For ocean maritime applications, EGNOS E5B has been identified as a relevant dissemination means in terms of cost and availability.

Table 13 – Summary of the suitability of the proposed integrity service for rail and maritime

8. DECISION CRITERIA

The decision criteria analysis was undertaken in qualitative terms and when possible, also in quantitative terms, considering the inputs coming from the experts consulted in ICHASE (as described in the first and second points above) and from related previous studies.

The analysis of the decision making aspects relied on the following main pillars:

- **Four decision criteria categories** which are crucial in the field of a new technology introduction, to which HAIS belongs, are considered: technical, strategic, economic and time.
- The analysis was made from the **perspectives of the GNSS Rx manufacturer, the TIER1 automotive supplier and the HAIS service provider**. The reason is that, in the considered value chain (illustrated in the next figure – validated by the experts, in the first interaction (reported in ICHASE D110 [RD-1]) and during the webinar)), they are key players in the introduction and adoption of HAIS in AD applications, as also confirmed by the experts in the frame of the first interaction reported in the first bullet above.
- Specifically for the economic decision criteria, a quantitative analysis was done from the **perspective of the GNSS Rx manufacturer and the TIER1 automotive supplier through a Break-Even Analysis (BEA)**, while the perspective of the HAIS service provider was considered in qualitative terms.

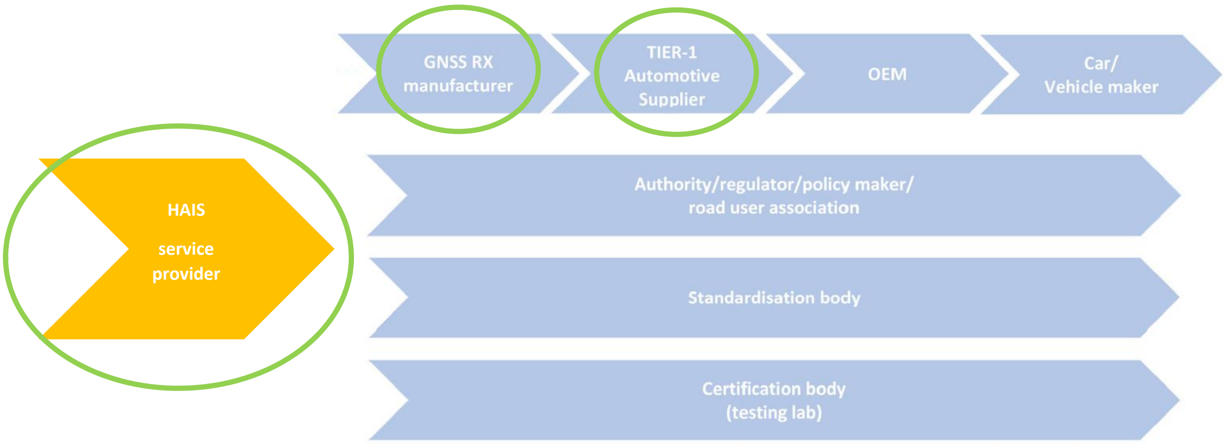

Figure 29 – Value chain for HAIS in AV applications

- The **inputs** used for the analysis come from:
  - ICHASE, and in particular from the experts consulted in the frame of the user needs analysis and of the integrity concept, and from the interview of ESSP. The answers and feedbacks received from the experts were analysed and reported in aggregated way, only the interview with ESSP is clearly mentioned. The reason for interviewing ESSP is because of its experience acquired in the EGNOS service provision.
  - Related previous studies. In the case of discrepancies between different inputs, those coming from ICHASE were applied, and the more recent ones overwrote the initial ones, because more updated and based on further progresses of the project.
- From the analysis' **outcomes/results**, validated with the experts in the third interaction listed above, recommendations/advices for GO/NO-GO decisions towards the introduction and adoption of HAIS were drawn, along with feedbacks towards the roadmap associated to HAIS.

Important elements can be drawn from the analysis of the economic decision criteria through the Break-Even Analysis for GNSS Rx manufacturers and TIER-1 automotive suppliers. The assumption derived from the consulted experts is that GNSS Rx manufacturers and TIER-1 both will not develop a new product/solution purposely for HAIS, while they will enhance their products/solutions to use HAIS. The assumption derived from the proposed service provision scheme is that any communication costs associated to the utilisation of HAIS are afforded by the HAIS service provider and by providers at the end-to-end level.

From the perspective of GNSS Rx manufacturers

- The market size needs to be sufficient to ensure that the 166,667 Rx break-even volume (Worst Case 666,667 Rx, Best Case 40,000 Rx) is reached in the assumed 10-year timeframe; and
- Existing Rx technology can be updated to support HAIS rather than developing a new GNSS Rx, which would be significantly more expensive and thus lead to a much Rx higher break-even volume.

Additional Fixed Costs (NRE – Non-Recurring Engineering, referring to the one-time cost to research, develop, design and test a new product) are the main costs for GNSS Rx manufacturers, as the Additional Variable Costs are relatively negligible. This means that Additional Fixed Costs drive GNSS Rx manufacturers' Rx Break-Even Volume. They may be targeted by external stimuli such as R&D grants (by institutions like the European Commission) to influence the Rx break-even volume to ensure GNSS Rx manufacturer support.

From the viewpoint of TIER-1 automotive suppliers:

- GNSS Rx are already available as off-the-shelf technology, which is critical to limit the Additional Costs (and thus the break-even Additional Revenues); and
- OBUs can be modified to add new function and services not possible with today's technology, bundled with existing functions and services.

As a result of the consultations and analysis of the economic decision criteria, the following recommendations were formulated:

- Stimulation of the market adoption of HAIS, through various actions, such as development of enablers (technology, combined with standardisation and opportune regulatory framework);
- Interventions to reduce the burden of this initial cost to the GNSS Rx manufacturers
- Insurance of a wider adoption, through promotion and support for possibly extending to other applications/domains, in order to increase the size of the potential market;
- Punctuality in the deployment of HAIS, to limit possible competitive market disadvantage with respect to other technologies. A step-wise plan is advisable.

9. SERVICE IMPLEMENTATION ROADMAP

As stated previously, EGNOS HAIS service is intended to complement the Galileo HAS service mainly adding an integrity layer, but also proposing an alternative to the HAS corrections for contingency cases.

As such, the roadmap for the EGNOS HAIS is naturally tightly coupled to that of the Galileo HAS.

This service declaration roadmap was assessed at different levels:

- The service key milestones roadmap,
- The engineering activities roadmap,
- The standardisation and certification activities roadmap.

It further considers dependencies and assumptions on different GNSS and dissemination infrastructures roadmap. These dependencies are divided as follows:

1 – GNSS systems and services roadmap

- Galileo

- EGNOS
- Potential future LEO PNT constellation
- Other GNSS systems roadmap, namely GPS

2 – Telecommunication Networks roadmap

3 – OBU positioning module baseline

This roadmap, takes as inputs the results of the HAIS service definition, the minimum requirements needed for the OBU, the results of the integrity concept, namely the results of the safety level allocation as per the Safety Assessment, and finally the recommendation on the service roadmap as provided in the decision criteria analysis, namely the minimum time laps needed between the introduction of each new step, related to the user segment life cycle of at least 4 years. However, building on the fact that no hardware modifications would be needed at the user level, this is not the main driver for the roadmap).

Further, and as already explained, the HAIS proposes two service levels, tightly coupled to those of the Galileo HAS:

1- SL1 : HAIS based on Galileo HAS SL1,
2- SL2 : HAIS based on Galileo HAS SL2, and including an independent HAS corrections generation module making use of EGNSS and non-EGNSS stations.

Knowing that the Galileo HAS SL2 is foreseen to be provided by 2024, and that initial demonstration infrastructure for the HAIS would be available by 2024 also, it is proposed to only base the first HAIS service demonstrations on the Galileo SL1, and to trigger the transition to the HAIS SL2 as soon as the Galileo HAS SL2 would be available.

It is proposed that a future HAIS service implementation roadmap would be fully integrated in the new “System of Systems (SoS)”[1] concept developed in the EGNOS Next project. The HAIS would in this frame have its own implementation / evolutions / maintenance roadmap, with no or very limited impact on other EGNOS and Galileo services.

The HAIS service is proposed to be developed and qualified in accordance with the target service performances and safety levels as defined in the ICHASE project for high autonomy levels, starting from level 4. The experts considered that Level 5 shall not be considered for a 10 to 15 years’ timeframe. It is rather foreseen in a timeframe of 20 to 30 years from now at least.

[1] This concept is understood as a SoS, on which the different constituents interact to provide tailored and efficient services. Under this approach each system may have its own modular development, implementation and resources, but it must be considered that each single element shall interact within the SoS to bring it full capabilities.

Further, it is important to recall that a wider extension of the HAIS use to other applications, for including also other AV levels, other road applications (such as those linked to ITS and C-ITS) and other sectors (such as rail and aviation/drones) was repeatedly remarked and deemed of interest in order to reach a large user community. This should be considered since the beginning (i.e., in the definition of requirements, in the specifications, and also in the standardisation aspects), and opportune synchronisations/synergies with correlated initiatives should be envisaged.

As such, and as a first step towards the service implementation roadmap, it is proposed to:

1 – Refine the service requirements to leverage these synergies, as well as to consider also different Operational Domains,

2 – Refine the service definition to leverage these synergies mainly in terms of relevant service provision and delivery, service level agreement, service commitment and responsibilities/liabilities,

3 – Refine the Safety Assessment to leverage the different synergies, and consolidate the final ASIL and Target Integrity Risk (TIR) levels associated to the HAIS service.

Based on the assumptions listed previously, the HAIS service adoption roadmap is illustrated on the figure below.

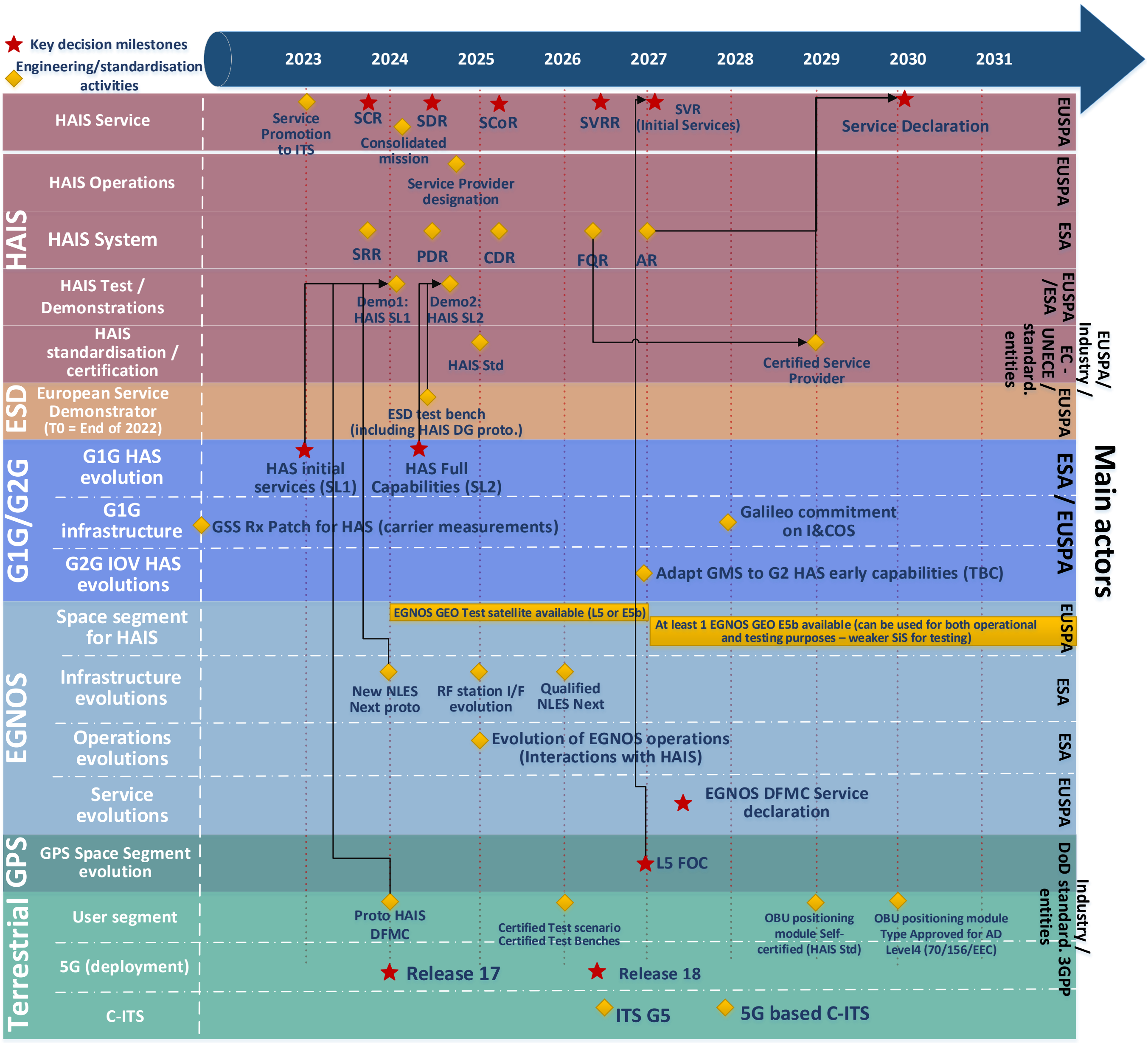

Figure 30 – EGNSS HAIS service adoption roadmap

Where, the red stars refer to key decision milestones, and the yellow diamonds refer to engineering activities.

The first step of this roadmap which is the Service Concept Definition shall include a holistic analysis of different applications that may rely on HAIS and thus refine the service requirements, definition and ASIL (Automotive Safety Integrity Level) and Target Integrity Level allocations. This is very important as any HAIS service certification shall take into account all of the applications that may use this service, in order to avoid (if possible) repeating the need to repeat the process for each application.

This first step can be initiated even if there are still open points at mission level, in order to avoid delaying the whole process which has a tight time to market.

In this roadmap, the NLES Next prototype being developed by Thales Alenia Space allows the implementation of testing capabilities at E5b frequency.

It is important to highlight the need for an evolution of the EGNOS RF station Interface in order to couple the new HAIS service NLES (operating over E5b namely, and additionally over L5 in testing phases), with the target EGNOS GEO satellite.

Table 14 below summarizes the major activities, the duration associated to each of them, and the dependencies between them.

Scope of activity	Duration	Dependencies / assumptions	Stakeholders involved
Service promotion to ITS	ASAP, and all through the service life cycle.	This shall be based on the output of the ICHASE / ITHACA projects.	EUSPA (can be done via support contract to industry) / EC / ITS actors like 5GAA and C-ITS
Review of Mission and Service requirements baseline in preparation for the SCR / SRR	5 months June 2023 to October 2023	The timeline for this activity takes into account a tender process starting by September or October 2022 and taking 9 months until the KO of the activity. This activity shall at least include a cross validation of the service and mission requirements baseline throughout different transportation domains. Further it shall consider the application of different sets of requirements of different Operational Design Domains (hence meaning addressing Level 4 of autonomy also).	EUSPA / ESA / industry
Mission and system requirements baseline consolidation and feasibility prior to SDR / PDR	8 months June 2023 to January 2024	The assumption here is that the SCR milestone can be initiated even if there are still open points at mission level (namely velocity related requirements and integrity concept baseline), in order to avoid delaying the whole process which has a tight time to market. The mission and system requirements are then consolidated for the SDR. For velocity requirements consolidation purposes, collaboration with laboratories collecting extensive field data need to be put in place (like GUIDE, UGE, IDIADA, Renault labs, etc.) The tender process for the mission consolidation for both cross domain analysis and velocity related integrity concept can be done in the same time / contract, including these two major steps.	EUSPA / industry

Service provider designation and certification	3 months September 2024 to November 2024	The service provider certification is usually (i.e. in civil aviation) done on the basis of system and operations cases to be provided to the certification authority. As such, once the service provider is designated, he needs to follow and provide these evidences prior to starting the certification process. It should be highlighted here that the main correlation is related to the system QR, where for example in EGNOS the time between the system QR and the Service Provider certification took about 2 years (2.5 years proposed here), and the time between the system QR and the service declaration was 3 years, 3.5 years proposed here, which is consistent.	EC / EUSPA / ESA
Demonstrations of HAIS SL1 and HAIS SL2 prior to CDR / SCoR	2 years and a half January 2023 to June 2025	These demonstrations are necessary in order to consolidate the service and system mission and design prior to SCoR and CDR. Taking as assumption the availability of the NLES Next prototype by 2024, and an ESD procurement launched by the end of 2022 / start of 2023, the HAIDG prototype (supposed to be part of the ESD procurement) is needed to start demonstrations. Accordingly, even if the ESD platform is not fully ready by 2024, based on the availability of the HAIDG and the NLES Next prototype, testing activities can be started. This definitely also means having an available GEO satellite, in test, and having defined the needed handover / handover back protocol with ESSP.	EC / EUSPA / ESA / Industry / EGNOs system operator / GEO satellites operators
Certified test scenarios and benches	32 months 2022/2023 to 2026	The indicated duration includes the scenarios, test benches and positioning algorithms definition and certification via accredited processes.	EC / EUSPA / Normative bodies (i.e. UNECE WP29 VMAD / ISO / CEN-CENELEC / ETSI / RTCM SC 134 / 3 GPP / IEEE P1952), Accredited labs (i.e. GUIDE / IDIADA, etc.)
GEO satellites for tests	Starting 2024	During the demonstration phase, EGNOS GEO satellites in Test can be used. The process of handover shall be defined. For test purposes, and in addition to the E5b frequency available over EGNOs GEO1 and GEO2 satellites, L5 may be used as long as no certified civil aviation DFMC service is declared (foreseen in 2027 so far). For the operational service, at least one GEO satellite is needed. This GEO satellite may be used for both an operational and a test signal that would be broadcast at lower power.	EC / EUSPA / ESA / EGNOS operator / Industry

Table 14 – List of major activities and related assumptions and dependencies

In accordance with the dates provided in this table, the list of major activities is represented through the following timeline.

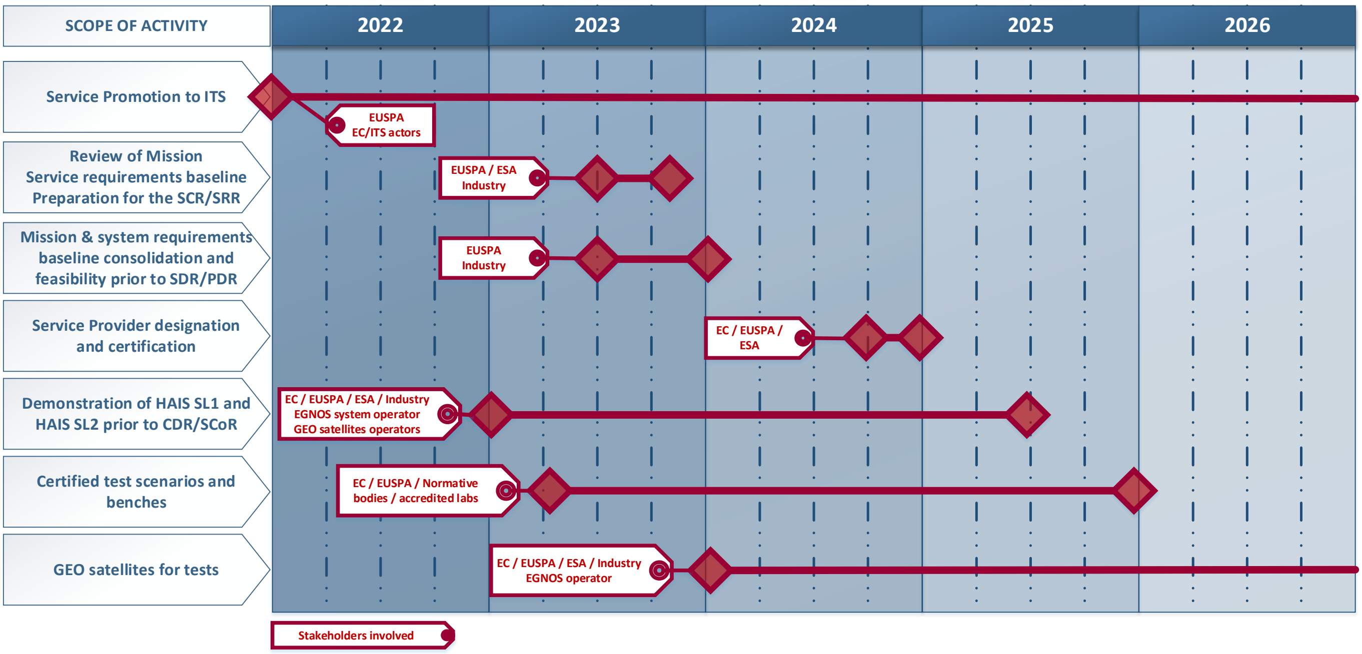

Figure 31 – EGNSS HAIS major activities timeline

The main actors of this roadmap were identified and their roles described in the D310 ([RD-6]), and recalled in Figure 32. The arrows define the types of relationship between the stakeholders, where SLA stands for Service Level Agreement.

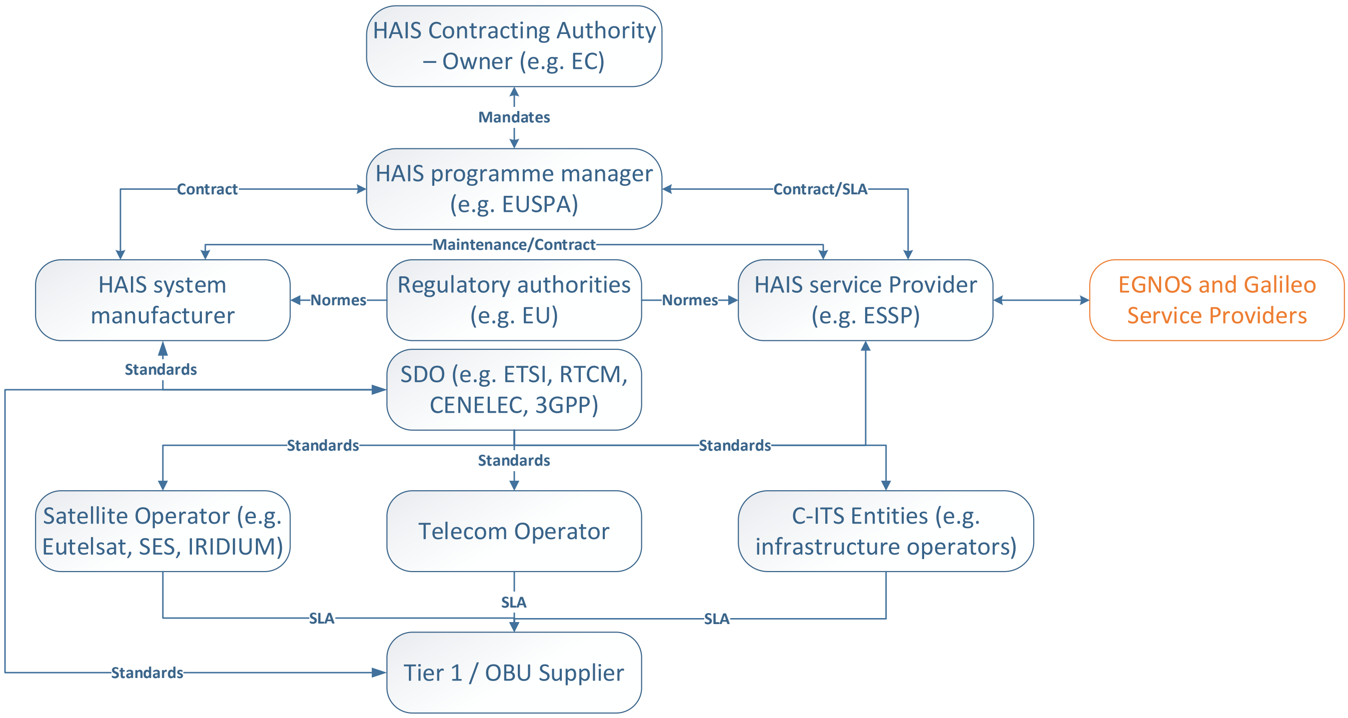

Figure 32 – Interactions between main service delivery actors

10. FOCUS ON CERTIFICATION AND STANDARDIZATION

In the frame of the ICHASE certification activities it is proposed to consider the overall OBU on one side and the HAIS on the other side as independent systems from a certification point of view. Rationales are the following:

- Complexity: each of these two systems namely OBU and HAIS infrastructure, are complex enough to not mix their specificity into a single huge system. Technologies behind are different and need to be separated in order to get simplified certification framework, that will be in definitive more easily applicable.

- Technology: OBU system is used inside downstream EGNSS context; HAIS infrastructure is used inside upstream context. This difference is relevant because these 2 worlds (downstream / upstream) don't address the same industries, engineering competencies and operators. This is important to correctly link the right stream to the right experts, industries and operator. For information, this is also the strategy proposed at ISO-TC20-SC14 (Space systems and operations).

- Monitoring: last but not least, monitoring of certification is different between OBU and HAIS service. If we can assume that an OBU will get its certification label once and for all, it may or may not be the case for HAIS service that would follow an EGNOS-like certification scheme (yet lighter in view of the allocated ASIL A and TIR levels). In all cases, the HAIS infrastructure will need a continuous monitoring of the data broadcasted by the system itself. That is to say, to keep its qualification for being used by the certified service provider, specific means will be deployed in order to monitor if data is still usable, accurate enough and finally usable by OBUs.

10.1. HAIS SERVICE CERTIFICATION

10.1.1. Need for HAIS certification

As shown in the proposed architecture for the ICHASE OBU in section 4.4, the High Precision GNSS based sensor is one the sensors to be used for the computation of the user final solution. IT is one of the basic sensors, but yet not the only one.

The Safety assessment carried out in the frame of ICHASE have led to the safety level targets to each of the components of the positioning OBU as in Figure 12 and Figure 24.

According to this Safety allocation, ASIL A is allocated to the GNSS (+HAIS) based sensor and a (Target Integrity risk of 5.10^{-3}/h) which are considered as the not highly constraining compared to current augmentation systems performances.

While these safety and integrity budgets induce lower constraints for the system and operations deployment, they imply the need for a certified HAIS SoL service.

Please recall that these ASIL and TIR allocations are dependent on the high level architecture that is proposed by ICHASE. The major assumptions on the architecture that have an impact on these budgets allocations are:

- The consistency check based architecture,
- Sensors fusion for each of the consistency check branches,
- and IMU being considered as fault free (owing to IMU redundancy as proposed).

All these assumptions were considered as valid by the consulted experts. The sensors used and their redundancy scheme may still be modified depending on each manufacturer, without major impact on the overall analysis.

10.1.2. Recall of Civil Aviation Certification and standardisation process

In the context of GNSS, and as long as Safety of Life applications are considered, a certification is the process where such service provision is certified to be compliant against existing standards and regulations. Accordingly, the certification process is completely correlated and dependent on the underlying standardization process.

Note that, more accurately, it is the service provider who is certified, not the service or the infrastructure itself (which is rather qualified with respect to the target performance and safety levels).

For Civil Aviation, the certification process is mandatory as per existing European Commission regulations (issued by the European Commission with a tight link with the EUROCAE working group namely).

The Civil Aviation certification process has two different objectives:

- Certification of the SBAS service provider as ANSP. This embeds in particular the verification of compliance with the international standards such as the SARPS (Standards And Recommended Practices), with SW and HW development standards, and with applicable regulations. The demonstration of compliance is done both at system design level (through a so-called Safety Case A), and at the operations level (through a so-called Safety Case B),

- Certification of the Civil Aviation Receiver in terms of compliance to the MOPS (Minimum Operational Performance Specification).

In Europe, the EASA (European Union Aviation Safety Agency) is the certification authority for both these activities. The certification file is held by the service operator, namely the ESSP (European Satellite Services Provider) in Europe for EGNOS.

The Safety Cases A and B are thus built by the service provider, however, so far, the system prime for the ground segment at least provided the needed evidence (Thales for the EGNOS V2 infrastructure for example). It shall also be mentioned that in some cases the EUSPA can mandate the system prime the responsibility to build the Safety Case A, holding on the compliance of the system design.

10.1.3. Potential certification process for the HAIS service at system level

The certification process of the HAIS service shall go through the following steps:

- Standardization of the HAIS service through the RTCM SC134 Working Group (for data formatting and content),

- Identify the set of standardized (and ideally certified) GNSS + HAIS related tests and data bases that would be used for service certification (standardized through ETSI / CEN TC5(Space) / ISO TC20(Space)),

- Endorsement of these standards by a Road Safety Agency. Today no such agency exists at the European level (nor at International level). This is rather managed at national level. The endorsement of the HAIS service standard for use in autonomous road applications shall be managed by a new European entity (like the ERA for rail, and EASA for Civil Aviation). This role may also be fulfilled by the EC DG MOVE, , as it is involved in the UNECE WG 29 technical activities.

- Provide accreditation to specific laboratories (through accreditation body like the COFRAC in France, the DAKKS in Germany), which in turn provide certification labels. Example of such laboratories are for example GUIDE, IDIADA, NAVCERT.

- Designation and certification of the HAIS service provider as done for the civil aviation use case, at both system and operations levels. It is anticipated that for the HAIS service, the service provider certification would be done, as for the civil aviation, on the basis of system and operations cases to be provided to the certification authority. As such, once the service provider is designated, he needs to follow and provide these evidences prior to starting the certification process, and before the system Qualification Review. For reference on this process, for example in EGNOS the time between the system QR and the Service Provider certification took about 2 years (2.5 years proposed here), and the time between the system QR and the service declaration was 3 years, 3.5 years proposed here, which is rather consistent with the scheme proposed for the HAIS.

10.2. AT USER LEVEL

The following major drivers are proposed for the ICHASE OBU certification and homologation scheme:

- A step by step process is probably the best option in order to cover of maximum of requirements: calibration of "self-sufficient" (or proprioceptive) sensors / GNSS receiver certification (thanks to test scenario) / PVT engine certification (Software in the Loop) / whole positioning system certification (Hardware in the Loop) / Real-world test drive (Vehicle in the Loop)

- Dealing with test scenario, it is important to clearly underline that they have to be designed and built following appropriate standards. And ideally the best option would be to find a way to certificate them. Allowing any laboratories or companies to build their own scenario without any standards is something to avoid; being one of the best way to be unfair.

- For automotive industry –specially autonomous or automated driving- UNECE is probably the major stakeholder to involve in. WP29 and its working group VMAD is already active on the topic of new test method for automated driving. A positive contribution could be to develop the GNSS part of NATM, which seems currently mainly address ADAS topics.

- With regard to labelling, at least two possibilities have been identified: type approval and self-certification. First one is based on regulation and has the higher level of requirement (because defined by law); this scheme is the one use in automotive industry. We could imagine a new partial acceptance for automated driving system which be part of a Whole Vehicle Type Approval (WVTA). Second one is self-certification; meaning that no additional tests (made by external actor) are required to prove the system is compliant to a standard. In that scheme, the label has to be adopted by the marked, and thus has to prove its relevance.

Please note that labelling a certification process or a type approval process is just a way to illustrate / show easily that the process is successful, thus avoiding to get / to read the formal document (certificate or tests report).

Figure 33 – Three pillars needed for ADAS type approval scheme according to TUV and dSPACE in order to cover requirements of UNECE R157[2].

[2] Source: https://www.tuvsud.com/en-gb/resource-centre/white-papers/virtual-homologation-of-an-alks-according-to-unece-r157

In summary, the next summarizes certification and type approval activities flow at OBU level.

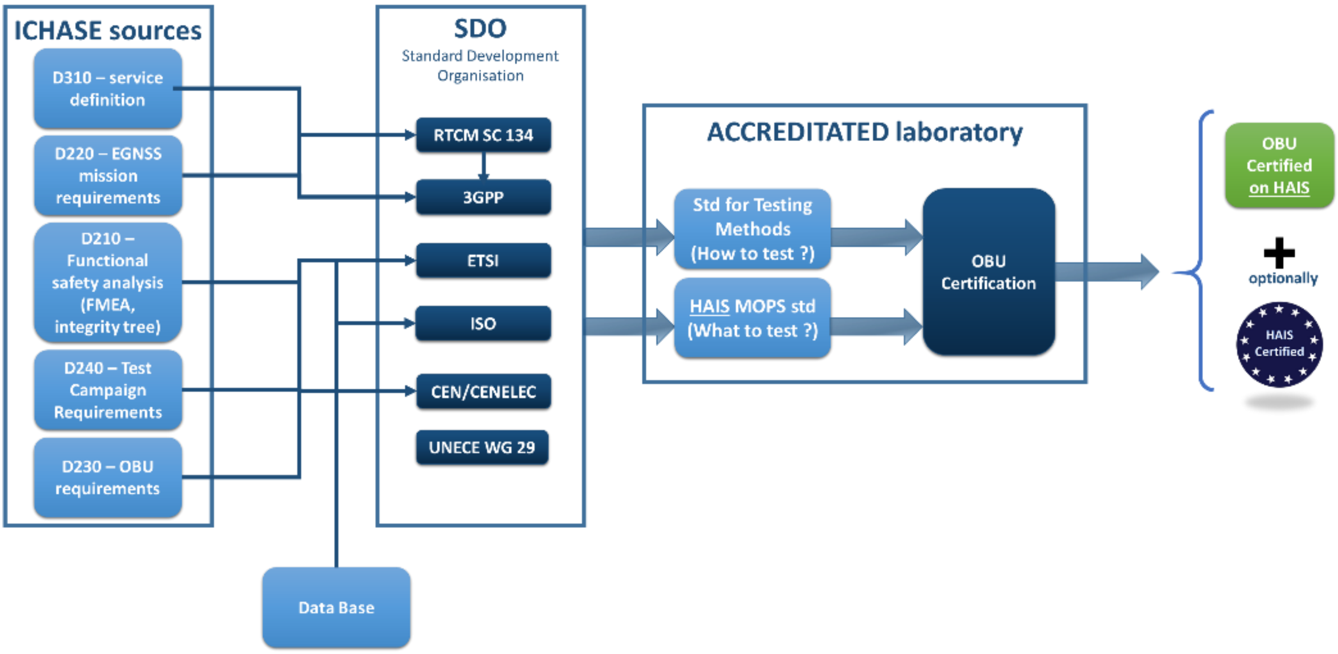

Figure 34 – OBU certification activities flow

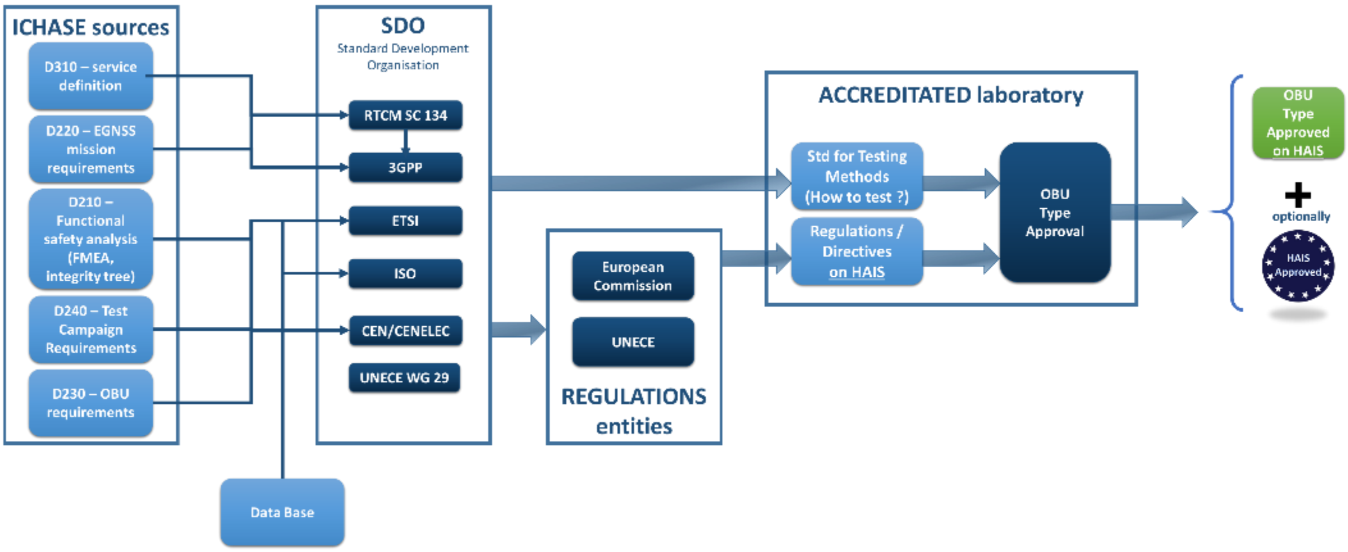

Figure 35 – OBU type approval activities flow

The OBU certification activities analysed so far are referred to as "OBU self certified", and "OBU Type Approved for AD level 4" in the roadmap provided in Figure 30.

10.3. LIABILITIES

10.3.1. Stakeholders implied in liability scheme

As already above, and recalled here, in order to define the liability of different actors of the service provision scheme, it is important to determine the main causes of a faulty or not reliable navigation solution at the OBU (user) level. In the integrity concept at user level defined in D210 [RD-2], the GNSS and the PPP corrections are one of the systems to be used by the OBU to compute a precise and reliable navigation solution. Even though the GNSS measurements are fused with other measurements from other sensors, the GNSS plays a key role in this integrity concept. Therefore, the performance of the navigation solution of the OBU depends directly on the GNSS measurements and their quality.

As illustrated in the , errors on the GNSS measurements could be classified into global, regional and local. The global errors such as orbits and clock errors should be guaranteed by the service via the corrections and the associated integrity data. The same goes for the regional effects (e.g. ionosphere) which are guaranteed by the service (SL2) by providing the corrections and integrity data. The local errors such multipath, NLOS and interference should be mitigated at the user level and could not be guaranteed by the integrity service.

Therefore, the main problems that may occur at the OBU and could not be mitigated at the user level are the unavailability of the integrity service and the non-integrity of the data provided by the service.

If the service is not available, the corrections data of HAIS could not be verified and the GNSS measurements could not be used by the OBU to compute a navigation solution. Due to the fusion of data from different sensors, this problem could be overcome for short period of times. However, a long outage of the integrity service may cause the unavailability of the navigation solution of the OBU.

On the other hand, a problem of integrity on the data provided by the service may cause lead to erroneous position estimation where the OBU will use the GNSS measurements and the integrity service supposing that they are reliable.

Accordingly, at least the following liabilities should be attributed for the following actors:

- European Union, as the owner of the EGNOS and Galileo systems,
- EUSPA as the EGNOS and Galileo Programme manager,
- HAIS System manufacturer, as it guarantees the development of the system following the applicable rules and standards. The developed system should meet the requirements in terms of availability of the service, ASIL, security and latency,
- HAIS Service provider as it guarantees the performance of the service by monitoring the signal and the provided data. It is responsible of alerting the user about any integrity flag in less than TTA seconds.

- Tier 1 / OBU supplier as they are responsible of the different equipment (e.g. antennas, GNSS receiver HW/SW, 5G receiver) at the user level that will be used to receive, decode and integrate the integrity data provided by the HAIS. These suppliers are then liable for the usage of applicable standards and rules in the development of these equipment. They are as well liable for the certification of these equipment prior to their usage by the end user. Tier 1 / OBU supplier are then responsible for the proper use of the integrity data following the conditions and rules defined by the HAIS.

- Non-GNSS dissemination networks operators (telecom, C-ITS, satellite): Each dissemination mean operator shall ensure the performance of the service and guarantee the compliance of their infrastructures with the defined requirements. This means that the service provider should be able to provide the data with the required performance to the dissemination means operators.

One main question shall be raised here: Would the HAIS service provider be liable for the service performance up to the user level, including the liability to guarantee these performances to the non-GNSS means, or would this liability be bounded to the GNSS space based dissemination means, and to the output of the GNSS server providing these corrections ?

Indeed, liability for service performance can be up to user level as long as user equipment including non GNSS means complies to a MOPS (Minimum Operation and Performance Specifications). However for HAIS, the number of applications can be huge and it will not be pragmatic to impose a one for all single solution through a MOPS. A liability bounded to the output of the GNSS server and dissemination means will likely ease the system adoption.

The answer to this question shall be done at two main levels:

– The feasibility of having a telecom operator committing on a Service Level Agreement for the provision of HAIS data (here the focus is put on the commitment from telecom 5G network operators namely). This feasibility is a must in all cases. Such commitment is discussed in the next section.

– New business models that can be created for the provision of such HAIS service.

10.3.2. Commitment of telecom 5G network

First please recall that the 3GPP first develops and maintains global technical specifications with the objective to make sure that network equipment and handset manufacturers can develop products that are interoperable all over the world. To do so, the process is split into 5 steps as illustrated in Figure 36 and explained in [RD-15].

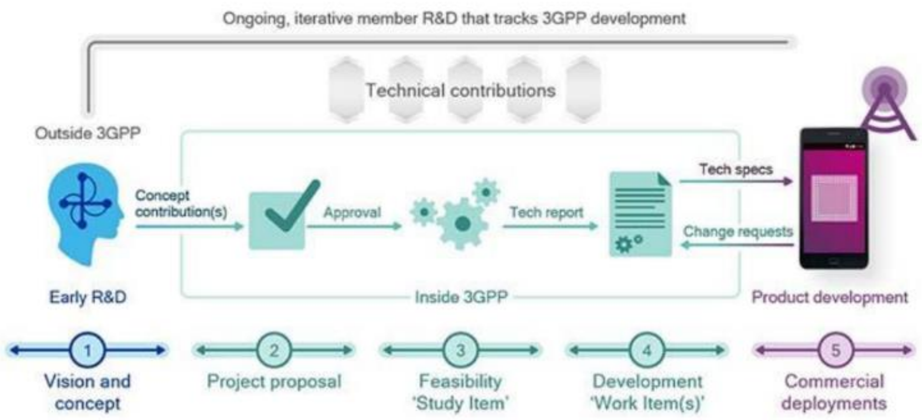

Figure 36 – 3GPP 5G working procedures and processes – [RD-15]

These 3GPP proposals are then standardized for example by the European Telecommunications Standards Institute (ETSI) TC-ITS European standards and the 1609 Wireless Access in Vehicular Environment (WAVE) protocol in the U.S.

Then, in terms of liability, the question is who is responsible for the service quality? Who is responsible for the correct delivery in terms of latency, availability, coverage, etc? For all solutions envisioned for the HAIS service, the only responsible is the network operator.

The service is defined by a specific QoS profile and the network operator is compelled to provide it to the user with the required QoS. This is continuously monitored by the Policy Control Function.

Regarding the coverage aspect, note that with Release 17, both Terrestrial Network (TN) and Non Terrestrial Network (NTN) are fully defined.

Therefore, the network operator is free to use either terrestrial base stations or satellites to ensure the required QoS.

This means that the quality of the data dissemination through telecommunication networks is already foreseen to be monitored and committed on by the telecom operator.

10.3.3. New business models

Experts have expressed their concern about possible impact on private commercial providers generating barriers/obstacles for the commercial exploitation of HAIS, although it was noted that a possible point of strength could be in having/offering multiple solutions in order to ensure redundancy and resilience.

Experts expressed the fact that investments into commercial services are endangered and finally it is risked that existing business will be lost with a free of charge HAIS service (co-existence unlikely without differentiation of services).

In an answer to these concerns, new business models can be found for such companies

- The EU would “buy” a data flow from existing private companies running highly reliable network of PPP stations,

- These private companies would mainly focus on the user segment algorithms differentiators making use of the HAIS corrections,

- The telecom operators may put in place collaborations with existing private PPP providers in order to propose end to end guaranteed solutions to the users. The cost of the final solution shall be compatible with the mass-market (yet safety critical) nature of the Autonomous Driving applications.

10.3.4. Conclusion on the HAIS liability scheme

The final liability scheme of the HAIS service is divided between the European Union, the EUSPA, the system manufacturer, the service provider, the Tier 1 positioning module provider, and the non-GNSS dissemination network operator.

In what follows, a proposition for a wording of a liability scheme for the HAIS provision for road applications is provided.

10.3.4.1. SCOPE OF THE HAIS SAFETY OF LIFE SERVICE

The HAIS comprises the provision of an augmentation signal to the GPS Standard Positioning Service (SPS) and the Galileo Service Definition Document and subject to the service limitations described in the HAIS Service Definition Document to be drafted (D310 [RD-6] provides inputs for such SDD).

Only minimum performance characteristics are included in the commitment even though the users can usually experience a better performance. These characteristics will be expressed in statistical values under given assumptions (open sky conditions for example).

Currently, the nominal HAIS performances are listed in Table 8 (from D220 [RD-3]). The minimum required performances are derived from this table, being either the same values or slightly degraded with respect to this table to take into account a margin of uncertainty in the different budgets.

10.3.4.2. WHO CAN USE THE HAIS SERVICE

The main target end users of the HAIS are the cars embedded positioning modules. Intermediate users can be non-GNSS dissemination networks operators.

Definition of other non-road related users shall be done also for other transport applications.

In general, the HAIS SoL Service is intended for road transport applications where lives could be endangered if the performance of the navigation system is degraded below specific accuracy limits without giving notice in the specified time to alert. This requires that the relevant authority of the road transport domain determines specific requirements for the navigation service based on the needs of that domain, as well as certification procedures if necessary. In addition, the navigation operations based on the HAIS SoL Service may require a specific authorisation, issued by the relevant authority, or the authority, or applicable regulation, may establish that no such authorisation is required.

HAIS (SL2) SoL signal covers the European territories.

The HAIS SL2 SoL signal is provided for SAE Autonomous Driving Level 4 and Level 5 applications, assuming that

- The use of the HAIS SoL service is done within the conditions and limitations of use set forth in the HAIS SoL SDD,
- The user equipment is compliant with the Minimum Operational Performance Requirements (To be consolidated based on D230 requirements),
- The user equipment is certified or approved by the relevant authority,
- The user equipment does not encounter local malfunctioning issues,
- The user is not authorised to use the HAIS service,

No case of Force Majeure event has occurred.

11. MAIN CHALLENGES AND RECOMMENDATIONS

11.1. USER NEEDS

Starting from the user needs, while requirements related to the position: Accuracy, Alert Limit, Time To Alarm, Integrity Risk, duration of operations (set to one hour), and Time To First Precise Fix, are considered as consolidated by the ICHASE project, those on **the velocity and the heading are still to be consolidated**. This consolidation shall mainly **focus on the Key Performance Indicators related to the End to End integrity concept** (Target Integrity Risk, Alert Limit), **and to the continuity and availability** requirements.

11.2. INTEGRITY CONCEPT

The proposed integrity concept is based on some hypotheses that remain to be challenged and **promising solutions that remain to be tested**. Propositions for a validation strategy were provided though.

A first validation of these results was performed in the frame of the ICHASE project, through experts consultations. While this consultation has allowed for closing some trade-offs, and validate many of the hypotheses taken for this End to End integrity concept, some remaining points are still open as listed below:

Topics	Open points
Pre-Processing methods	○ To consolidate the improvement brought by: • the multi correlator techniques • The multi antenna techniques • The multi constellation / multi frequency improvements ○ To characterize the IMU FDE performances, and identify / design new FDE methods for the other sensors.
Error Characterization Approaches	○ To benchmark different characterisation approaches to determine which one is best suited, or propose a hybrid modelling of these residual errors: • Student T • Gaussian
Measurement Rejection Approaches	○ To benchmark the Solution Separation and Majority voting architectures in order to gain maturity on each of them, ○ To quantify the improvement brought by the KFMI.
Hybridization	○ To test the improvement in terms of availability brought by the PPP with respect to GNSS only, in urban environments where phase measurements continuity may be at stake, ○ To evaluate through real tests the performance of the system in terms of several KPIs (Availability, Integrity, Accuracy, Continuity and others) ○ To test how long the system can fulfil the requirements in different operational scenarios and in particular during a GNSS outage and in urban environment, ○ To determine how the hybridization can help in the PPP convergence/reconvergence time, in both floating ambiguity and integer ambiguity resolution cases.

Table 15 – Integrity concept – open points

A major point raised with no clear answer so far is how would maps based positioning concept be used for such Safety of Life applications? To our knowledge, and based on discussions with many experts, **no such integrity compatible maps concept exist yet**.

11.3. SERVICE DEFINITION

Concerning the service definition, additional room for improvement apply to the simulation results in order to ensure that the service performance requirements on orbits and clocks accuracy (at 95%) could be met with the proposed network of stations. Indeed, the preliminary results showed that these performance requirements are not achieved at 95%. The simulations done in the frame of this task consider only 24 Galileo as a conservative configuration, but in practice there would also be the GPS constellation, adding more observability and helping improve the accuracy. The estimation algorithms themselves can also be further refined and tuned.

The ionospheric delays modelling and dissemination propositions, based on a two-layer grid of Ionospheric Grid Points has to be further consolidated. For the tropospheric corrections, the ESA blind model will be implemented at user level, and accordingly the service does not broadcast tropospheric corrections.

Concerning the HAIS data authentication, the trade-off is between :

1. bringing the maximum protection against threats,

2. reducing the impacts of the authentication schemes regarding the HAIS service provision,

3. reducing the impacts of the authentication scheme on the latency (Authenticate and use or Use and Authenticate schemes), available bandwidth, Time To First Precise Authenticated Fix,

4. reducing the impacts of the authentication schemes at the system level (namely EGNOS infrastructure),

5. reducing the impacts at the user level in terms of implementation complexity and performance,

6. and providing a long term protection (at least several years).

Finally, the use of LEO constellations for the service dissemination needs to be further assessed. In this context, a particular attention should be paid to the visibility of LEO satellites to verify that at least 2 satellites are visible at any time. This would ensure a redundancy in the system and enhance the safety aspects.

11.4. CERTIFICATION ROADMAP

The service level certification roadmap has to be further consolidated. The following questions are still open:

- Who would finally be the service certification authority for the road sector ? Would current National level Notify Bodies be responsible for the service certification as well ?

- Who would manage the service provision, namely when considering different applications for this service ?

Recalling that the certification process itself applies to the service operator, synergies with other applications shall be further consolidated.

A major open question for the final certification of the OBU is the process that shall apply to the underlying maps. So far, no known integrity related process are applied by maps providers.

12. NEXT STEPS

It is recommended to start launching the following activities as first steps.

12.1. MISSION AND SERVICE CONCEPT DEFINITION OPEN POINTS

Velocity user requirements and more globally dedicated safety assessment and integrity concept are very relevant especially that regulations are starting to be in place on this subject (regulation on ISA for example). For user requirements, a wider round of car manufacturers consultation shall be held, and for the safety assessment and integrity concept collaboration with laboratories carrying on extensive testing campaigns shall be held in order to derive the residual error modelling.

12.2. STANDARDISATION ACTIVITIES

Several standardization activities can be identified:

- Activities to push the HAIS service definition through the 3GPP standards,

Assuming that the HAIS would be broadcasted thanks to posSIB as described the D510 ([RD-8]), it is required to push this proposal to 3GPP. This requires to build a case with deep analysis. This require times and for the time being, this would apply to Release 18 since previous one are already freeze.

- Activities to push the defined HAIS service through the RTCM SC134 working group,
- Activities to push the minimum operational requirements (as per D230) through the ETSI (for example TCSES / SCN, as was done for GBLS) standard,

12.3. REGULATION ACTIVITIES

Apart from standardization there are also regulation activities

- Push towards normalisation of the use of HAIS service for Autonomous Driving OBUs, through the UNECE for example,

As with any regulation or certification entities, to push new standards it is required to build a case with performances analysis, and impact analysis. This case has to be presented and discussed in session to be or not adopted by the regulation entities.

- Raise the need to the European Parliament to issue mandate for the use of HAIS for road OBUs,

12.4. Certification activities

- Launch a study to analyse synergies between different applications, mainly in terms of allocation of the user needs to the HAIS service. This was done for the rail and maritime domains, but it needs to be completed for other transport domains like drones. Complete the safety analysis for cross transport domains to allocate the TIR and ASIL / SIL / DAL levels needed at the system level depending on the target application.

- Define standardised and certified data base and tests procedures, that shall allow qualification of a GNSS + HAIS based OBU.

- Work on a certification of the HAIS for Level 3 autonomous vehicle to increase the number of possible users and use cases.

12.5. System infrastructure

- Demonstration activities: To broadcast the HAIS and to study its performances at user level, testing activities have been proposed in D510 ([RD-8]). It is a step by step testing activity that nevertheless requires the definition of a precise test plan to use optimally the required resources and to have access to them at the required time.

- Studies on the evolutions that apply to the EGNOS infrastructure, namely coupling with EGNOS NLES. This essentially applies to the service dissemination through the EGNOS GEO infrastructure, where the GEO RF station and Payload would be shared with those of the EGNOS civil aviation signal. This needs the implementation of a coupling scheme between both signals

END OF DOCUMENT