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LOCALISATION WORKING GROUP (LWG)

EUG Position on BASTP

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1 Executive Summary

The current evolution of the CCS as foreseen by the STIP, includes the improvement and development of new functions of the ETCS odometry in the framework of the Advanced Safe Train Positioning (ASTP). The integration of and migration to the complete ASTP has been the topic of several discussions between stakeholders (mainly railway undertakings and ETCS suppliers).

This document proposes a modular ASTP that is introduced in two steps. First, modularity is introduced (basic ASTP) on newly equipped vehicles to prepare ETCS on-board for the upgrade of ASTP. Second, the ASTP is upgraded with more functionalities which are still in development (full ASTP). The ASTP is introduced as an interoperability constituent and the interface between the ASTP and the ETCS on-board as well as other consumers of the localisation information is specified.

This is based on several arguments:

- Today and since the early beginnings of ETCS, an odometry interoperability constituent is already foreseen in the TSI even though its interfaces have not been specified.

- A CCS Consist Network (CCN) is being introduced that standardises the communication within the CCS onboard (CCS-OB) system. This network supports the distribution of data within the CCS-OB system as well as with external onboard components (e.g. TCMS) and thus supports a modular architecture of the CCS-OB system. The ETCS products will be developed to use the network. The separation of the odometry (through basic ASTP) from the ETCS on-board system at the same time the CCN is introduced creates synergies.

- The localisation information needed by the ETCS system can be defined today. This allows to define a stable interface that can already support the evolution from basic ASTP to full ASTP.

- Considering the introduction of full ASTP in 2040, the upgrade does not imply major changes on the core on-board ETCS system and does not require the whole ETCS system to be exchanged/upgraded on the vehicles already equipped with the ASTP interface. Looking at the cost reduction for the full ASTP upgrade, the economic evaluation is positive for the modular approach (see [1]).

- The mechanism of grouping interoperability constituents is allowed for a transition period. This supports the migration of the products to a modular system. The ETCS on-board needs to be prepared to be able to switch to the new interface with the upgrade to full ASTP. Even in case of grouped ICs ETCS and ASTP, the new standard ASTP interface is accessible for all other consumers.

Table of Contents

2 List of references and acronyms

2.1 References

[1] R2DATO WP23, "D23.4 – Proposal on TSI202x, SS147 Release 03," 2025-02-01.

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

[3] R2DATO WP21, "D21.2 – System requirements of ASTP system, Revision 6," 2024-11-26.

[4] Blue Arches, "Economic Analysis - ASTP," 2024-12-10.

2.2 Acronyms

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
MD	Message Data
OB	Onboard
OMS	Onboard 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)
SP	System Pillar
STIP	Standardisation and TSI Input Plan
TRDP	Train Real-Time Protocol
TSI	Technical Specification for Interoperability
WP	Work Package

2.3 Definitions

3 Scope of the document

3.1.1.1 In the STIP, which outlines the System Pillars plan for the evolution of the ETCS system, Advanced Safe Train Positioning (ASTP) is introduced in two steps with basic ASTP (STIP_29) introduced in the timeframe of TSI CCS 2027 and full ASTP (STIP_30) introduced in the timeframe of TSI CCS 2032. The scope of the basic ASTP, especially the level of modularity of the ASTP have generated discussions in the railway community. This document outlines and clarifies the opinion of the ERTMS Users Group (EUG) Localisation Working Group (LWG) on the level of modularity and the interface definition to be introduced within the scope of the basic ASTP.

3.1.1.2 To do this, 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).

3.1.1.3 The document then presents the following two options for the basic ASTP step and how they will migrate to full ASTP.

3.1.1.4 Baseline scenario: The odometry is part of the ETCS on-board subsystem. Full ASTP will be introduced in a second step. This introduces the new functionalities of full ASTP along with some external interfaces (e.g. map, augmentation) that are needed for these functionalities. Full ASTP remains integrated in the ETCS on-board subsystem.

3.1.1.5 Modular scenario: Basic ASTP is a separate interoperability constituent containing today's odometry functionality. There is a FFFIS interface between ASTP and ETCS on-board, which can be used also for other sub-systems. Full ASTP, which is an upgrade of the basic ASTP interoperability constituent only, can be introduced without modification of the ETCS-OB due to the same interface as Basic ASTP. External interfaces to new components (e.g. map, augmentation) can be added at a later stage.

3.1.1.6 The two options are discussed and finally, the position of the EUG LWG is summarised.

4 Introduction

4.1 Definition of IC and grouping of IC

4.1.1.1 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:

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

4.1.2 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 4-1 : TSI 2023 extract, chapter 5

4.1.3 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 4-2 : TSI 2023 extract, chapter 5.2.2

4.1.4 Odometry equipment Interoperability Constituent

4.1.4.1 TSI 2023 and former versions already define an IC related to odometry defined 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 4-3 : 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 4-4 : TSI 2023 extract, chapter 5.3, table 5.1

4.1.5 Odometry equipment Interoperability Constituent interface

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

4.2 Previous initiatives

4.2.1.1 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.

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

4.2.2.1 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:

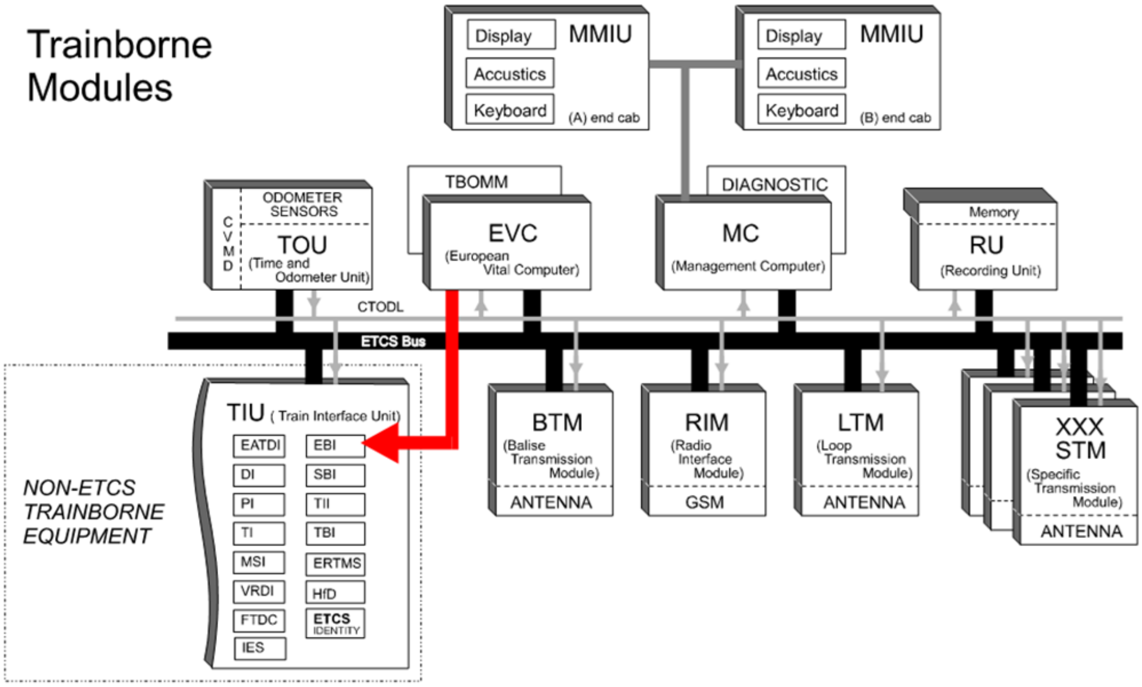

Figure 4-5: Extract from UIC ETCS SRS version 3.01 (A5499J-03.01-960809)

4.2.2.2 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.

4.2.3 Previous definition of an ODOMETER FFFIS

4.2.3.1 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

4.3 Ethernet CCS Consist Network

4.3.1 Introduction

4.3.1.1 Today many interfaces between different CCS components on the vehicle are proprietary. The proprietary interfaces lead to a complex lifecycle management including strong supplier dependence, resulting in high costs and risks for the operator of the on-board ETCS. Furthermore, 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 [1]).

4.3.1.2 The communication stack proposed for SS-147 v2 in [1] is briefly summarised here:

4.3.1.2.1 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.

4.3.1.2.2 Middle layers (OSI layers 4-6): The middle layers are divided into different communication types and specified according to communication type:

4.3.1.2.3 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.

4.3.1.2.4 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.

4.3.1.2.5 Remote Procedure Calls (RPC): RPC communication shall use HTTP over TCP or TLS (HTTPS) depending on the security needs.

4.3.1.2.6 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.

4.3.1.2.7 Audio & Video Streaming: For the transfer of streaming data several streaming protocols are proposed such as RTSP, RTP, SRTP or RTCP.

4.3.1.3 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 FFIS interface.

4.3.1.4 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.

4.3.1.5 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.

4.3.1.6 In the following table the protocol stack for process data based on [1] 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[1])	(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 4-1: Protocol Stack Process Data based on [1]

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

4.3.2.1 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.

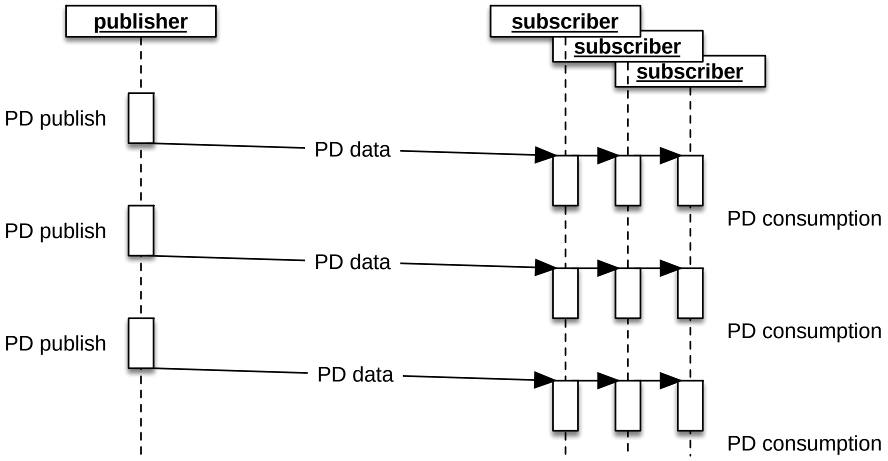

Figure 4-6: Communication Pattern TRDP PD Multicast

[1] Safety Layer is only applicable for safety-related data traffic.

4.3.2.2 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.

4.4 Application Layer Interface ASTP

4.4.1 Introduction

4.4.1.1 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 4.3.2).

4.4.1.2 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.

4.4.2 Definition of datasets for ASTP

4.4.2.1 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.

4.4.2.2 Moreover, WP21 already defined a proposal concerning the output datasets of ASTP (see [2] and [3]). Even though this proposal is subject to evolution, it gives a certain number of datasets that already consider full ASTP.

4.4.2.3 For more information some of the datasets mentioned above and which are of interest to the ASTP communication for basic ASTP are included in the appendix of this document (see section 7).

5 Migration from today to Full ASTP

5.1 Baseline scenario (non-modular approach)

5.1.1.1 In the baseline scenario, 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 EVC can be proprietary interfaces (black arrows in Figures below). This is illustrated in Figure 5-1 below. The interfaces to other consumers such as ATO or other consumers would have to be implemented according to the interface specification (blue arrows in Figure 5-1 and Figure 5-2). These interfaces are the same as in the modular scenario in Chapter 5.2. They 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 any consumer who is interested in. Distributing this data enables innovation in the future. This publish/subscribe mechanism of the CCN also minimizes the effort in case of future enhancements.[2]

5.1.1.2 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 (e.g. “shared services”). It is used for non-safe purposes only like OMS part of ETCS-OB (SS-149).

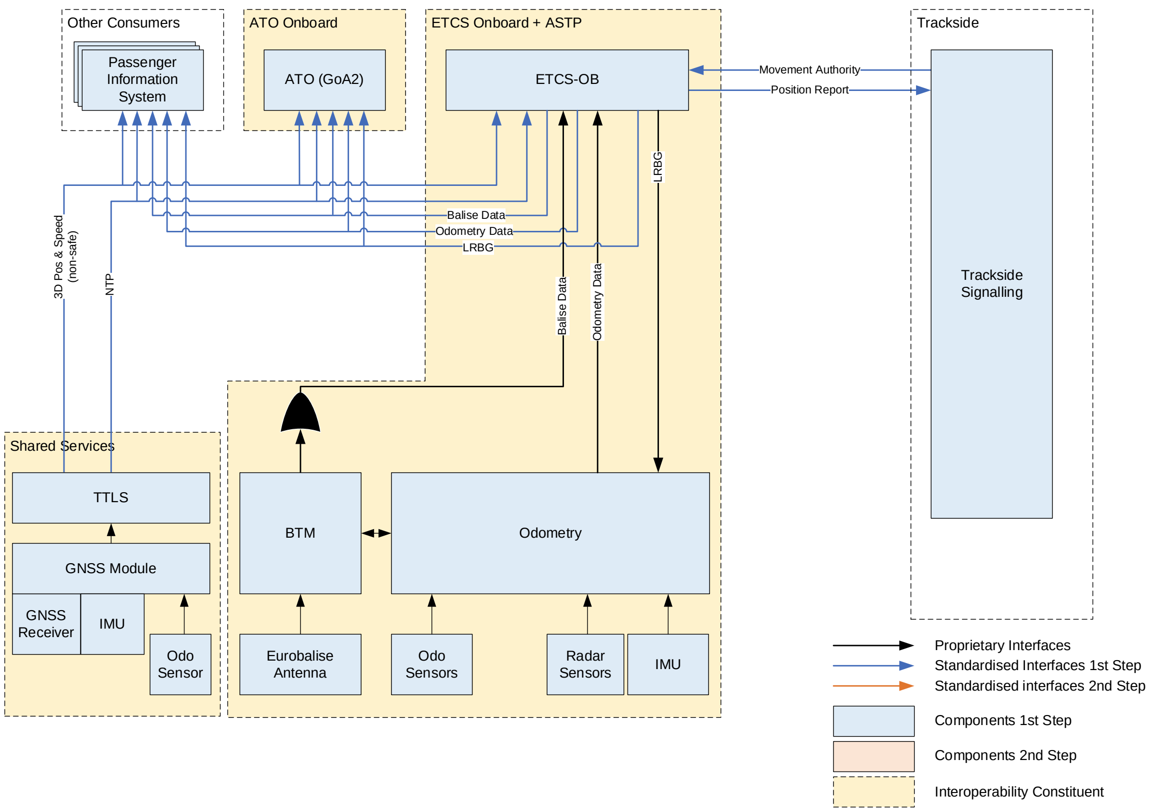

Figure 5-1: Architecture for base scenario before implementation of full ASTP.

5.1.1.3 The migration to full ASTP in the base scenario keeps the integration of ASTP, BTM and ETCS on-board. External standardised interfaces (red arrows in Figure 5-2) 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, these are inserted in the Balise data stream through a logical *or*-gate.

5.1.1.4 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-

[2] The exact definition and type of the distributed data is part of further investigations.

OB, BTM needs to be replaced by products of another supplier. This results in additional high investments for railway undertakings without any benefits besides ASTP.

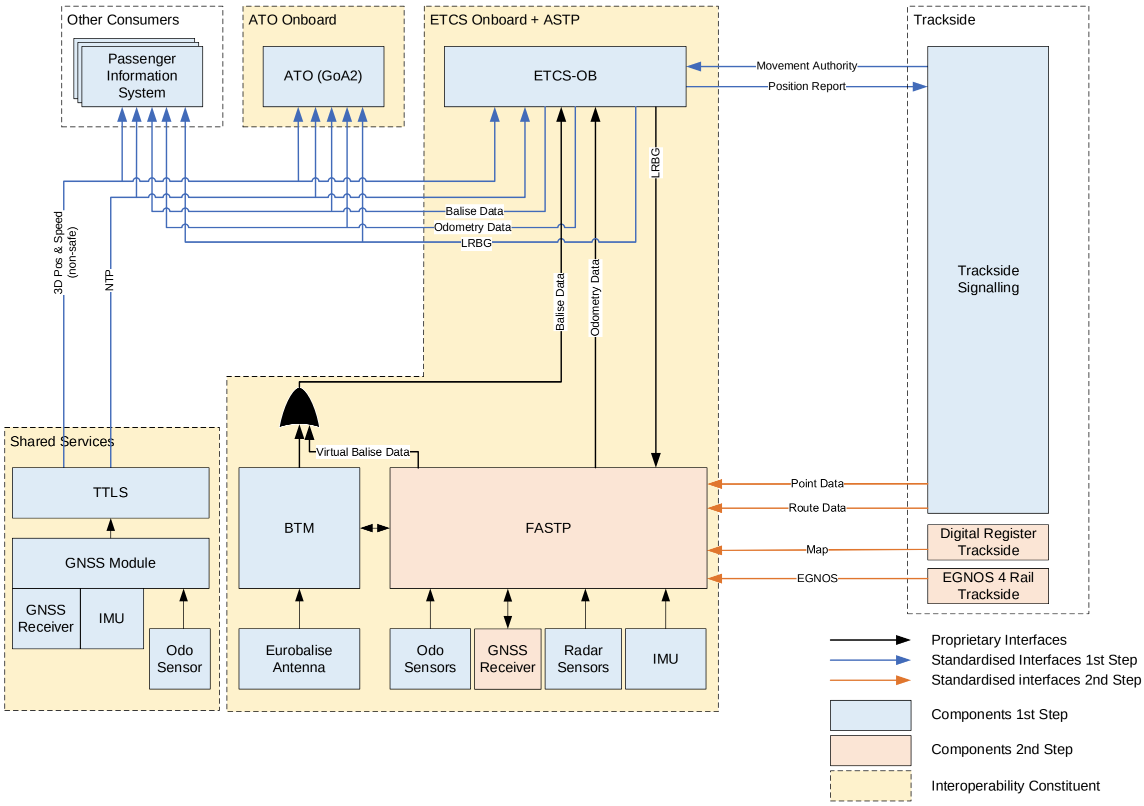

Figure 5-2: Architecture for base scenario after migration to full ASTP.

5.1.1.5 TTLS is drawn as separate IC. 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.

5.2 Modular scenario

5.2.1.1 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 4.3.2) 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. Figure 5-3 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. Alternatively, a grouping of ASTP with the BTM could be considered.

5.2.1.2 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 shown in Figure 4-1.

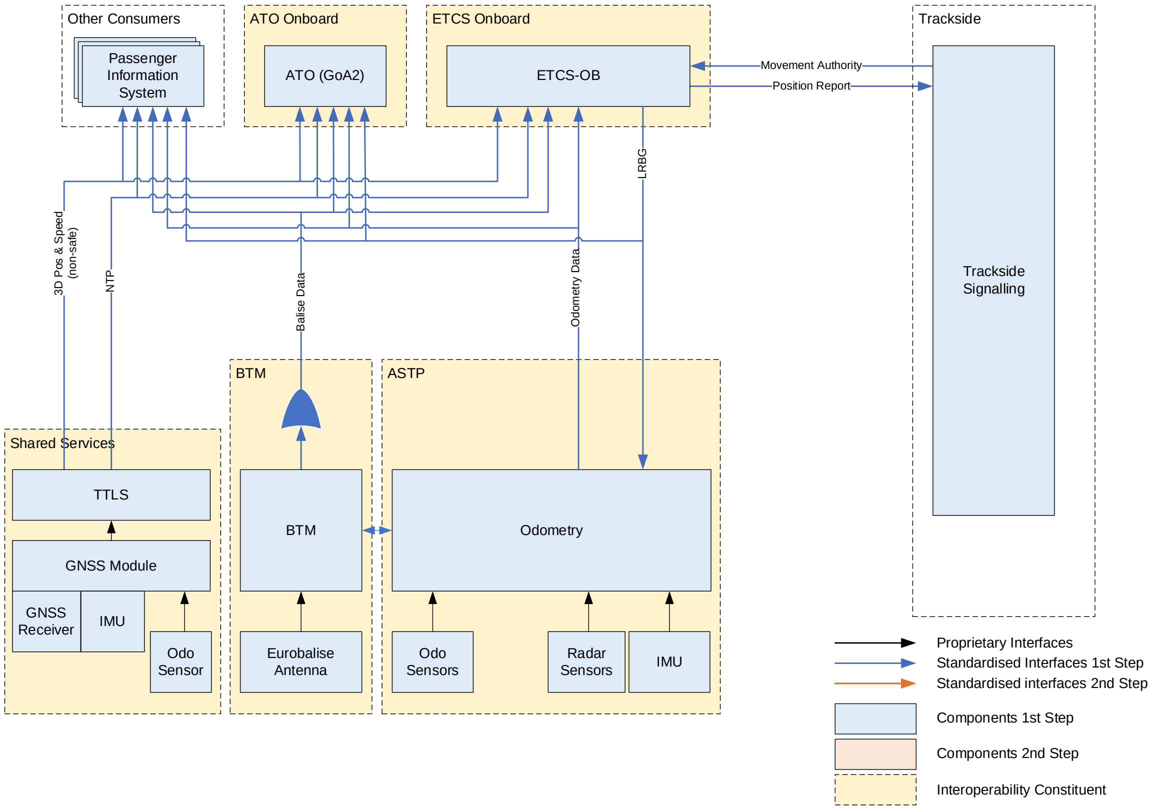

Figure 5-3: Architecture for the modular scenario before migration to full ASTP.

5.2.1.3 The migration to full ASTP introduces similarly to the baseline scenario, standardised external interfaces (red arrows in Figure 5-4) for the additional information needed by the full ASTP, such as Route or Map data. Figure 5-4 shows the architecture after migration to full ASTP.

5.2.1.4 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, even though the *or*-gate is shown as part of the BTM, no preparation is needed for this transition. Additionally, the input to ASTP from ETCS on-board concerning the identification of the last relevant balise group (LRBG) also needs to be defined.

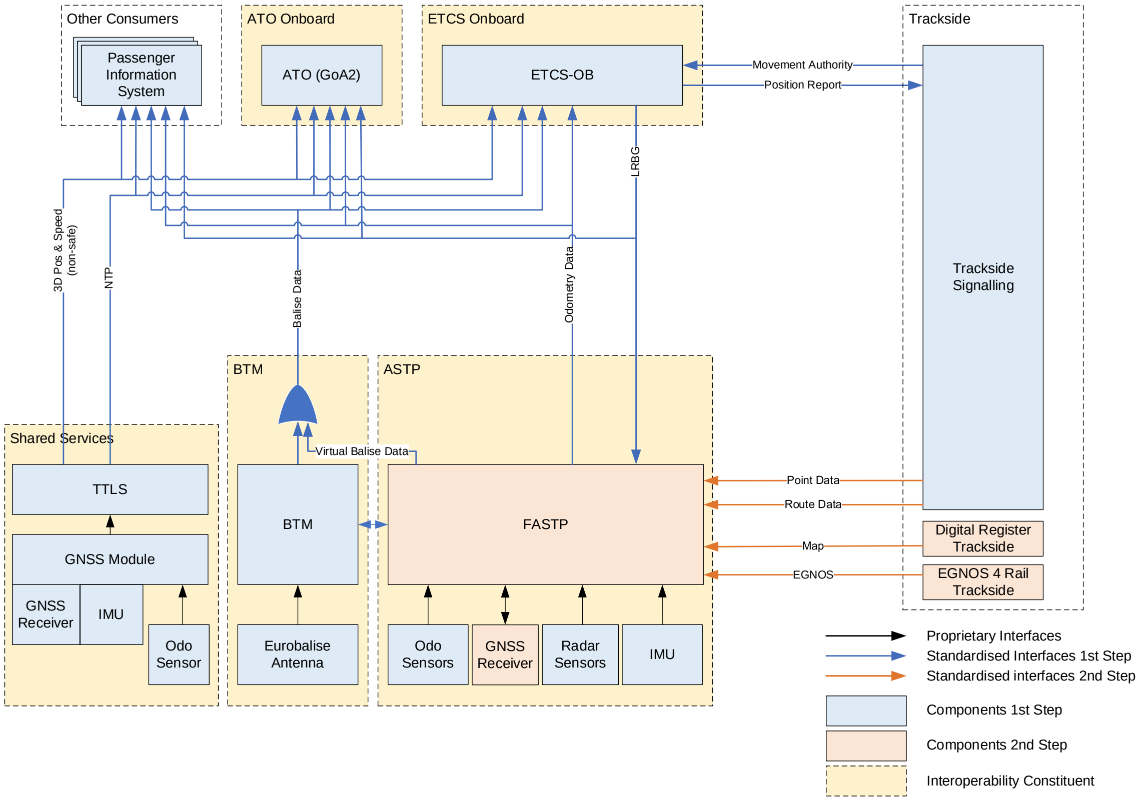

Figure 5-4: Architecture for the modular scenario after migration to full ASTP.

5.3 Possibilities of grouping

5.3.1.1 In the modular scenario, three interoperability constituents, the BTM, the ASTP and the ETCS on-board, are defined. In current supplier architectures, these constituents are often integrated into one subsystem. Due to the mechanism of grouping, even if interoperability constituents are defined, they can be grouped within the framework given by the TSI (see also section 4.1.3). This gives flexibility to the suppliers to design the systems accordingly. However, this also reduces the benefits of defining a modular solution. Here possible grouping options are discussed.

5.3.2 Grouping of the BTM, the ASTP and the ETCS on-board.

5.3.2.1 In this case, the situation as presented in the baseline scenario (section 5.1) is recovered. The ASTP interface to external systems still needs to be provided but internal interfaces can be implemented differently. This grouping can be useful during a transition period to help with the migration of current supplier architectures to a modular system. To get the benefits of the modular approach, especially the reduction of complexity and costs during a partial upgrade, this solution should not be implemented beyond the transition period unless the internal interfaces of the subsystems are prepared according to the specification of the standardised interfaces.

5.3.3 Grouping of BTM and the ETCS on-board.

5.3.3.1 In this case, the ASTP remains a separate subsystem. The upgrade from basic to full ASTP is feasible as the interfaces of the ASTP are implemented as defined in the specification. This grouping does not restrict ASTP and can be accepted from this point of view.

5.3.4 Grouping of the BTM and the ASTP.

5.3.4.1 In this case, the BTM and ASTP are separated from the ETCS on-board but grouped into one subsystem. This creates a dependency between the BTM and the ASTP. Upgrading one system can have an impact on the other. The grouping is acceptable from the point of view of ASTP as the dependency remains limited to the BTM and as the systems are closely linked anyway (virtual balise, odometry relocation with balise). A proprietary interface between ASTP and BTM can also help the performance of the interface for time-critical information exchanges between ASTP and BTM which might be needed.

5.4 Impact of the introduction of the CCN

5.4.1.1 With the introduction of the Ethernet CCS Consist Network (CCN), as a backbone for CCS communication, each equipment including ETCS on-board and ASTP will need to comply with the CCN specifications and constraints such as a safe and secure protocol and time stamp mechanism.

5.4.1.2 The suppliers will need to add a software and/or hardware component to interface with the CCN that will handle, among other things, the encoding and decoding of the communication protocols and the time synchronisation and verification.

5.4.1.3 It is important to note here that CCN compliance will need to be demonstrated to fulfil SUBSET 147 for all components. The cost to develop the CCN interface are thus not attributable to ASTP.

5.4.1.4 Assuming the availability of the CCN, the impact of introducing the ASTP FFFIS for all consumers (modular scenario) or for all consumers except the ETCS on-board (baseline scenario) is very similar. In the following paragraphs an example of a possible ETCS-OB evolution is described.

5.4.1.5 Figure 5-5 shows for illustration purposes an example implementation for the baseline scenario that allows for minimal change to the ETCS system. The standardised datasets are generated by the ETCS on-board from its supplier-specific odometry data and distributed to the other consumers of the odometry data over the CCN. As the CCN interface is mandatory for ETCS on-board anyway, this can be done with minimal effort.

5.4.1.6 Figure 5-6 shows how this situation can be realised for the modular scenario with the ASTP as a separate interoperability constituent while also considering a minimal change to the ETCS system. For this illustration, the BTM was grouped with the ETCS on-board. The main difference is that here, the supplier-specific odometry data is generated from the standardised datasets that are available on the CCN. In the baseline scenario, the CCN interface only needed to transfer the supplier-specific data to the standardised data sets. Here, the CCN interface of the ETCS-OB needs to do the transfer in the opposite direction, namely generate the supplier-specific data from the standardised data sets. Therefore, the odometry part of the former ETCS-OB can be deactivated. In this example the ETCS-OB is still fed by the proprietary odometry interface. As a result, the impact on ETCS-OB is minimized.

5.4.1.7 Even though every supplier might have different internal odometry data representations, the data are translatable to and from the datasets defined for the ASTP FFFIS.

5.4.1.8 If this is considered during the development of the CCN interfaces, the separation of the ASTP as an interoperability constituent can be introduced with only small additional efforts.

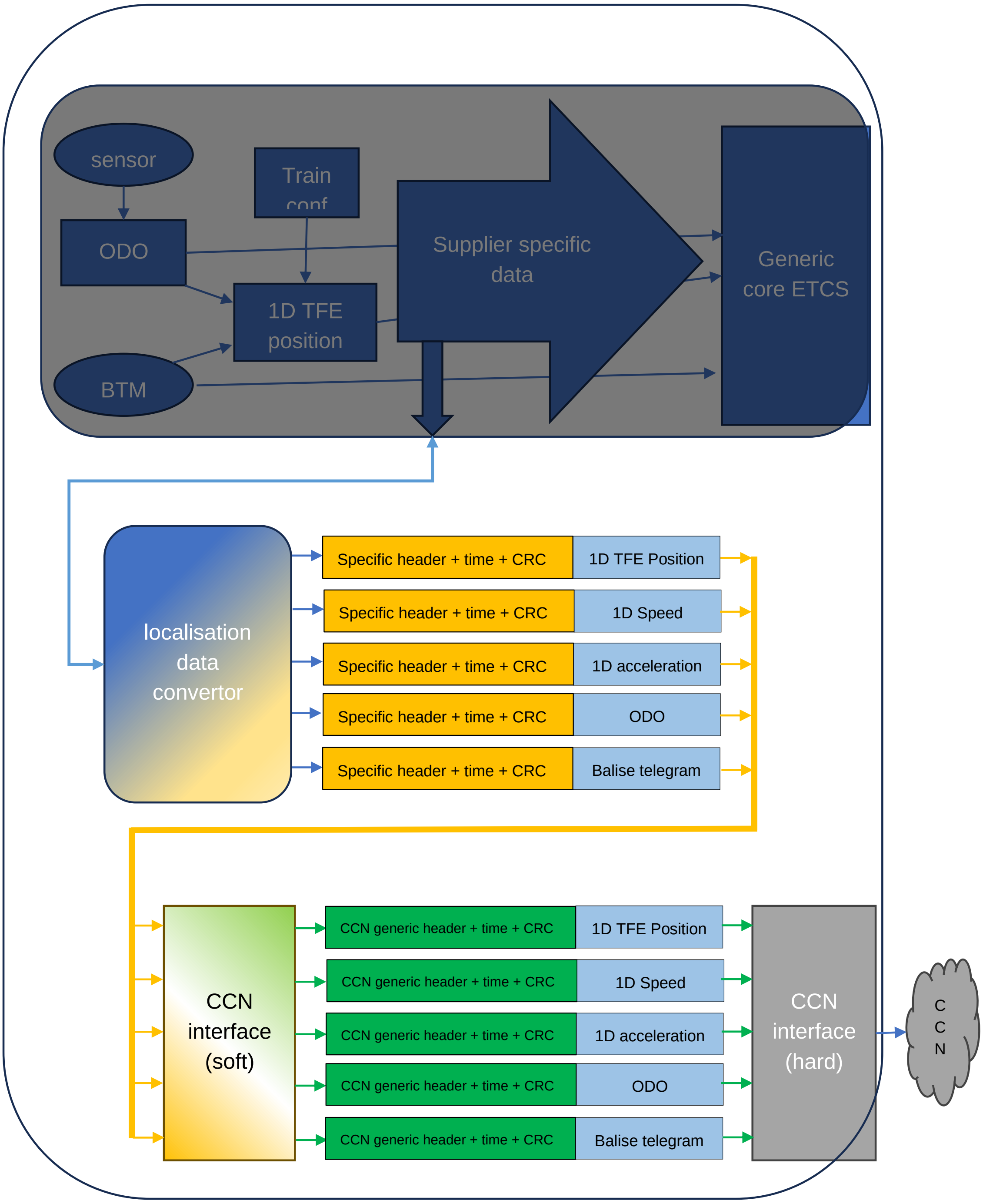

Figure 5-5 : implementation of the ASTP interface within a monolithic ETCS on-board

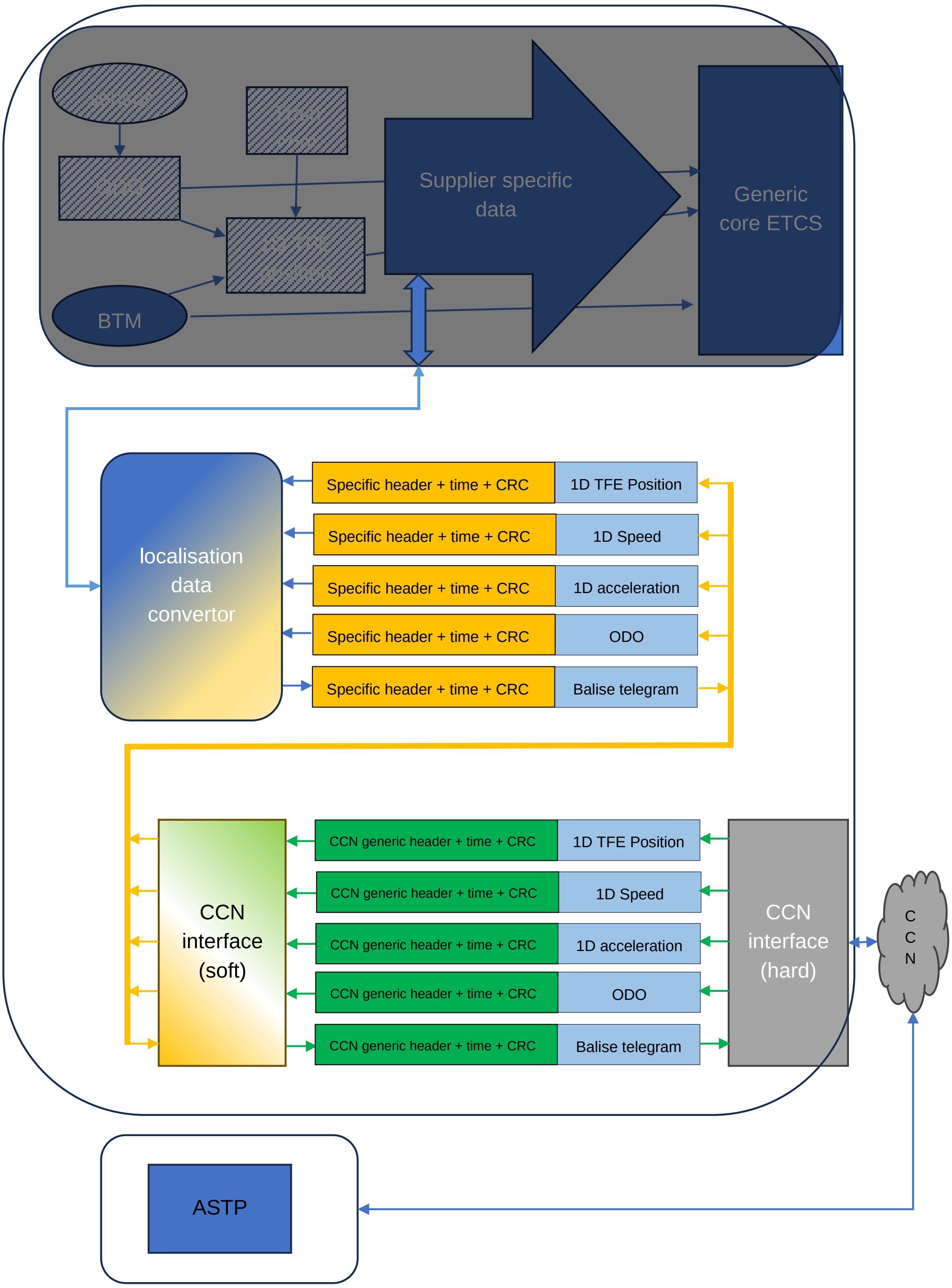

Figure 5-6 : introduction of an external Full ASTP reusing the ASTP interface

5.5 Cost Benefit Analysis

5.5.1.1 The introduction of a modular ASTP through the ASTP interface and the associated migration, as outlined in section 5.2, should take place if it leads to an advantageous cost-benefit assessment for the total lifecycle. Especially the costs on the operator side should not be neglected.

5.5.1.2 The cost of the modular ASTP comes from the additional standardisation effort and the development costs of the ETCS system suppliers to update their products when the ASTP interface is introduced.

5.5.1.3 The benefits of a modular ASTP are realised when the modular ASTP system is updated or upgraded, as the modularity with standardised interfaces reduces the scope of the update or upgrade and thus leads to savings on the cost of the upgrade.

5.5.1.4 The costs and benefits depend strongly on the future evolution of the vehicle fleet and the ETCS systems the vehicles are equipped with. However, it is widely accepted by the railways and the ETCS system suppliers that a full ASTP shall be introduced once mature. This is assumed to happen around 2040 and gives a scenario that can be analysed in terms of costs and benefits.

5.5.1.5 Based on the scenario of the introduction of full ASTP around 2040, a cost-benefit analysis [4] was performed within the system pillar activities. This analysis shows a clear positive cost-benefit assessment (net present value of 101 M€, see also Figure 5-7) for the introduction of a modular ASTP (according to chapter 5.2) already with TSI CCS 2027/28 under the following assumptions:

- The modular ASTP (according to chapter 5.2) is only implemented on new vehicles equipped with ETCS, introduced after 2032, considering development time to adapt the ETCS products.

5.5.1.5.1 Total development costs of 85 M€ for the specification work as well as the development of adapted ETCS products of all suppliers.

- 20 % of the vehicle fleet is upgraded with full ASTP from 2042 to 2044.
- A modular ASTP (modular scenario described in chapter 5.2) reduces the upgrade cost of full ASTP by 50 k€ per vehicle compared to the baseline scenario described in chapter 5.1.

5.5.1.6 In the point of view of the authors of this document, these assumptions (especially the cost reduction during the upgrade to full ASTP and the development costs) are considered conservative and should thus be realistically attainable. The assumed development costs could even be reduced by the fact, that the products will need to be adapted to the newly introduced CCN, which presents an opportunity to introduce modular systems and make full use of the CCN and its communication capabilities (see section 5.4). This synergy will not be able to be leveraged if the architecture is updated only during the full ASTP upgrade.

5.5.1.7 In the case where the supplier of the initial ETCS installation takes advantage of the vendor lock-in, the benefit would be even higher as assumed in the CBA.

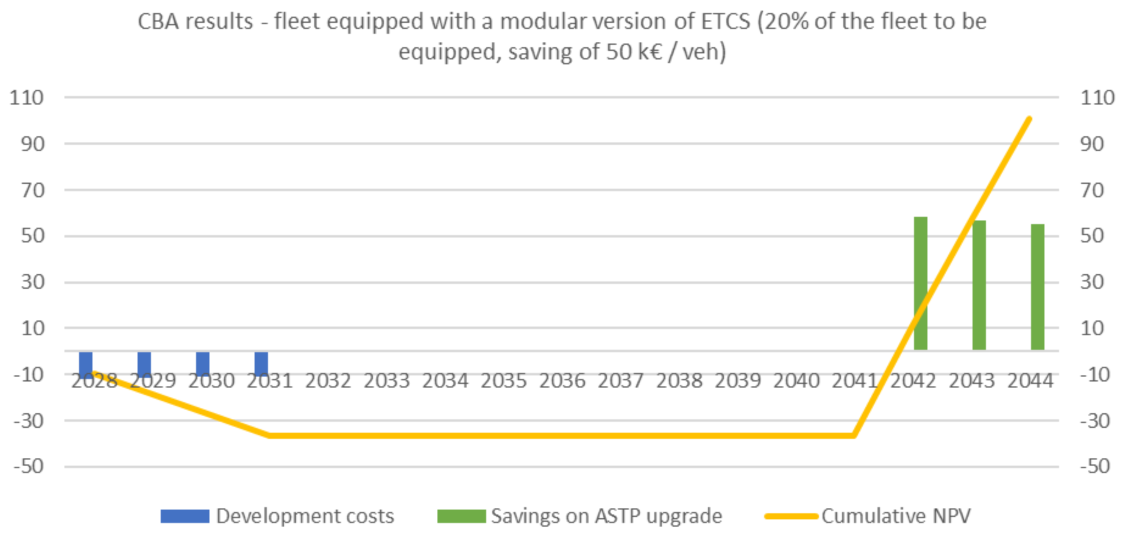

Figure 5-7: CBA results – fleet equipped with a modular version of ETCS (20% of the fleet to be equipped, savings of 50 k€ / veh), reproduced from [4]

6 Summary of EUG-LWG position

6.1.1.1 The EUG-LWG is in favour of defining ASTP as new IC replacing the current "odometry equipment" IC and specifying a FFFIS interface for ASTP to profit from the benefits of this architectural decision.

6.1.1.2 The interface shall also include ASTP to ETCS on-board communication in line with the modular approach (see section 5.2)

6.1.1.3 The interface definition should be introduced together with the first step of basic ASTP and provide evolvability/upgradability to full ASTP. This is supported by the CCN which will reach maturity with the next TSI. The modular approach provides a positive cost-benefit assessment compared to the baseline scenario due to the investment protection of core ETCS on-board. The effort to define the FFFIS ASTP to ETCS on-board interface is comparable whether it is done with basic ASTP or with full ASTP. There is no point in delaying this effort.

6.1.1.4 Grouping of ASTP, BTM and ETCS on-board, or a subset of these, can be allowed for a transition period. This supports the migration of the products to a modular system. The ETCS on-board needs to be prepared to be able to switch to the new interface with the upgrade to full ASTP.

6.1.1.5 Even in case of grouped ICs ETCS and ASTP, the new standard ASTP interface shall be accessible for all other consumers.

7 Appendix A: Output datasets of ASTP

7.1.1.1 In order to define output datasets for ASTP, it is interesting to consider the information currently available. This is composed by other interfaces distributing odometry information nowadays and deliverables of the R2DATO project WP21. An introduction to these interfaces and datasets is given in the subsequent sections.

7.2 ETCS – STM interface (SUBSET-035 and SUBSET-058)

7.2.1.1 SUBSET-035 defines the Specific Transmission Module FFFIS including odometry.

7.2.1.2 The defined bus is PROFIBUS. Odometry data is multicast using the reserved address 127.

5.2.3 Odometer

5.2.3.1 Odometry data & parameters shall be sent by the ERTMS/ETCS on-board to all STMs using multicast messages.

Figure 7-1: SUBSET 35 extract

7.2.1.3 SUBSET 58 defines the data packets that need to be provided by ETCS including odometer information

7.3.2 Packet STM-8: Odometer multicast

Subset-035 Ref.	§5.2.3.1, 5.3.1.1, 6.5.1.5, 12.1, 12.2, 12.3		
Allowed to send in states	any state, multicast		
Description	Periodic transmission of odometer data.		
Direction of information	**From ERTMS/ETCS on-board function to STM**		
Content	**Variable**	**Length**	**Comment**
	NID_PACKET	8	Packet identifier Value = 8
	L_PACKET	13	Packet length
	T_ODO	32	Timestamp
	V_MAX	16	Upper bound of the measured speed.
	V_EST	16	Estimated speed value.
	V_MIN	16	Lower bound of the measured speed.
	D_MAX	32	Positive direction side of the confidence interval.
	D_EST	32	Estimated value of distance.
	D_MIN	32	Negative direction side of the confidence interval.
	D_RES	8	Resolution of distance measurement.

Figure 7-2: SUBSET-058 extract

7.3 ETCS – ATO interface (SUBSET-130)

7.3.1.1 SUBSET 130 defines the ATO-OB / ETCS-OB FFFIS Application Layer. The transport layer concerning the ETCS / ATO interface is assumed to be defined in SUBSET 147.

7.3.1.2 Packet Number 6 includes localisation information but also balise information and is reproduced below:

6.2.2.2 Packet Number 6: ETCS_ATO_Dynamic

Packet Number		***6***			
Item	**Variable Name**		**Description**	**Data Type**	**Resolution/Formula**
Positioning Information					
	Bit	POSITION_REPORT_SET	Position Report BITSET	BITSET8	
5	0..1	Q_DIRSOLR	See [Ref 5] §4.2.3.5		See [Ref 5] §4.2.3.5
6	2..3	Q_DSOLR	See [Ref 5] §4.2.3.5		See [Ref 5] §4.2.3.5
7	4..7	Spare			
8	N_LOC_REF		Value of the position counter at the moment the data of the packet is determined.	INT32	**Resolution:** 1 cm **Special value:** $(2^{31}-1)$ = spare Note: the "spare" value is used as a special value in other variables which depend on this counter (e.g. N_LOC_REFBALISE).
9	T_LOC_REF		Time at which the position counter is determined.	UINT32	**Resolution:** 1 ms **Special value:** $(2^{32}-1)$ = unknown
10	N_LOC_REFBALISE		Value of the position counter at the center of balise used as location reference by the ETCS on-board, i.e. the reference balise of the ETCS SOLR or the balise duplicating this one, see [Ref 4] §3.16.2.3.3.	INT32	**Resolution:** 1 cm **Special value:** $(2^{31}-1)$ = unknown
11	NID_ACTIVE_ANTENNA_SOLR		Identification of the antenna active when the reference balise of the ETCS SOLR was passed	UINT8	**Values:** 0 = antenna 1 1 = antenna 2 2 = antenna 3 3 = antenna 4 **Special Values:** 4 - 255 = spare

Packet Number	6			
Item	**Variable Name**	**Description**	**Data Type**	**Resolution/Formula**
12	NID_REFBALISE	Identification of the balise used as location reference by the ETCS on-board, i.e. the reference balise of the ETCS SOLR or the balise duplicating this one, see [Ref 4] §3.16.2.3.3.	BITSET32	**Values:** Bit00 to bit02 = N_PIG as defined in [Ref 4] § 7.5.1.81 Bit03 to bit16 = NID_BG as defined in [Ref 4] § 7.5.1.85 Bit17 to bit26 = NID_C as defined in [Ref 4] § 7.5.1.86 Bit27 to bit31 = not relevant **Special values:** $(2^{32}-1)$ = unknown
13	T_LOC_REFBALISE	Time at which the position counter was equal to N_LOC_REFBALISE.	UINT32	**Resolution:** 1 ms **Special value:** $(2^{32}-1)$ = unknown
14	N_LOC_BALISERUNOVER1	Value of the position counter at the last balise passed.	INT32	**Resolution:** 1 cm **Special value:** $(2^{31}-1)$ = unknown
15	NID_ACTIVE_ANTENNA_BRO1	Identification of the antenna active when the last balise was passed	UINT8	**Values:** 0 = antenna 1 1 = antenna 2 2 = antenna 3 3 = antenna 4 **Special Values:** 4 - 255 = spare
16	NID_BALISERUNOVER1	Identification of the last balise passed.	BITSET32	**Values:** Bit00 to bit02 = N_PIG as defined in [Ref 4] § 7.5.1.81 Bit03 to bit16 = NID_BG as defined in [Ref 4] § 7.5.1.85 Bit17 to bit26 = NID_C as defined in [Ref 4] § 7.5.1.86 Bit27 to bit31 = not relevant **Special values:** $(2^{32}-1)$ = unknown
17	T_LOC_BALISERUNOVER1	Time at which the position counter was equal to N_LOC_BALISERUNOVER1.	UINT32	**Resolution:** 1 ms **Special value:** $(2^{32}-1)$ = unknown
18	N_LOC_BALISERUNOVER2	Value of the position counter at the balise passed before NID_BALISERUNOVER1.	INT32	**Resolution:** 1 cm **Special value:** $(2^{31}-1)$ = unknown
19	NID_ACTIVE_ANTENNA_BRO2	Identification of the antenna active when the last balise before NID_BALISERUNOVER1 was passed	UINT8	**Values:** 0 = antenna 1 1 = antenna 2 2 = antenna 3 3 = antenna 4 **Special Values:** 4 - 255 = spare
20	NID_BALISERUNOVER2	Identification of the balise passed before NID_BALISERUNOVER1.	BITSET32	**Values:** Bit00 to bit02 = N_PIG as defined in [Ref 4] § 7.5.1.81 Bit03 to bit16 = NID_BG as defined in [Ref 4] § 7.5.1.85 Bit17 to bit26 = NID_C as defined in [Ref 4] § 7.5.1.86 Bit27 to bit31 = not relevant **Special values:** $(2^{32}-1)$ = unknown

Packet Number		*6*		
Item	**Variable Name**	**Description**	**Data Type**	**Resolution/Formula**
21	T_LOC_BALISERUNOVER2	Time at which the position counter was equal to N_LOC_BALISERUNOVER2.	UINT32	**Resolution:** 1 ms **Special value:** $(2^{32}-1)$ = unknown
22	L_UNCERTAINTY_OVERREADING	Over-reading amount of the confidence interval to the train position referred to the SOLR.	UINT32	**Resolution:** 1 cm **Special values:** $(2^{32}-1)$ = unknown
23	L_UNCERTAINTY_UNDERREADIN G	Under-reading amount of the confidence interval to the train position referred to the SOLR.	UINT32	**Resolution:** 1 cm **Special values:** $(2^{32}-1)$ = unknown
Speed and Acceleration Information				
49	V_EST	Current estimated train speed calculated by ETCS Odometry.	UINT16	**Resolution:** 1 cm/s **Special values:** 16668 - 65534 = spare 65535 = unknown
50	V_DELTA0	Compensation of the inaccuracy of the speed measurement. See [Ref 4] §3.13.9.3.2.10.	UINT16	**Resolution:** 1 cm/s **Special values:** 16668 - 65534 = spare 65535 = unknown

Packet Number		*6*		
Item	**Variable Name**	**Description**	**Data Type**	**Resolution/Formula**
51	A_EST	Current estimated train acceleration calculated by ETCS-OB.	INT16	**Resolution:** 1 mm/s² **Values:** -5000 … +5000 = Deceleration (negative)/Acceleration (positive) **Special Values:** -32768 … -5001 = spare 5001 … 32766 = spare **Special values:** 32767 = unknown

Figure 7-3: SUBSET 130 extract

7.4 R2DATO WP21

7.4.1.1 R2DATO WP21 defined a first proposal concerning the output datasets (see [2] and [3]). This proposal is subject to evolution. Some datasets that are relevant for the ASTP to ETCS on-board communication are reproduced here, more datasets can be found in [3]:

- Safe train front end 1D position dataset (FP2-ASTP-SRS-002):

Data	Unit / resolution	Range	Safety assumption	default invalid value
Reference location id	N/A	$[0;2^{32}-2]$	Safety related	$2^{32}-1$
Position qualifier	N/A	0 Reverse 1 Nominal 2 Unknown	Safety related	Unknown
Estimated distance	Cm (0.01m) / 1 cm	$[0; 2^{32}-2]$	Safety related (used to define the max/min train safe front end)	$2^{32}-1$
Underestimation of the estimated distance	Cm (0.01m) / 1 cm	$[0; 2^{32}-2]$	Safety related	$2^{32}-1$
Overestimation of the estimated distance	Cm (0.01m) / 1 cm	$[0; 2^{32}-2]$	Safety related	$2^{32}-1$
Track edge id	N/A	$[0; 2^{32}-2]$	Safety related if no trackside train detection is available	$2^{32}-1$
Validity timestamp	Depending on the selected technique	Depending on the selected technique	Safety related (safe time management)	Depending on the selected technique
Function status	N/A	0 Non-available 1 Available	Not safety related	Non-available

- Safe train speed dataset (FP2-ASTP-SRS-003):

data	Unit / resolution	Range	Safety assumption	default invalid value
Movement direction	N/A	0 Reverse 1 Nominal 2 Unknown	Safety related	Unknown
Estimated ASTP speed	0.1km/h | 0.1km/h	[0;6000]	Safety related (used to define the max safe speed)	6001
Underestimation ASTP speed	0.1km/h | 0.1km/h	[0;6000]	Safety related	6001
Overestimation ASTP speed	0.1km/h | 0.1km/h	[0;6000]	Safety related	6001
Validity timestamp	Depending on the selected technique	Depending on the selected technique	Safety related (safe time management)	Depending on the selected technique
Function status	N/A	0 Non-available 1 Available	Not safety related	Non-available

- Safe train acceleration dataset (FP2-ASTP-SRS-004):

data	Unit / resolution	Range	Safety assumption	default invalid value
Estimated ASTP acceleration	$0.01m/s^2$ | $0.01m/s^2$	[-1000;1000]	Safety related (used to define the max safe acceleration)	1001
Underestimation ASTP acceleration	$0.01m/s^2$ | $0.01m/s^2$	[-1000;1000]	Safety related	1001
Overestimation ASTP acceleration	$0.01m/s^2$ | $0.01m/s^2$	[-1000;1000]	Safety related	1001
Validity timestamp	Depending on the selected technique	Depending on the selected technique	Safety related (safe time management)	Depending on the selected technique
Function status	N/A	0 Non-available 1 Available	Not safety related	Non-available

- Odometer output dataset (FP2-ASTP-SRS-010):

data	Unit / resolution	Range	Safety assumption	default invalid value
Estimated distance travelled	cm / 1 cm	$[-2^{31}; 2^{31}-2]$	Safety related (used to define the max/min train safe front end)	$2^{31}-1$
Estimated distance max	cm / 1 cm	$[-2^{31}; 2^{31}-2]$	Safety related	$2^{31}-1$
Estimated distance min	cm / 1 cm	$[-2^{31}; 2^{31}-2]$	Safety related	$2^{31}-1$
Estimated train speed	0.1m/s | 0.1m/s	[0;1700]	Safety related (used to define the max safe speed)	1701
Maximum train speed	0.1m/s | 0.1m/s	[0;1700]	Safety related	1701
Minimum train speed	0.1m/s | 0.1m/s	[0;1700]	Safety related	1701
Validity timestamp	Depending on the selected technique	Depending on the selected technique	Safety related (safe time management)	Depending on the selected technique
Function status	N/A	0 Non-available 1 Available	Not safety related	Non-available

- Virtual Reference Location dataset (FP2-ASTP-SRS-086):

Data	Unit / resolution	Range	Safety assumption	default invalid value
Reference location id	N/A	$[0;2^{32}-2]$	Safety related	$2^{32}-1$
Region ID	N/A	$[0;2^{32}-2]$	Safety related	$2^{32}-1$
Orientation	N/A	0 Reverse 1 Nominal 2 Unknown	Safety related	Unknown
Validity timestamp	Depending on the selected technique	Depending on the selected technique	Safety related (safe time management)	Depending on the selected technique
Function status	N/A	0 Non-available 1 Available	Not safety related	Non-available