ERJU SYSTEM PILLAR

System architecture description - Basic ASTP

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1 Management Summary

In the STIP, which outlines the System Pillar's plan for the evolution of the CCS system, Advanced Safe Train Positioning (ASTP) is proposed to be introduced in two steps with basic ASTP (STIP_29) in the timeframe of TSI CCS 2027 and full ASTP (STIP_30) in the timeframe of TSI CCS 2032. This document describes different architecture variants for the introduction of basic and full ASTP. Based on a technical and economic evaluation a conclusion is drawn and the way forward to the upcoming TSI CCS is outlined.

The technical and economic evaluation both concluded that **it is not beneficial to introduce a new ASTP interoperability constituent (IC) with the next TSI CCS** release expected in 2027. A clear added value from a technical or economic standpoint would be necessary to justify the increase in solution complexity. This means that the arguments in favor of a separate ASTP IC must significantly outweigh those against. No decisions have been made concerning subsequent stages.

As in the preferred variant there is no separate constituent ASTP with the next TSI CCS release, it could be misleading to continue to name the first migration step Basic ASTP. We propose to **rename the first migration step "odometry enhancement"** with the following scope: odometry performance enhancement, odometry robustness specification and odometry output interface.

One of the most awaited features of the ASTP is a **single source of localisation for all CCS-OB users**. This feature shall be introduced with the next TSI CCS release by defining an **output interface for applications outside the ETCS On-board using localisation and balise information**. The specification of such an odometry and balise output interface could ease the implementation of a potentially separated ASTP interoperability constituent in a subsequent step after the next TSI CCS release.

2 Preamble

2.1 Scope and Purpose

In the STIP, ASTP is proposed to be introduced in two steps with basic ASTP (STIP_29) in the timeframe of TSI CCS 2027 and full ASTP (STIP_30) in the timeframe of TSI CCS 2032.

The document starts by presenting background concepts, which are important for the discussion, namely the definition of interoperability constituents and the concept of grouping as defined in the TSI and the Ethernet CCS Consist Network (CCN) which is introduced in the current TSI CCS 2023 and intended to be updated in the next version of the TSI CCS (STIP_68).
The document then presents six architecture variants for the basic ASTP step and how they will migrate to full ASTP.

Based on a technical and economic evaluation a conclusion is drawn and the way forward to the upcoming TSI CCS is outlined.

2.2 References

SPT2TRAIN-8225 - Technical Assessment ASTP

SPT2TRAIN-8222 - Blue Arches, "Economic Analysis - ASTP", 2024-12-10.

SPT2TRAIN-6792 - Blue Arches, "ASTP CBA", 2025-07.

SPT2TRAIN-6789 - R2DATO WP23, "D23.4 – Proposal on TSI202x, SS147 Release 03," 2025-02-01

SPT2TRAIN-6790 - R2DATO WP21, "D21.1 - Operational needs and system capabilities of an ASTP system (Use Cases), Revision 6," 2024-12-11

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SPT2TRAIN-6791 - R2DATO WP21, "D21.2 – System requirements of ASTP system, Revision 6," 2024-11-26.

SPT2TRAIN-6920 - Granularity Principles Application for ASTP

2.3 Glossary

ASTP	Advanced Safe Train Positioning
ATO	Automatic Train Operation
BTM	Balise Transmission Module
CBA	Cost Benefit Analysis
CCN	CCS Consist Network
CCS	Control Command and Signalling
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
EU	European Union
EUG	ERTMS Users Group
FFFIS	Form Fit Functional Interface Specification
GNSS	Global Navigation Satellite System
HTTPS	Hypertext Transfer Protocol Secure
IP	Innovation Pillar
IC	Interoperability Constituent
LRBG	Last relevant Balise Group
LTM	Loop Transmission Module
MD	Message Data
OB	Onboard
OMS	Online Monitoring System
OSI	Open Systems Interconnection
PD	Process Data
RPC	Remote Procedure Call
RU	Railway Undertaking
R2DATO	Rail to Digital Automated Train Operation (Name of Focus Project Nr. 2 of Innovation Pillar)

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SP	System Pillar
STIP	Standardisation and TSI Input Plan
TRDP	Train Real-Time Protocol
TSI	Technical Specification for Interoperability
WP	Work Package

Table 1 Glossary

3 Introduction

3.1 IC and grouping of IC

3.1.1 Definition of IC and grouping of IC

Interoperable Constituent is a key concept of the TSI. The concept and key definitions are available in § 5 of the COMMISSION IMPLEMENTING REGULATION (EU) 2023/1695 of 10 August 2023 available online:

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R1695&qid=1694158367331

3.1.2 Definition of Interoperability Constituents:

5. INTEROPERABILITY CONSTITUENTS

5.1. Definition

In accordance with Article 2(7) of Directive (EU) 2016/797, interoperability constituents means any elementary component, group of components, subassembly or complete assembly of equipment incorporated or intended to be incorporated into a subsystem, upon which the interoperability of the rail system depends directly or indirectly, including both tangible objects and intangible objects.

Figure 1 TSI 2023 extract, chapter 5

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3.1.3 Grouping of Interoperability Constituents

5.2.2. *Grouping of interoperability constituents*

5.2.2.1. The functions of basic interoperability constituents may be combined to form a group. This group is then defined by those functions and by its remaining external interfaces. If a group is formed in this way, it shall be considered as an interoperability constituent.

Compliance of interfaces internal to the group of Interoperability Constituents to basic parameters of Chapter 4 does not have to be verified. Compliance of interfaces external to the group of Interoperability Constituents has to be verified to demonstrate conformity with the basic parameters related to the requirements of these external interfaces.

5.2.2.2. When interoperability constituents are grouped, the grouped functions and their addressing must be configurable in such a way that the grouped functions of the ATO, ETCS and the radio ICs can be replaced during the life cycle of the CCS subsystem by an external ATO, ETCS or Radio ICs. Therefore, the following interfaces in a grouped Interoperability Constituent shall be made externally accessible on the CCS Consist network communication layers as specified in Appendix A, Table A 1, 4.2.6 i:

(1) Interface between ATO On-Board and ETCS On-Board as specified in Appendix A, Table A 1, 4.2.6 h;

(2) Interface between ATO On-Board and GSM-R data radio On-Board as specified in Appendix A, Table A 1, 4.2.6 j;

(3) Interface between On-board FRMCS and the CCS applications (ETCS in Appendix A, Table A 1, 4.2.6 g and ATO in Appendix A, Table A 1, 4.2.6 k);

Figure 2 TSI 2023 extract, chapter 5.2.2

3.1.4 Odometry equipment Interoperability Constituent

TSI 2023 and former versions already define an IC related to odometry named as "odometry equipment"

5.3. Constituents' performance and specifications

For each basic interoperability constituent or group of interoperability constituents, the tables in Chapter 5 describe:

(1) in column 3, the functions and interfaces. Note that some interoperability constituents have functions and/or interfaces that are optional;

(2) in column 4, the mandatory specifications for the conformity assessment of each function or interface (where applicable) by reference to the relevant section of Chapter 4

Figure 3 TSI 2023 extract, chapter 5.3

Odometry equipment	Reliability, Availability, Maintainability, Safety (RAMS): Safety Availability/Reliability Maintainability	4.2.1.1 4.2.1.2 4.2.20.1
	On-board ETCS functionality: only Odometry	4.2.2
	Construction of equipment	4.2.16

Figure 4 TSI 2023 extract, chapter 5.3, table 5.1

3.1.5 Odometry equipment Interoperability Constituent interface

The interface between this odometry equipment IC and other ICs is not defined today and is, therefore, supplier-specific.

3.2 Previous initiatives

It is interesting to highlight the fact that the modular approach that is described in this document was already considered in the first initiative to develop ETCS. In the following subchapters, several former documents are presented.

3.2.1 Previous definition of a "modular" architecture centred around an "ETCS Bus"

Older initiatives proposed a modular system approach, which can be found in the UIC ETCS SRS version 3.01 (A5499J-03.01-960809), and looked as follows:

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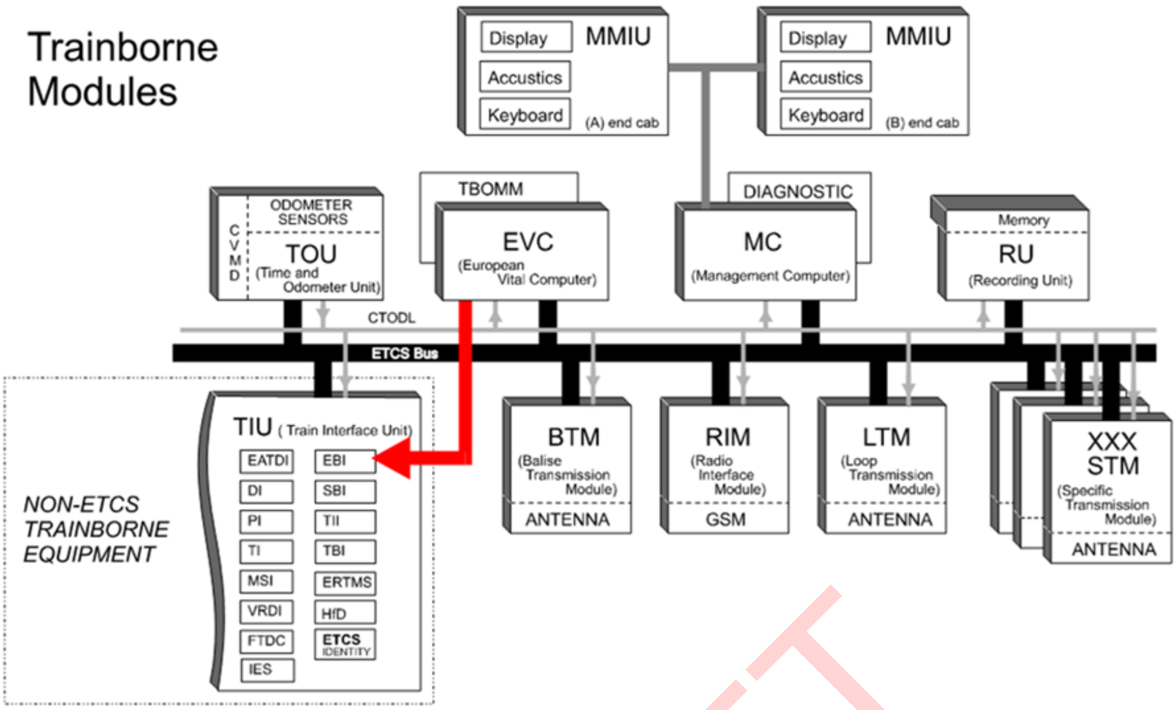

Figure 5 Extract from UIC ETCS SRS version 3.01 (A5499J-03.01-960809)

The ETCS Bus represents the backbone of the modular approach as it is foreseen with the Ethernet CCS Consist Network with the TSI CCS 2023.

3.2.2 Previous definition of an ODOMETER FFFIS

An attempt to define an ODOMETER FFFIS ended with the delivery of a document which was not embedded in the mandatory but informal part of the TSI until B3 R2:

https://www.era.europa.eu/system/files/2022-11/index004_-_97e2675_v5.pdf

3.3 Ethernet CCS Consist Network

3.3.1 Introduction

Today many interfaces between different CCS components on the vehicle are proprietary. The existing proprietary interfaces do not allow to easily add new functions impeding innovation. Based on this motivation, a standard for the communication technology on all OSI-Layers is being established to improve modularity, exchangeability and evolvability. Today, the SUBSET-147 v1.0.0 defines a standard communication solution on OSI-Layers 1 & 2 for some interfaces on new vehicles. The update of the existing SUBSET-147 to a new release version 2.0.0 will also define the OSI-Layers 3 to 6 and the safety layer unambiguously. Together with the application layer specifications in other SUBSETs (e.g. SS-119 for the interface between ETCS and TCMS) a full standard communication stack is created. IP R2DATO WP23 established a proposal for this update (see SPT2TRAIN-6789)

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The communication stack proposed for SS-147 v2 in SPT2TRAIN-6789 is briefly summarised here:

- Low layers (OSI layers 1-3): Ethernet communication over CAT-6 or higher cables. Separation and priorisation of data streams as well as segmentation of the network is based on VLANs. Addressing is done over IPv4.
- Middle layers (OSI layers 4-6): The middle layers are divided into different communication types and specified according to communication type:
- Process Data Communication: For process data communication the Train Real-Time Data Protocol (TRDP) Process Data (PD) are used together with safety protocols SDTv2 and SDTv4 where needed. TRDP PD supports multicasting.
- Event-based Communication: Event-based communication is based on the Advanced Message Queuing Protocol (AMQP), a broker-based system. Alternatively, TRDP message data (MD) may be used for event communication during a transition phase.
- Remote Procedure Calls (RPC): RPC communication shall use HTTP over TCP or TLS (HTTPS) depending on the security needs.
- Bulk Data Communication: Bulk data communication shall use HTTP over TCP or TLS depending on the security needs. The endpoints shall implement the bulk data transfer services in a RESTful designed API.
- Audio & Video Streaming: For the transfer of streaming data several streaming protocols are proposed such as RTSP, RTP, SRTP or RTCP.

The standardised communication stack shall be used for the on-board CCS communication, on the interfaces internal to the CCS subsystem, among different applications (e.g. ETCS on-board, ATO on-board) and on the interfaces to the subsystem rolling stock. It will thus also apply to the communication between the ASTP and its consumers, notably the ETCS on-board. To complete the communication stack for the ASTP to ETCS on-board communication, an application layer specification will be needed. This should be done through the ASTP – ETCS on-board FFFIS interface.

For the lower layers (OSI Layers 1-6) an Ethernet-based communication using TRDP is foreseen, as the communication between ASTP and the ETCS on-board is process data. For safety-related packets, SDTv2/v4 will be used as safety layer.
The specification of the Ethernet CCS Consist Network is already part of the current TSI 2023 and will provide a mature solution with the next TSI. It is thus relevant to take it into account when discussing the interface of ASTP.

In the following table the protocol stack for process data based on SPT2TRAIN-6789 is shown. The physical and the data link layers are already specified in SS-147 v1.0.0 as part of TSI 2023:

Layer	Protocol	Standard
(Safety Layer)	(SDTv2/v4)	IEC 61375-2-3
Session Layer	TRDP Process Data	IEC 61375-2-3
Transport Layer	UDP	RFC 768
Network Layer	IPv4	RFC 791
Data Link Layer	Standard Ethernet with QoS	IEEE 802.3 IEEE 802.1Q
Physical Layer	1000BASE-T (optionally 100BASE-TX for end devices)	IEEE 802.3 Clause 40 IEEE 802.3 Clause 25

Table 2 Protocol Stack Process Data based on SPT2TRAIN-6789, Safety Layer is only applicable for safety-related data traffic

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3.3.2 Data-driven approach with Multicast Process Data (Pub/Sub)

The Ethernet CCS Consist Network was specified with modern modular architectures in mind. It supports multicast schemes such as Pub/Sub for the process data exchanges between different modules. In a multicast communication, the source of the data (for instance localisation data) publishes the data to a defined multicast address. The consumers of the data can subscribe to the multicast address to receive the data. In this way, one interface can be used to simultaneously distribute the information to multiple consumers. Moreover, the source of the data (e.g. ASTP) publishes the data in the same way regardless of the number and type of consumers.

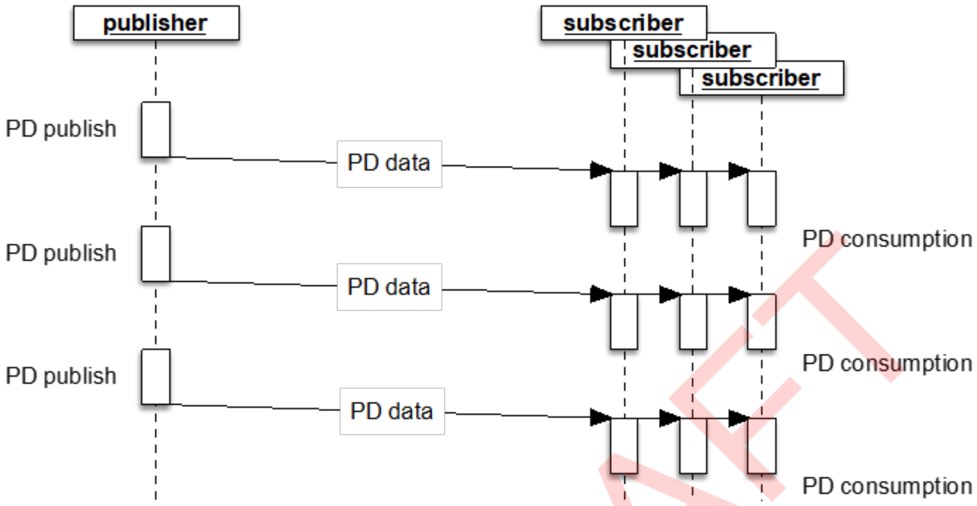

Figure 6 Communication Pattern TRDP PD Push with Multicast

This supports a data-driven approach, where one well-defined interface is specified for the odometry data, that the ASTP uses to distribute the data to all possible consumers. A data-driven approach allows for the evolvability of the ETCS on-board as well as functionalities such as ATO or the upgrade from basic ASTP to full ASTP.

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3.4 Application Layer Interface ASTP

3.4.1 Introduction

The application layer interface for ASTP completes, together with the Ethernet CCS Consist Network, the specification of ASTP communication. The interface will also be called ASTP FFFIS. The main part of the interface definition will be to define standard datasets to be exchanged between the ASTP and ETCS on-board as well as other subsystems. Moreover, to facilitate the evolvability of the different subsystems considered, the interface should be defined in such a way that several consumers can access the data from ASTP over a multicast process of the Ethernet CCS Consist Network (see also section 3.3.2).

In order for the upgrade to full ASTP not to imply major modification of the CCS system, it is important that the datasets defined in the interface description are identical for basic ASTP and full ASTP.

3.4.2 Definition of datasets for ASTP

The definition of datasets for basic ASTP and full ASTP is possible within the horizon of the basic ASTP. Indeed, most of the information which is needed by ETCS on-board or provided today by ETCS to other consumers is known. The need for the odometry data of ETCS on-board is given in SUBSET 026. The interface ETCS – STM (as defined in SUBSET-035 and SUBSET-058) includes odometry data as part of the data transmitted to the STM and the interface ETCS – ATO (as defined in SUBSET-130) includes the odometry data transmitted to the ATO system. SUBSET-130 also includes data related to physical balises which is a first step to define the balise telegram interface.

Moreover, WP21 already defined a proposal concerning the output datasets of ASTP (see SPT2TRAIN-6790 and SPT2TRAIN-6791). Even though this proposal is subject to evolution, it gives a certain number of datasets that already consider full ASTP.

4 Functional analysis

In chapter 5 - Architecture Variants ASTP there are the main components ASTP, ETCS-OB and BTM shown and grouped to different options of interoperbility constituents. In this chapter the main functions of the components ASTP, ETCS-OB and BTM are described on a high level in order to give a short overview of the components. This is done by listing up the input and output information of the components. The component ASTP for the basic ASTP scenario mainly contains a current odometry system. Therefore, ASTP can be read as synonym of odometry in the basic ASTP scenario. The defined input and output information shown here is a possible example. The detailes are to be clarified as part of the ASTP FFFIS specification once the target architecture is defined.

4.1 ASTP Functions

ASTP is delivering safe 1D position and speed as well as accelleration. It follows the localisation-related logic needs of the current ETCS specification SUBSET-026 regarding the determination of the longitudinal train front end position along the route, regardless of the complexity of the track layout. Data property terms used in this functions are illustrated in the following figure.

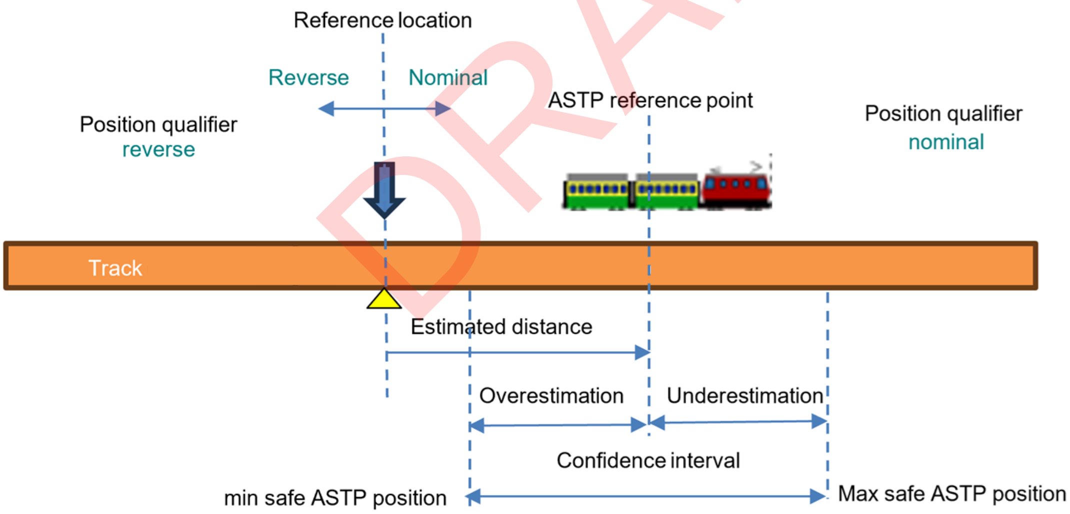

Figure 7 Provide safe ASTP Safe 1D Position

The outputs are mainly derived from internal sensor information but also additional information from ETCS-OB and BTM. From ETCS the last relevant balise group (LRBG) to be able to distribute the position according to it as well as active cab to determine the train front end is needed. From BTM the time information when a balise was passed is needed. The information is shown in more detail in the tables in the follwing subchapters.

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4.1.1 Outputs

4.1.1.1 Static

Output	Description	Remark
Reference Point to End 1	Distance from reference point to consist end 1	
Reference Point to End 2	Distance from reference point to consist end 2	

Table 3 Static ASTP Output

4.1.1.2 Dynamic

4.1.1.2.1 Safe 1D Position

Output	Description	Remark
Estimated Distance LRBG to ref point	Estimated distance from LRBG to reference point	
Estimated Distance LRBG to train front end	Estimated distance from LRBG to train front end	Depends on allocation of transformation from reference point to train front end
Position Qualifier	Position in nominal or reverese side of the balise group	
LRBG ID	Last relevant balise group ID	
Overestimation	Estimated overreading distance	
Underestimation	Estimated unterreading distance	

Table 4 Dynamic ASTP Output of Safe 1D Position

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4.1.1.2.2 Safe travelled Distance since Power-on

Output	Description	Remark
Estimated Distance	Estimated travelled distance since power on	
Overestimation Distance	Estimated overreading distance	
Underestimation Distance	Estimated unterreading distance	

Table 5 Dynamic ASTP Output Safe travelled Distance from Power-on

4.1.1.2.3 Safe Speed

Output	Description	Remark
Movement Direction	Direction of the movement in relation to reference frame	
Estimated Speed	Estimated speed value (1D) of the vehicle	

Overestimation Speed	Safe lower bound of the speed of the vehicle	
Underestimation Speed	Safe upper bound of the speed of the vehicle	

Table 6 Dynamic ASTP Output Safe Speed

4.1.1.2.4 Accelleration

Output	Description	Remark
Estimated Acceleration	Signed estimated accelleration value (1D) of the vehicle in relation to reference frame	
Overestimation Accelleration	Safe lower bound of the accelleratioin of the vehicle	
Underestimation Accelleration	Safe upper bound of the speed of the vehicle	

Table 7 Dynamic ASTP Output Accelleration

4.1.1.2.5 Virtual Balises (only valid for Full ASTP)

As far as future supportive services are available (e.g. Digital Map) ASTP should be able to generate and distribute virtual balise data. This can be done in the same way as physical balises according to TSI CCS SS-026-7.

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4.1.2 Inputs

4.1.2.1 Static from BTM

Input	Description	Remark
Balise antenna 1 to End 1	Distance from Balise antenna 1 to End 1	Dependant on BTM allocation
Balise antenna 1 to End 2	Distance from Balise antenna 1 to End 2	Dependant on BTM allocation
Balise antenna 2 to End 1	Distance from Balise antenna 2 to End 1	Dependant on BTM allocation
Balise antenna 2 to End 2	Distance from Balise antenna 2 to End 2	Dependant on BTM allocation

Table 8 Static ASTP Input from BTM (Note: simplyfied to 2 instead of 4 possible balise antennas)

4.1.2.2 Dynamic from BTM

Input	Description	Remark
Balise ID	Balise ID of the passed balise	
Antenna ID	Antenna reading the balise	
Balise Passing Time	Time information of the passed balise at the reference mark	
Balise Passing Time Error Est	Error estimate of time information of the passed balise	

Table 9 Dynamic ASTP Input from BTM

4.1.2.3 Dynamic from ETCS-OB

Input	Description	Remark
Active Cab	Active cab on End 1 or End 2	Depends on allocation of transformation from reference point to train front end
LRBG	Information which balise group is the last relevant	
Antenna ID	Antenna reading the balise group	
Balise group Passing Time	Time information of the passed balise group at the reference mark	
Balise group Passing Time Error Est	Error estimate of time information of the passed balise group	

Table 10 Dynamic ASTP Input from ETCS-OB

4.2 BTM Functions

The BTM delivers to ETCS-OB, ASTP and potentially to other consumers the balise data according to the TSI CCS SUBSET-026-7. The standardisation of the BTM interface prepares the introduction of future virtual balises.

To ASTP the BTM has to deliver accurate time information when a balise is passed. This information in conjunction with the information of last relevant balise group (LRBG) from ETCS-OB is relevant to reset the estimate distance to LRBG. Additionally, the static configuration of the BTM antenna(s) have to be transmitted.

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4.2.1 Static Output

Output	Description	Remark
Balise antenna 1 to End 1	Distance from Balise antenna 1 to End 1	Dependant on BTM allocation
Balise antenna 1 to End 2	Distance from Balise antenna 1 to End 2	Dependant on BTM allocation
Balise antenna 2 to End 1	Distance from Balise antenna 2 to End 1	Dependant on BTM allocation
Balise antenna 2 to End 2	Distance from Balise antenna 2 to End 2	Dependant on BTM allocation

Table 11 : Static BTM Output

4.2.2 Dynamic Output

Output	Description	Remark
Balise ID	Balise ID of the passed balise	
Balise Data	Balise telegram	
Antenna ID	Antenna reading the balise	
Balise Passing Time	Time information when a balise was passed	
Balise Passing Time Error Est	Error estimate of time information of the passed balise	

Table 12 Dynamic BTM Output

4.3 ETCS-OB Functions

ETCS-OB has to deliver dynamic output data to ASTP like the last relevant balise group (LRBG) as well as the active cab. Alternatively, the active cab is deliverd from the actual source of information which is TCMS. As input it needs the main static and dynamic input from BTM and ASTP.

4.3.1 Dynamic Output to ASTP

Ouput	Description	Remark
Active Cab	Active cab on End 1 or End 2	Depends on allocation of transformation from reference point to train front end
LRBG	Information which balise group is the last relevant	
Antenna ID	Antenna reading the balise group	
Balise group Passing Time	Time information of the passed balise group at the reference mark	
Balise group Passing Time Error Est	Error estimate of time information of the passed balise group	

Table 13 Dynamic ETCS-OB Output

4.3.2 Input

4.3.2.1 Static

4.3.2.1.1 ASTP Reference Point location

Output	Description	Remark
Reference Point to End 1	Distance from reference point to consist end 1	
Reference Point to End 2	Distance from reference point to consist end 2	

Table 14 Static input from ASTP

4.3.2.1.2 Balise Antenna location

Output	Description	Remark
Balise antenna 1 to End 1	Distance from Balise antenna 1 to End 1	Dependant on BTM allocation
Balise antenna 1 to End 2	Distance from Balise antenna 1 to End 2	Dependant on BTM allocation
Balise antenna 2 to End 1	Distance from Balise antenna 2 to End 1	Dependant on BTM allocation
Balise antenna 2 to End 2	Distance from Balise antenna 2 to End 2	Dependant on BTM allocation

Table 15 : Static input from BTM

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4.3.2.2 Dynamic

4.3.2.2.1 Safe 1D Position from ASTP

Output	Description	Remark
Estimated Distance LRBG to ref point	Estimated distance from LRBG to reference point	
Estimated Distance LRBG to train front end	Estimated distance from LRBG to train front end	Depends on allocation of transformation from reference point to train front end
Position Qualifier	Position in nominal or reverese side of the balise group	
LRBG ID	Last relevant balise group ID	
Overestimation	Estimated overreading distance	
Underestimation	Estimated unterreading distance	

Table 16 Dynamic input of Safe 1D Position from ASTP

4.3.2.2.2 Safe travelled Distance since Power-on from ASTP

Output	Description	Remark
Estimated Distance	Estimated travelled distance since power on	
Overestimation Distance	Estimated overreading distance	
Underestimation Distance	Estimated unterreading distance	

Table 17 Dynamic input of Safe travelled Distance since Power-on from ASTP

4.3.2.2.3 Safe Speed from ASTP

Output	Description	Remark
Movement Direction	Direction of the movement in relation to reference frame	
Estimated Speed	Estimated speed value (1D) of the vehicle	
Overestimation Speed	Safe lower bound of the speed of the vehicle	
Underestimation Speed	Safe upper bound of the speed of the vehicle	

Table 18 Dynamic ASTP input Safe Speed

4.3.2.2.4 Accelleration from ASTP

Output	Description	Remark
Estimated Accelleration	Signed estimated accelleration value (1D) of the vehicle in relation to reference frame	

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Overestimation Accelleration	Safe lower bound of the accelleratioin of the vehicle	
Underestimation Accelleration	Safe upper bound of the speed of the vehicle	

Table 19 Dynamic ASTP Output Accelleration

4.3.2.2.5 Balise Data

Output	Description	Remark
Balise ID	Balise ID of the passed balise	
Balise Data	Balise telegram	
Antenna ID	Antenna reading the balise	
Balise Passing Time	Time information when a balise was passed	
Balise Passing Time Error Est	Error estimate of time information of the passed balise	

Table 20 Dynamic balise data from BTM

4.4 TTLS Functions

The Train Time and Location Services (TTLS) provide on one hand a common reference time and on the other hand the current location information for all applications on the vehicle. They are both defined as a non-safe service function. Primary using a GNSS module as time and location source, the TTLS provides an NTP server for time distribution and a location service delivering absolute estimated position along with an uncertainty. The provided services have to be used by all applications connected to the network which require a common time or (non-safe) absolute location, velocity or accelleration information like ETCS-OB and ATO-OB mainly for diagnostic purposes.

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4.4.1 Time Service

The time service implements an onboard NTP server. Over the NTP protocol every system (NTP client) can synchronize its system time to the system time of the NTP server.

4.4.2 Location Service

The high-level information delivered by the location service of the TTLS is shown in the tables in the following subchapers.

4.4.2.1 Static Output

Output	Description	Remark
GNSS antenna to End 1	Distance from GNSS antenna to End 1	
GNSS antenna to End 2	Distance from GNSS antenna to End 2	

Table 21 Static TTLS Location Output

4.4.2.2 Dynamic Output

Output	Description	Remark
Position	Estimated absolute (3D) position of the GNSS antenna	
Position Error	Estimated position error (horizontal and vertical)	
Velocity	Estimated velocity (3D)	
Accelleration	Estimated accelleration (3D)	
Attitude	Estimated attitude / heading (3D)	

Table 22 Dynamic TTLS Location Output

4.5 Functions not part of ASTP

The following functions that are not considered as part of the ASTP:

a) Generation and transmission of the Train Position Report (chapter 3.6.5.1.4 of SUBSET-026).

b) Determination of the train rear end position (chapter 3.6.4.4.1, 3.6.5.2 of SUBSET-026)

c) Determination of the train length (chapter 3.6.5.2 of SUBSET-026).

d) Determination of the train integrity status (TIMS-status).

e) Determination of standstill (chapter 3.14.4 of SUBSET-026).

f) Determination of track occupancy.

g) Determination of the LRBG or other reference location.

h) Physical balises reader and forwarding Eurobalise telegram (ETCS-OB/BTM).

i) Management of the Map Data between the trackside and the on-board (On-board Digital Register management and functions see document).

j) Determination of Cold Movement Detection (CMD)

When required, data provided by those external functions or devices are considered as ASTP inputs.

To be noticed that the previous assumtions on the grouping of IC and the CCS Consist Network can also by applied to these functions.

5 Architecture Variants ASTP

The Train Time and Location Service (TTLS) as specified in current TSI 2023 delivering a time synchronisation and a non-safe 3D localisation is proposed to be part of a new interoperability constituent. It is used for non-safe purposes only (e.g. OMS part of CCS-OB according to SS-149). This interoperability constituent is separated from ETCS-OB, ATO, BTM and ASTP in all of the following variants. In case full ASTP implements a GNSS receiver, full ASTP can deploy the TTLS services. In this case the TTLS-IC could be grouped with ASTP-IC.

In all variants there are standardised output interfaces to other consumers such as ATO or other consumers would have to be implemented according to the interface specification (blue arrows in figures). These interfaces are the same in baseline scenario and in the modular scenarios (e.g. in chapter 5.6). The interefaces should be defined in such a way that the upgrade to full ASTP does not provoke a change in the datasets. They include a standardised output of all available odometry but also balise information to

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any consumer who is interested in. Distributing this data enables innovation in the future. The publish/ subscribe mechanism of the CCN also minimizes the effort in case of future enhancements.

5.1 Variant 1: Baseline scenario

5.1.1 Variant 1 Basic ASTP situation

In this variant, the functions of ASTP/odometry, BTM and ETCS on-board are integrated (grouped) in one interoperability constituent. The ASTP FFFIS ("Odometry Data" and "LRBG" in the following architecture figures) is only relevant as an output of this group to other consumers like ATO or TCMS systems. The interfaces between the ASTP, BTM and ETCS-OB can be proprietary interfaces (black arrows in Figures below).

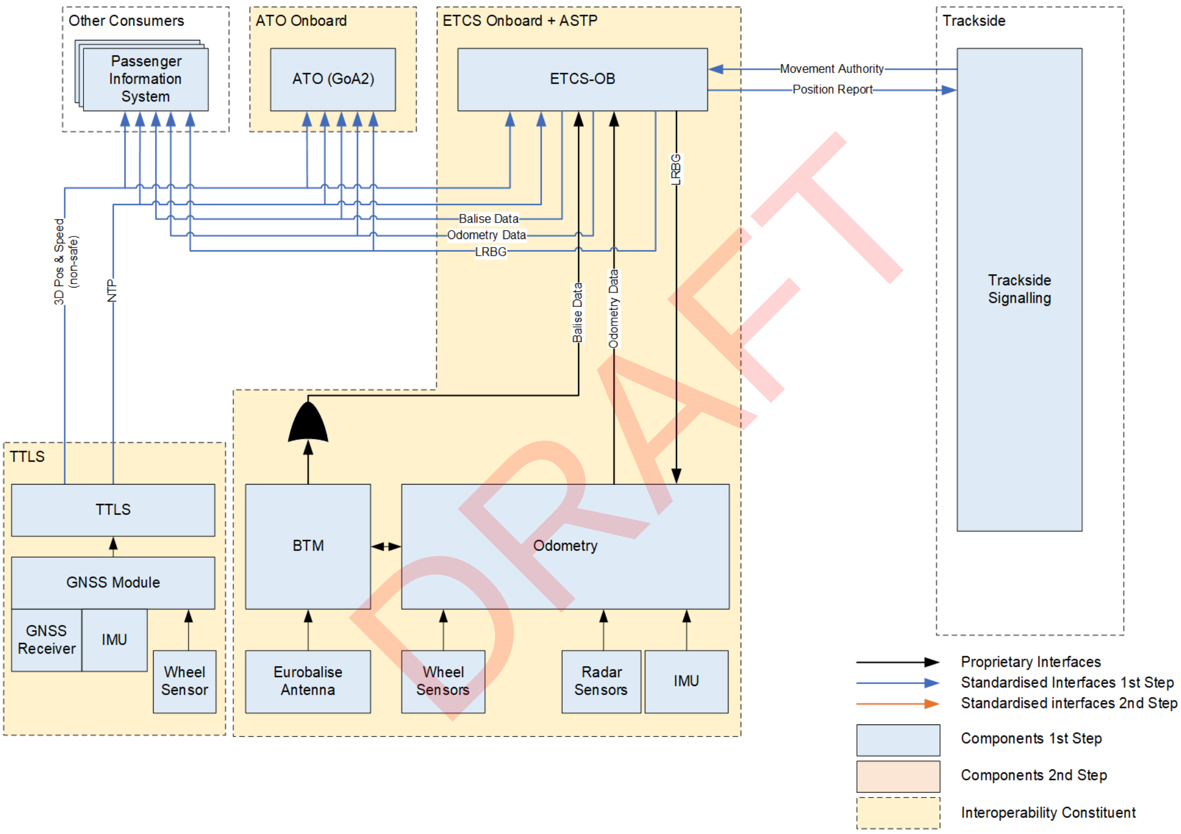

Figure 8 Architecture variant 1 basic ASTP situation

5.1.2 Variant 1 Full ASTP situation

The migration to full ASTP in the baseline scenario keeps the integration of ASTP, BTM and ETCS on-board. External standardised interfaces (red arrows in Figure below) are added for the additional information needed by the full ASTP, such as Route or Map data. Full ASTP also has an interface to the balise data as it can trigger virtual balises. The insertion of virtual balises is shown in with a logical or-gate. But the real implementation of it in this variant is supplier specific and therefore proprietary.

The migration to full ASTP requires an upgrade of the integrated ASTP, BTM and ETCS on-board unit. If an upgrade to full ASTP is not possible or too expensive with the initial supplier, the entire IC "ETCS on-board + ASTP" with all its components ASTP, ETCS-OB, BTM needs to be replaced by products of another supplier.

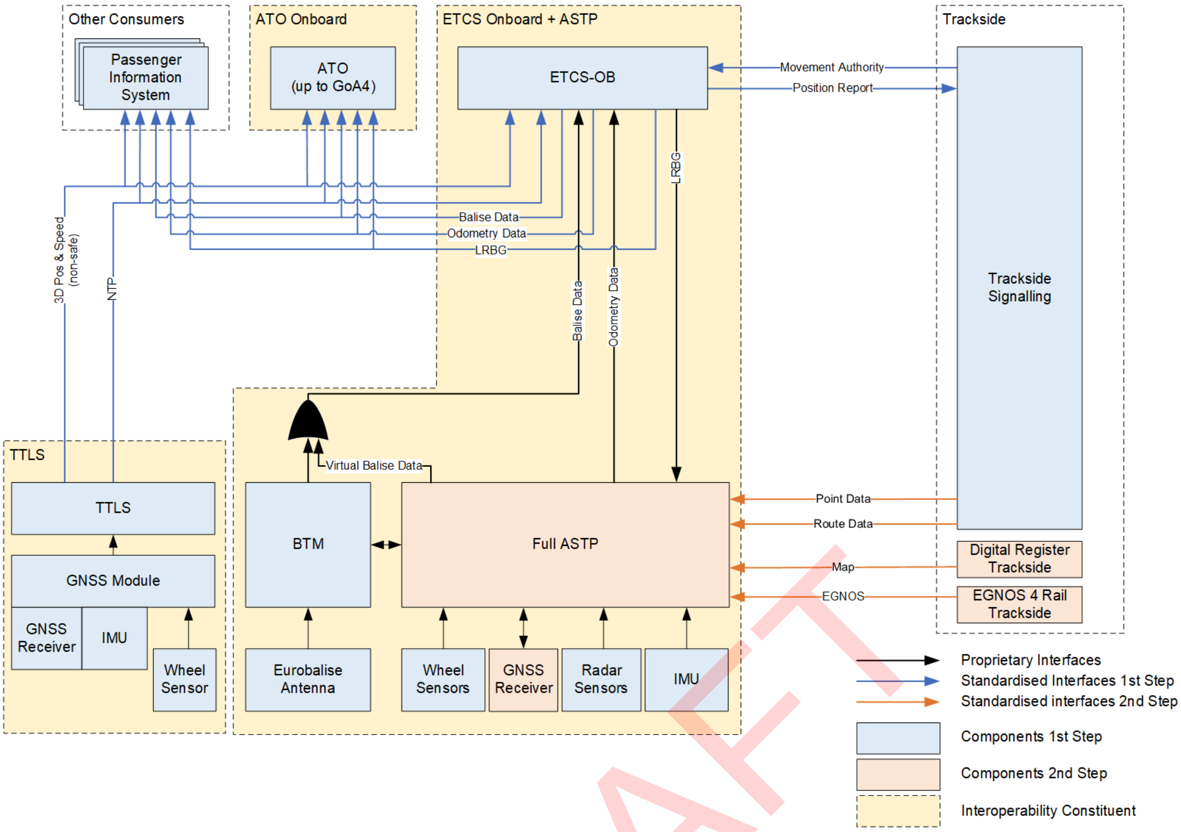

Figure 9 Architecture variant 1 full ASTP situation

5.2 Variant 2: Half modular scenario only for full ASTP

The variant 2 is a mix of the baseline variant 1 for the basic ASTP and the modular variant 3 for the full ASTP.

5.2.1 Variant 2 Basic ASTP situation

The basic ASTP situation for variant 2 is identical to the variant 1. Therefore, the description of chapter 5.1.1 for variant 1 basic ASTP is also valid for variant 2 basic ASTP.

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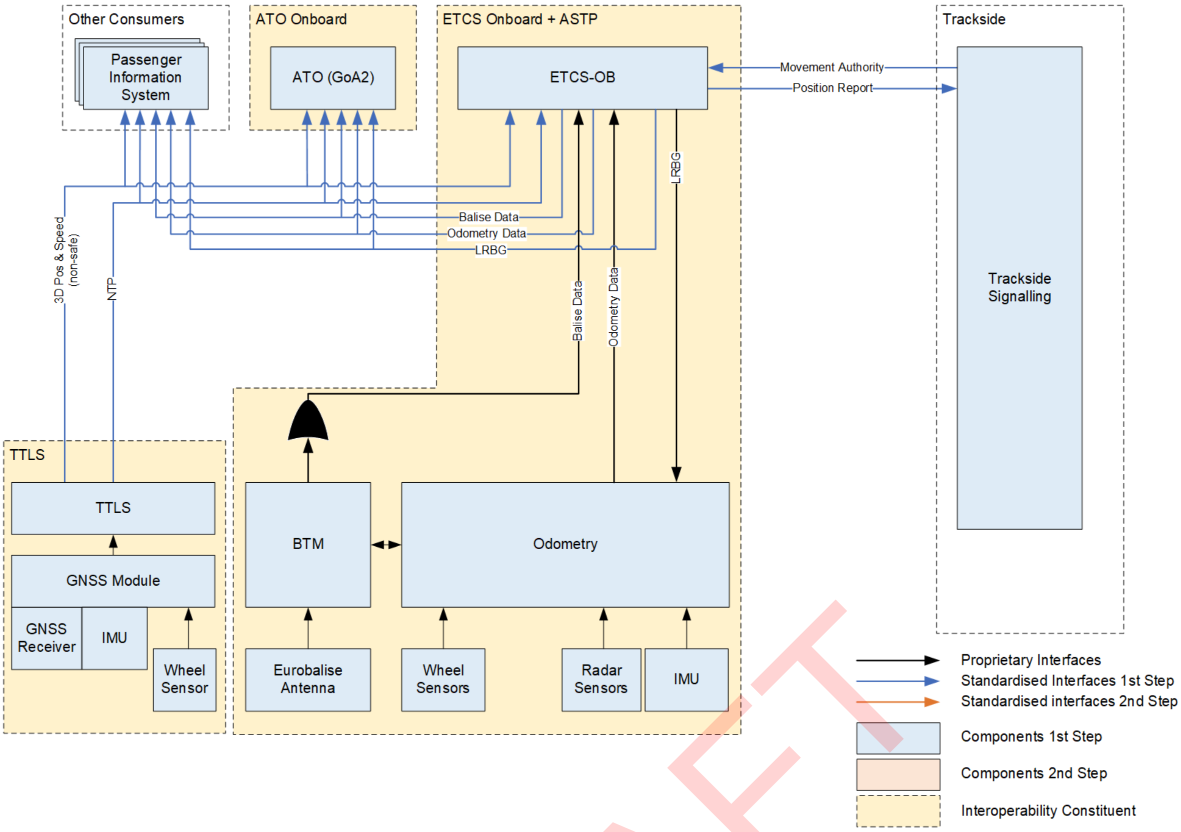

Figure 10 Architecture variant 2 basic ASTP situation

5.2.2 Variant 2 Full ASTP situation

At the same time the full ASTP is introduced, the joined ASTP & BTM functions are separated from ETCS-OB. The full ASTP situation for variant 2 is identical to the variant 3. Therefore, the description of chapter 5.4.2 for variant 3full ASTP is also valid for variant 2 full ASTP.

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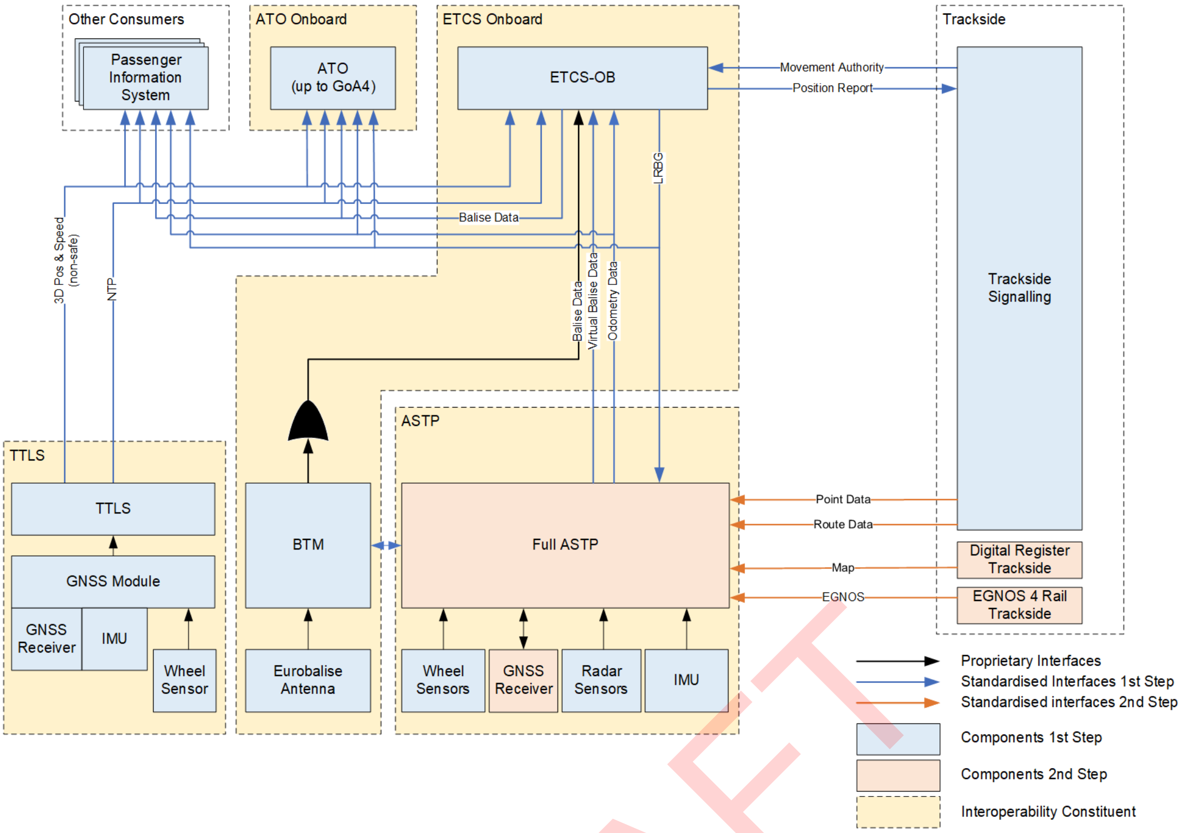

Figure 11 Architecture variant 2 full ASTP situation

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5.3 Variant 3: Half modular scenario, BTM in ETCS-OB

5.3.1 Variant 3 Basic ASTP situation

In the variant 3 the ASTP is separated from the ETCS on-board as separate interoperability constituent. The BTM function is part of the ETCS-OB IC. The interfaces with the ASTP are specified using standardised interfaces (blue arrows in Figures). Using multicast communication schemes (see section 3.3.2) of the Ethernet CCS communication network, the ASTP FFFIS interface definition is used to transmit the odometry data to the ETCS on-board as well as to other consumers. The interface between BTM and ETCS remain proprietary. As the balise data is interesting for other consumers as well, a standardised balise data interface from ETCS to other consumers can be specified additionally. The time-critical interface between BTM and ASTP has to be standardised in this variant as well. The figure below shows the situation before migration to the full ASTP. In this scenario the interface between the ASTP and the BTM needs to be also specified.

Allowing the grouping of the different interoperability constituents during a transition phase would allow the smooth transition of products by the suppliers from the current integrated solutions to a half modular or even modular solution. If grouping would be applied to ETCS-OB, BTM and ASTP, the situation would be equivalent to the baseline scenario showed in variant 1.

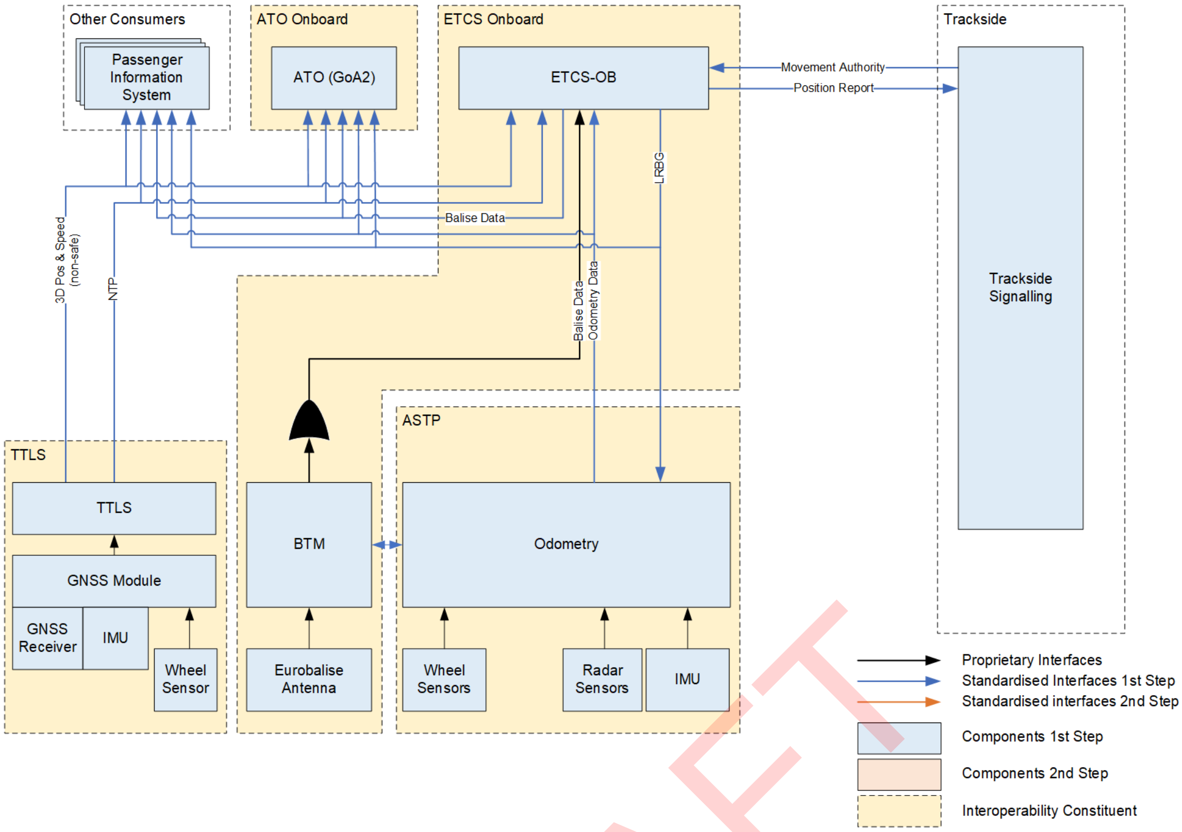

Figure 12 Architecture variant 3 basic ASTP situation

5.3.2 Variant 3 Full ASTP situation

The migration to full ASTP introduces standardised external interfaces (red arrows in figures) for the additional information needed by the full ASTP, such as Route or Map data. Figure below shows the architecture after migration to full ASTP.

The interfaces between the ETCS on-board and the ASTP can be kept with the migration to full ASTP. Thus, no significant change to the ETCS on-board is needed. The introduction of virtual balise data has to be standardised separately from the physical balise data.

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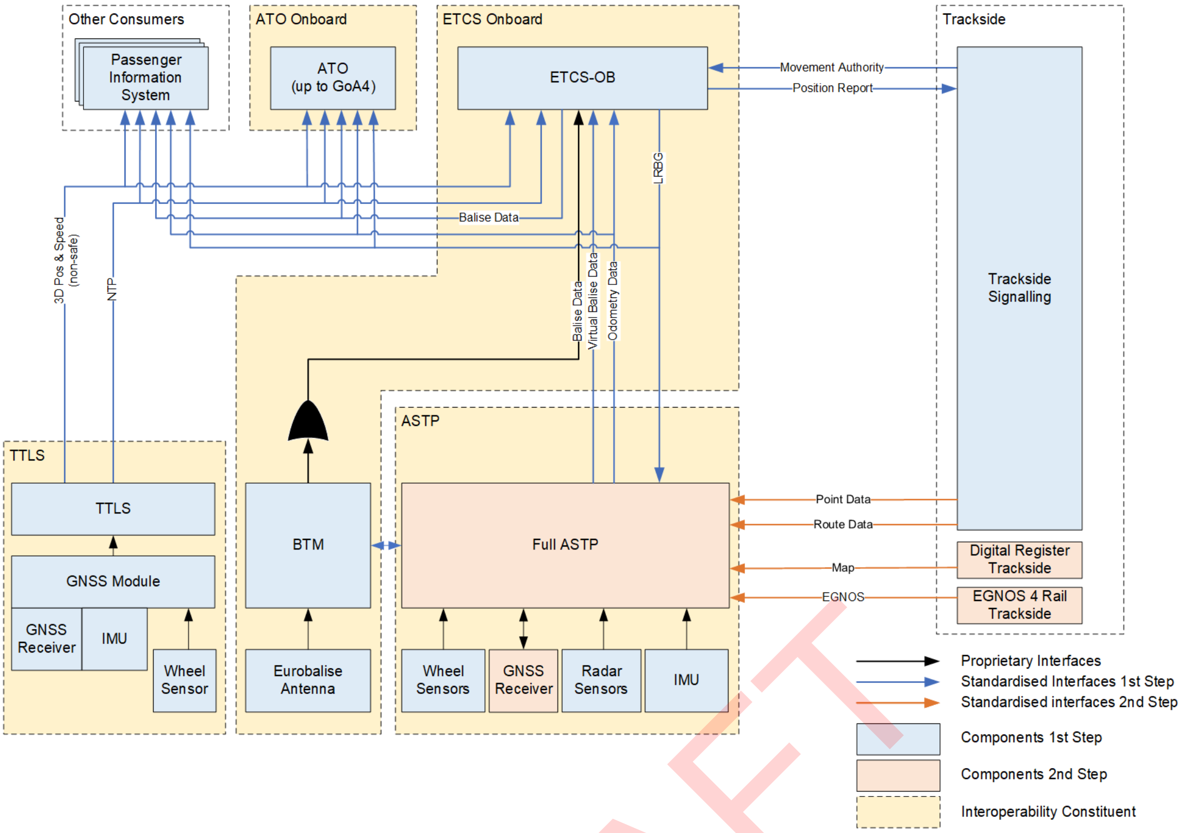

Figure 13 Architecture variant 3 full ASTP situation

5.4 Variant 4: Half modular scenario, BTM in ASTP

5.4.1 Variant 4 Basic ASTP situation

In the variant 4 the BTM and ASTP are separated from the ETCS on-board but grouped into one interoperability constituent. This creates a dependency between the BTM and the ASTP. Upgrading one subsystem can have an impact on the other. The advantages of the combination of BTM and ASTP is the fact that the systems are closely related from a functional point of view (virtual balise, odometry relocation with balise). A proprietary interface between ASTP and BTM can support the performance of the interface for time-critical information exchanges between ASTP and BTM which might be needed.

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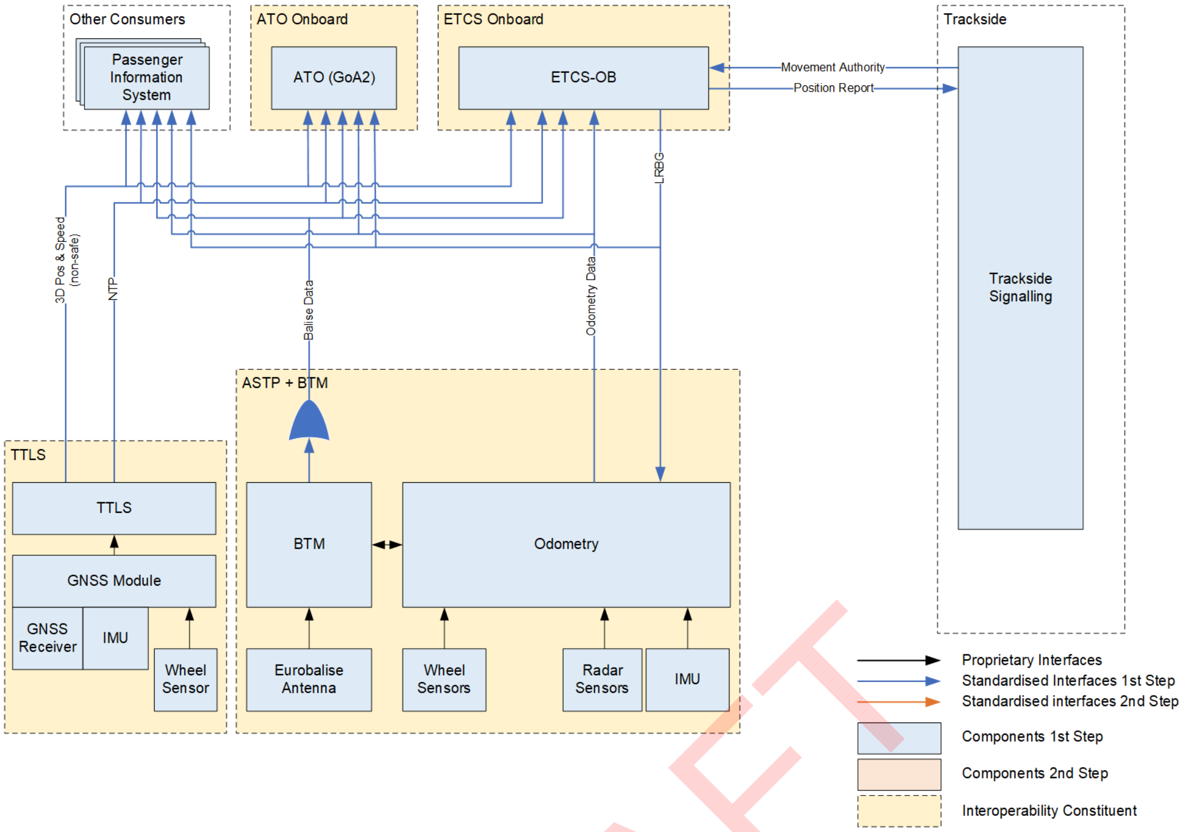

Figure 14 Architecture variant 4 basic ASTP situation

5.4.2 Variant 4 Full ASTP situation

The migration to full ASTP introduces standardised external interfaces (red arrows in figures) for the additional information needed by the full ASTP, such as Route or Map data. Figure below shows the architecture after migration to full ASTP.

The interfaces between the ETCS on-board and the ASTP can be kept with the migration to full ASTP. Thus, no significant change to the ETCS on-board is needed. The insertion of possible virtual balise data from the full ASTP into the balise data stream can be done within the ASTP+BTM interoperability constituent itself.

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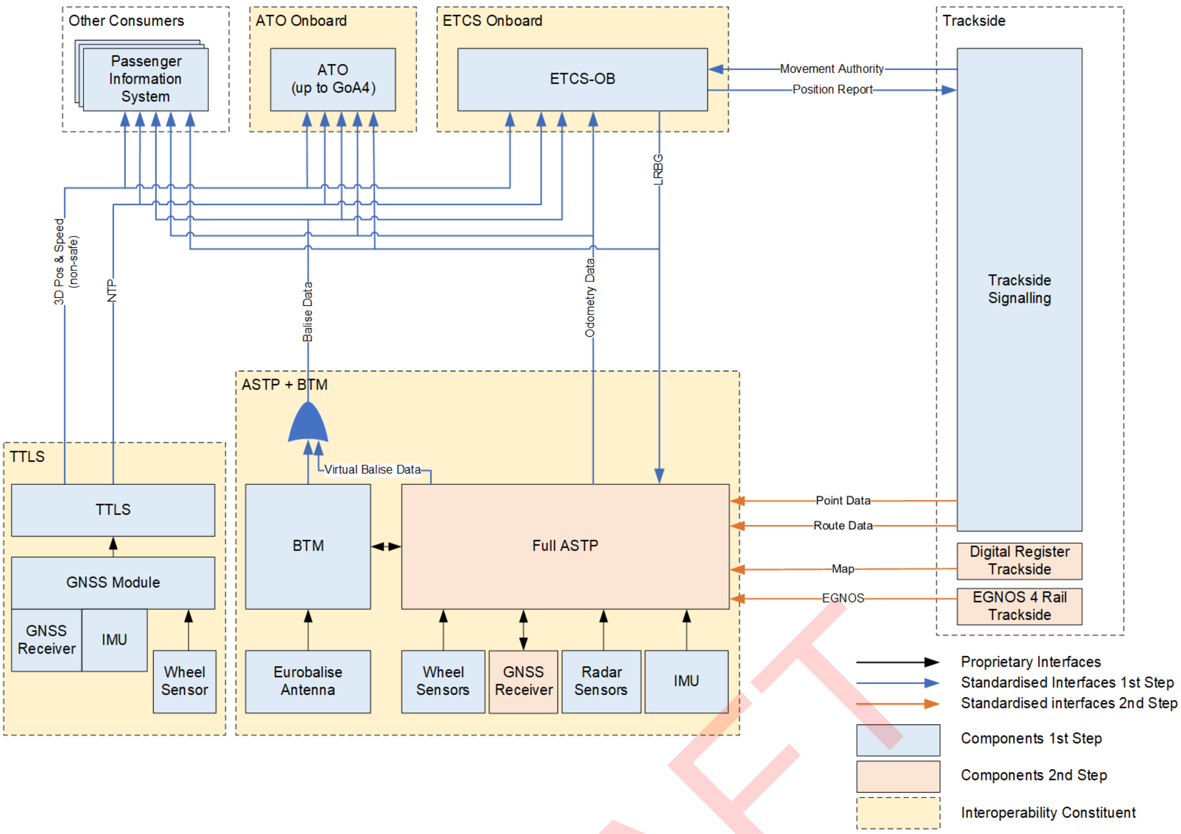

Figure 15 Architecture variant 4 full ASTP situation

5.5 Variant 5: Full Modular scenario only for Full ASTP

The variant 5 is a mix of the half modular variant 3 for the basic ASTP and the full modular variant 6 for the full ASTP.

5.5.1 Variant 5 Basic ASTP situation

The basic ASTP situation for variant 5 is identical to the variant 3. Therefore, the description of chapter 5.4.1 for variant 3 basic ASTP is also valid for variant 5 basic ASTP.

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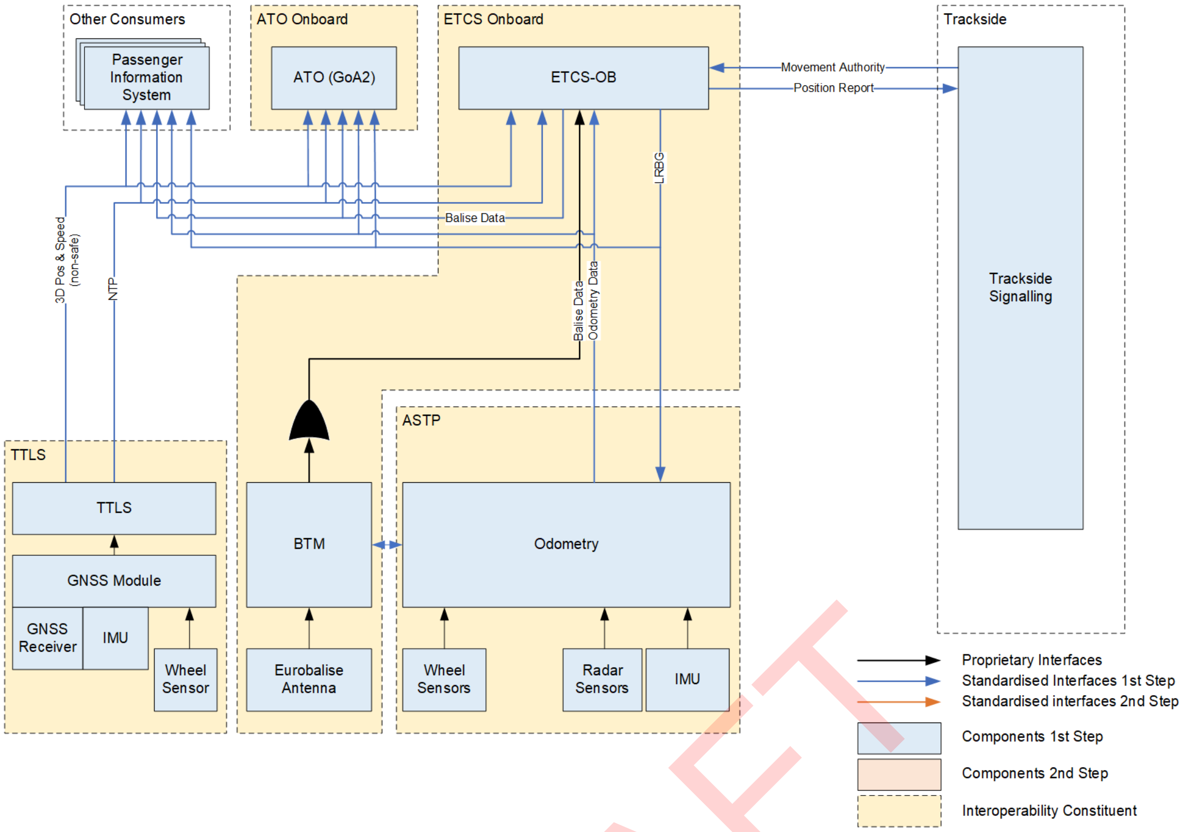

Figure 16 Architecture variant 5 basic ASTP situation

5.5.2 Variant 5 Full ASTP situation

With the introduction of full ASTP the modularity is extended from half modular to full modular. With this step the separation of the BTM function from ETCS-OB is proposed. The full ASTP situation for variant 5 is identical to the variant 6. Therefore, the description of chapter 5.6.2 for variant 6 full ASTP is also valid for variant 5 full ASTP.

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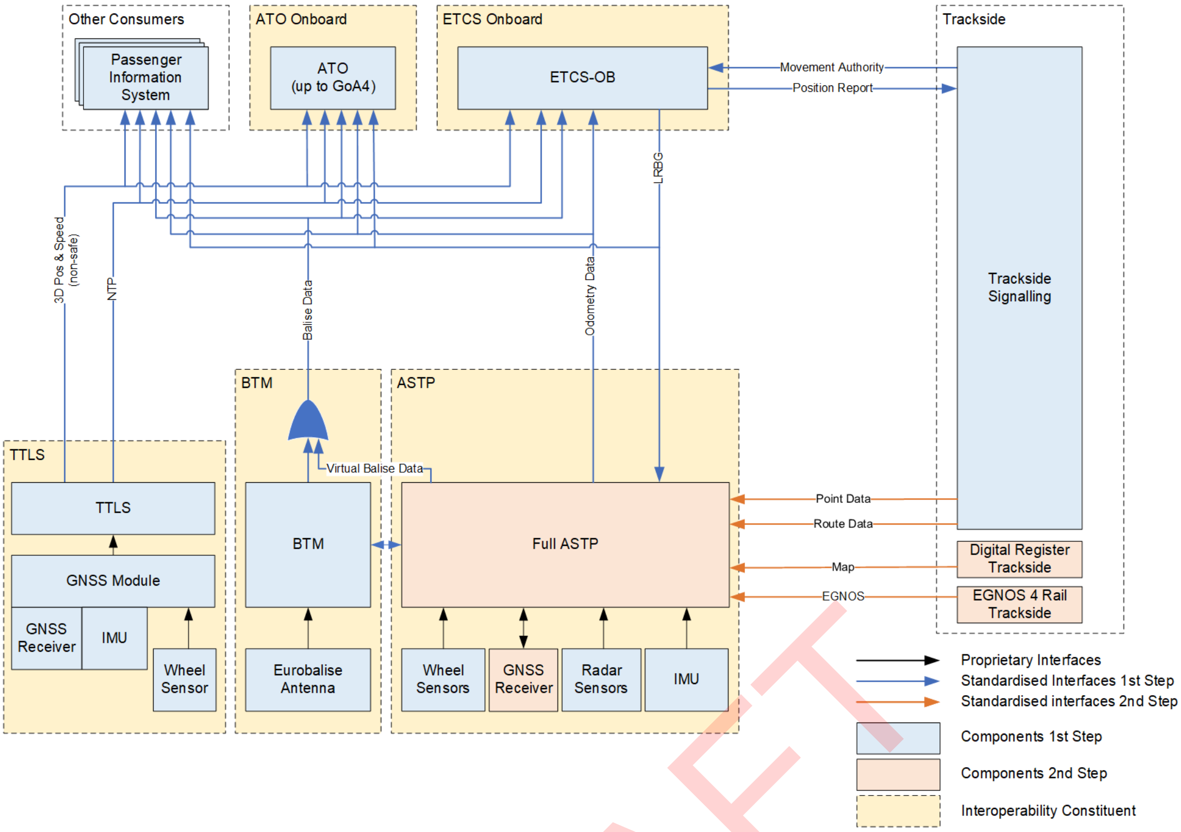

Figure 17 Architecture variant 5 full ASTP situation

5.6 Variant 6 Full Modular scenario in Basic and Full ASTP

5.6.1 Variant 6 Basic ASTP situation

In the modular scenario, the ASTP, BTM and ETCS on-board are each defined as a separate interoperability constituent (IC). The interfaces between them are specified using standardised interfaces (blue arrows in Figures). Using multicast communication schemes (see section 3.3.2) of the Ethernet CCS communication network, the ASTP FFFIS interface definition is used to transmit the odometry data to the ETCS on-board as well as to other consumers. Proprietary interfaces are kept to a minimum. The main goal of this variant is the flexibility of the allocation of the BTM. In this variant either a grouping with ETCS-OB or ASTP is possible in order to allow different supplier choices. The figure below shows the situation before migration to the full ASTP. In this scenario the interface between the ASTP and the BTM also needs to be specified.

Allowing the grouping of the different interoperability constituents during a transition phase would allow the smooth transition of products by the suppliers from the current integrated solutions to a modular solution. If grouping would be applied to ETCS-OB, BTM and ASTP, the situation would be equivalent to the baseline scenario.

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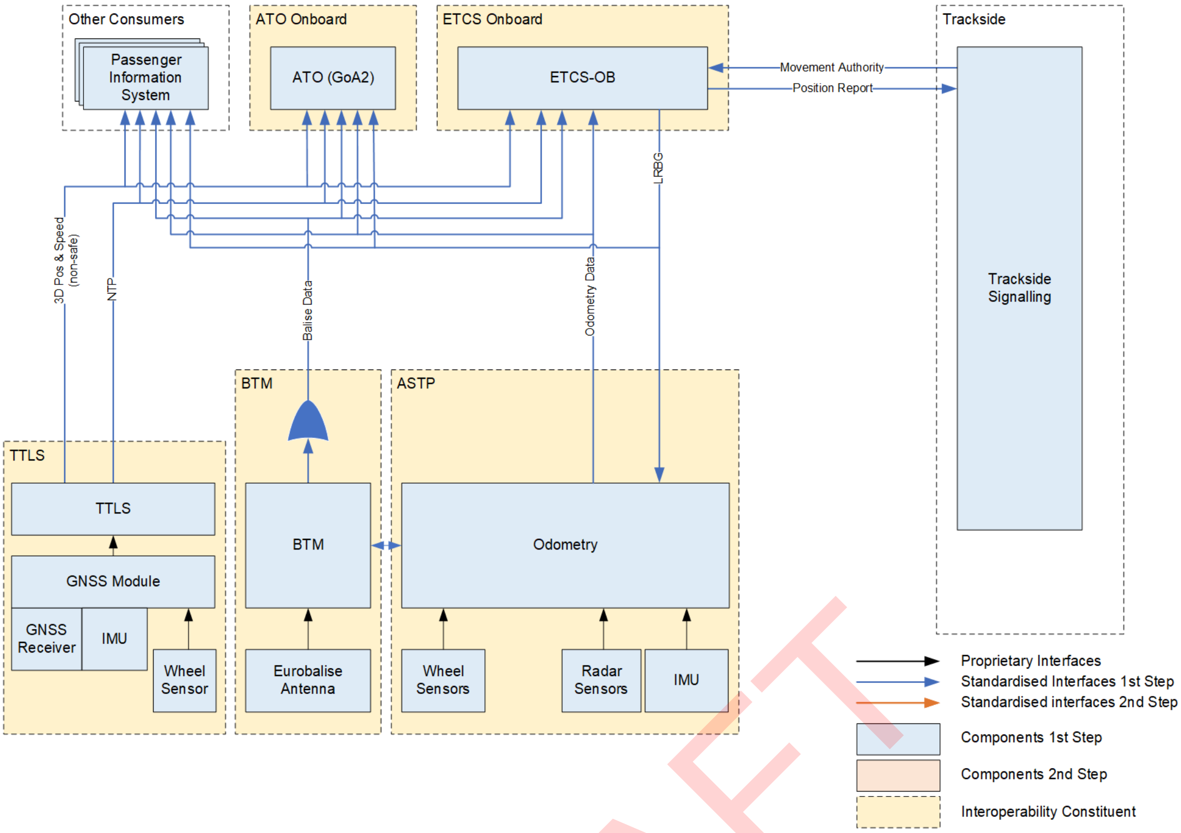

Figure 18 Architecture variant 6 basic ASTP situation

5.6.2 Variant 6 Full ASTP situation

The migration to full ASTP introduces similarly to the baseline scenario, standardised external interfaces (red arrows in figures) for the additional information needed by the full ASTP, such as Route or Map data. Figure below shows the architecture after migration to full ASTP.

The interfaces between the ETCS on-board and the ASTP can be kept with the migration to full ASTP. Thus, no significant change to the ETCS on-board is needed. The insertion of possible virtual balise data from the full ASTP into the balise data stream can be done by distributing the information from full ASTP to the same multicast address as the physical balise data. Thus, the preparation of virtual balises is done through the introduction of the standardised physical balise data interface. Additionally, the input to ASTP from ETCS on-board concerning the identification of the last relevant balise group (LRBG) also needs to be defined.

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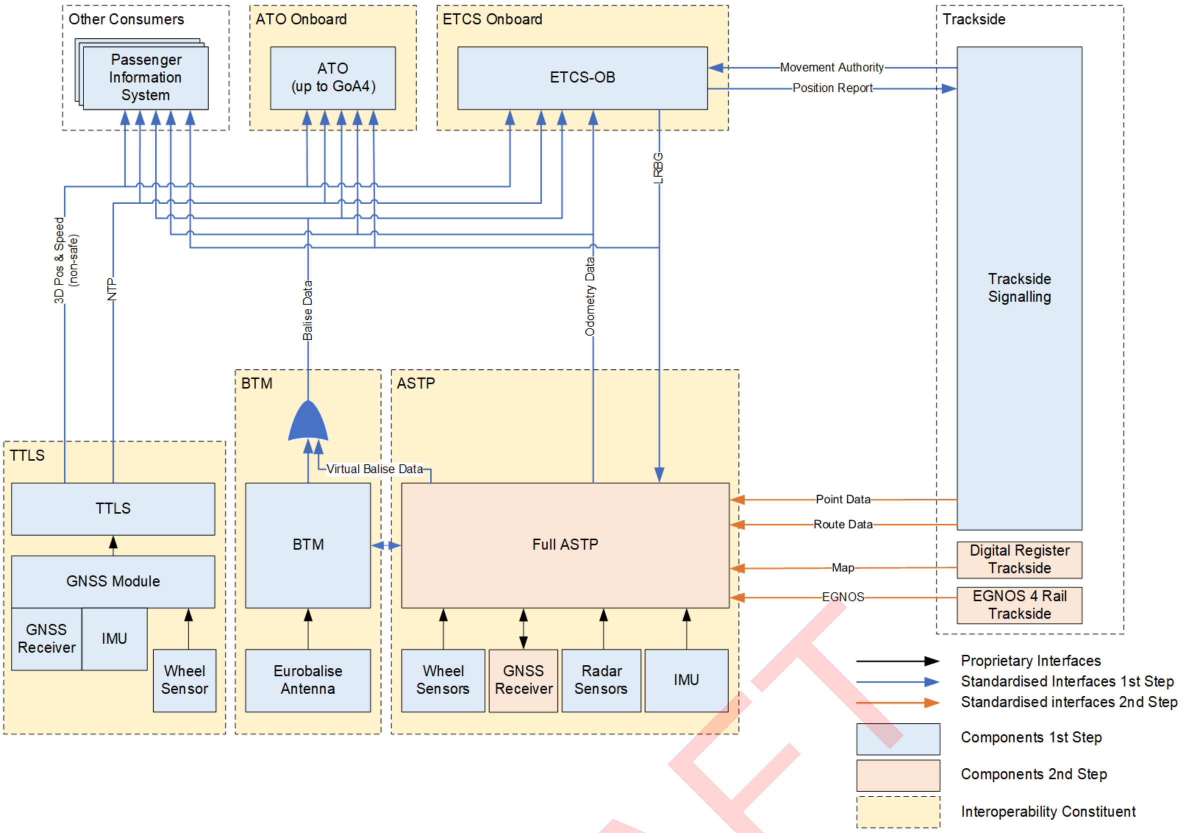

Figure 19 Architecture variant 6 full ASTP situation

6 Evaluation

Basically, the evaluation is split into a technical and an economical evaluation. The evaluation effort for all 6 variants presented in this document was expected to be too high. Therefore, the members of the Train CS Task 7A voted individually for two options from a list of the six variants presented in this document. Initially, the variants 2 and 6 have been chosen for further evaluation in addition to the baseline scenario in variant 1. During the technical evaluation (see SPT2TRAIN-8225) the technical feasibility of variant 6 was discoverd to be challenging until the next TSI due to a current lack of transmission latency supervision in SUBSET-147. Therefore, the task group decided to change the variant to be assessed to the variant 4 as it circumvents this challenge. So, the variants that are assessed are:

- Variant 2
- Variant 4

6.1 Technical Evaluation

After determining the two variants to be evaluated, a set of criteria was established based on granularity principles applied to the ASTP (see SPT2TRAIN-6920) and additional inputs from Train CS members. The selected criteria are intended to be purely technical and reflect the life cycle of the CCS subsystem, from the definition of harmonized specifications to its operation and maintenance. For each criterion, the technical assessment provides two qualitative descriptions for the basic ASTP step for each selected variant. Finally, conclusions are drawn from a comprehensive analysis of the

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qualitative assessments. The preferred variant of the technical evaluation regarding the basic ASTP step with the next TSI release was the following:

- Variant 2

No technical assessment was provided concerning architecture related to the introduction of the full ASTP.

6.2 Economic Evaluation

The economic evaluation was done by the external supplier BlueArches contracted by the SP Core Group (see SPT2TRAIN-6792). This economic evaluation is an update of the draft version from December 2024 (see SPT2TRAIN-8222). The economic evaluation compares the two modular scenarios of variants 2 and 6 with the non-modular baseline scenario in variant 1. Changing the economic analysis from variant 6 to variant 4 is expected to result in lower development. But as the development costs of variant 4 will not be as low as the variant 2 there are no major impacts on the conclusion of the economic evaluation. The main result of the economic evaluation regarding the basic ASTP step was the following:

The preferred variant of the economic evaluation regarding the basic ASTP step is:

- Variant 2

As an outlook to a future full ASTP the main result of the economic evaluation is: "Moving towards a modular full ASTP (Variant 2) outperforms not doing so (Variant 1) by 96M€ (ca.23%) in 30 years at the financial discount rate of 8%." That means a future full ASTP introduced in a modular way as own interoperability constituent is favorable from an economic point of view. However, there is currently no common decision on the full ASTP architecture.

7 Conclusion

7.1 Results

Modularity (not necessarily harmonized modularity) is a best practice and most of the present day EVCs are designed following supplier specific modularity: In most cases, it is composed of various electronic boards and external equipment, each of which implements either “independent” functions or functions that are combined with other physical components (boards or external equipment).

Harmonized modularity, understood as the application of logical modularity to introduce a new Interoperability Constituent into railway regulations, is a topic that should not be taken lightly.

As demonstrated in the technical assessment document ASTP - Technical Evaluation of architecture variants (see SPT2TRAIN-6920), there are general arguments both in favour and against. A detailed analysis is necessary to justify that the increase in solution complexity is supported by clear added value from a technical standpoint, meaning that the arguments in favour must significantly outweigh those against.

Introducing a new ASTP Interoperability Constituent at the Basic ASTP stage is not deemed beneficial considering that all major suppliers already have existing certified EVCs. Introducing new IC would mean to modify existing EVCs without improvement of performance or major technical benefit. Moreover, the CR-07692-ASTP robustness and the CR-07695-ASTP-performance can be processed in both monolithic or modular approaches.

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The permission to use grouping does not alleviate the impact of creating new Interoperability Constituents (e.g. ASTP) from existing ones (e.g. ETCS-OB). The requirement to make the interfaces of the grouped ICs externally accessible on the CCS Consist network communication layers (so that a grouped function could be replaced by an external IC during the CCS subsystem life cycle) means that the FRS/SRS for the new IC must also be implemented accordingly.
Extensive work is needed to reach a consensus on an architectural and functional proposal for (Full) ASTP before making any decisions about the necessity of a dedicated Interoperability Constituent. The impacts concerning certification—such as performance and compatibility testing—must also be carefully considered.
The transition from a monolithic approach to distributed approach will also raise the question of integration responsibility that may be transferred to the integrator.

After conducting technical and economical assessments, **it has been concluded that the logical architecture identified as Variant 2** (on the basic ASTP step) **is preferred** regarding the Basic ASTP step (STIP-29) **with the next TSI CCS release**. No decision have been made concerning subsequent stages.

One of the most awaited features of the ASTP is a **single source of localisation for all CCS-OB users**. This feature shall be introduced with the next TSI CCS release by defining an **output interface for applications outside the ETCS using localisation and balise information**.

As in the preferred variant there is no separate constituent ASTP with the next TSI CCS release, it could be misleading to continue to name the first migration step Basic ASTP. We propose to **rename the first migration step "odometry enhancement"** with the following scope: odometry performance enhancement, odometry robustness specification and odometry output interface.

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7.2 Next steps

To harmonize Variant 2, it is essential to work on defining the FFFIS for applications outside the ETCS using odometry information. The goals of this interface are:

- Provide ETCS odometry information to other users (e.g. Onboard recording device, train, ATO, National systems etc.)
- Provide additional information (e.g. Balises data, LRBG)
- Improve testability of the ETCS odometry

Although not exhaustively analyzed yet, some technical decisions have already been made as a starting point for defining this interface:

- The odometry FFFIS must be based on the Ethernet CCS Consist network (according to SUBSET-147)
- The communication pattern must be Process Data push pattern, point to multipoint (according to IEC 61375)

The definition of the ETCS external interface “Odometry for applications outside the ETCS/ERTMS” allows for the objectives of STIP 29 to be addressed from a solid and reasonable foundation, considering the targeted timeline:

- It will provide localisation information (position, speed, reference location etc) to other onboard systems.
- It could improve the testability of the ETCS odometry. This objective must be accomplished in tune with the CR-07692-ASTP robustness solution.
- The improvement of the performance of the ETCS odometry is better addressed in the CR-07695-ASTP-performance_Target from a stable architecture, without modification of the reference architecture.

- It will provide valuable information for the Full ASTP specification. It allows to reflect the odometry needs of ETCS and “other users” in a standard (e.g. in data, performances and integrity level). The output interface allows to define a stable ASTP interface later.

7.3 Outlook to (Full) ASTP

The FFFIS for a potential ASTP interoperability constituent should be introduced into the TSI at the same time as the interoperability constituent is ready to be placed on the market. This requires substantial effort to demonstrate that the technology is suitable for commercial service, supported by a stable specification and an appropriate level of technology readiness.

The definition and implementation of the ETCS external interface “Odometry for applications outside the ETCS/ERTMS” will provide precious feedback on the feasibility of the ASTP FFFIS since it is assumed (but unproved) that the data exchanged on both interfaces are identical. In the best case, ASTP FFFIS and “Odometry for applications outside the ETCS/ERTMS” FFFIS could be merged.

The definition and implementation of the ETCS external interface “Odometry for applications outside the ETCS/ERTMS” can be considered as a pragmatic step on the full ASTP preparation:

- If the ETCS external interface “Odometry for applications outside the ETCS/ERTMS” return of experience shows that a ASTP FFFIS is not feasible, users could still rely on the ETCS external interface “Odometry for applications outside the ETCS/ERTMS”.
- If the ETCS external interface “Odometry for applications outside the ETCS/ERTMS” return of experience shows that an ASTP FFFIS considering an independent ASTP IC is feasible, the implementation of the ASTP interface will be eased by reusing the ETCS external interface “Odometry for applications outside the ETCS/ERTMS”.

Railways and suppliers must collaborate to ensure that any gaps in the specifications concerning the functionalities related to odometry do not require frequent updates or the implementation of national technical rules.

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