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GNSS Augmentation for ERTMS/ETCS

System Requirement Specification

EUG Solution for Enhanced Onboard Localisation Change Request (CR1368) – GNSS Augmentation for ERTMS/ETCS

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1 Introduction

1.1 Scope and Purpose

- 1.1.1.1 GNSS Augmentation (GA) for ERTMS/ETCS aims to provide a framework to support the use supported GNSS Augmentation System such as EGNOS (the European Geostationary Navigation Overlay Service) to enable the use of Global Navigation Satellite Systems (GNSS) within enhanced on-board localisation in a technology-neutral manner.
- 1.1.1.2 GNSS Augmentation Systems use ground monitoring stations at known positions to receive and process navigation signals from core GNSS constellations with the objective of protecting users from feared events (e.g., satellite failures), estimating common errors (e.g., satellite orbit / clock errors, ionospheric errors that are also applicable to users) and providing differential corrections and integrity information (statistical bound on the correction residual errors and ionospheric errors) to users to improve accuracy and increase confidence in the positioning solution.
- 1.1.1.3 GNSS Augmentation (GA) can play an important role in supporting safe positioning concepts for enhanced on-board localisation with benefits including the following:
- GA is very effective in detecting system faults as it has access to ground truth. Techniques such as RAIM for the detection of satellites faults is intrinsically weaker, as receiver autonomous techniques require the navigation solution to be overdetermined, and therefore require at least 5 satellites (more for fault detection and exclusion) and requirements for strong geometry. GA can protect the user against system faults even with only 4 satellites.
 - The use of GA allows GNSS satellites to be utilised more efficiently, as a failed satellite does not need to be detected by the GNSS receiver. In the case of a failed satellite, the receiver performance is not impacted other than by the loss of a ranging source.
 - The use of regional augmentation systems such as EGNOS provides an opportunity to leverage existing investments made for aviation with regional-level service coverage.
- 1.1.1.4 The **scope** of this document is to define the system functional requirements for GA in ERTMS/ETCS, focusing on interoperability-relevant requirements that enable the use of GNSS augmentation in a technology-neutral manner.
- 1.1.1.5 The **purpose** of this document is to define the system requirements that must be fulfilled to provide interoperable GA. This document defines the following:
- GA functional architecture and interfaces (defined to the level required to support interoperability and safety analyses);
 - GA-related functions; and
 - GA operational states.
- 1.1.1.6 The annexes of this document provide additional support information:
- Principles of GNSS augmentation for ERTMS/ETCS;
 - EGNOS-based GA for ERTMS/ETCS; and

- Open points to be addressed.

1.1.1.7 This document is part of a package of documents on the GS for ERTMS/ETCS in support of Change Request (CR1368). The package is comprised of the following documents:

- GNSS Augmentation for ERTMS/ETCS – System Requirement Specification [EUG-20E085] (this document)
- GNSS Augmentation for ERTMS/ETCS – Interface Control Document for GA-OB / GA-TS (Airgap) [EUG-20E087]
- GNSS Augmentation for ERTMS/ETCS – System Functional Hazard Analysis [EUG-20E086]
- SBAS L1 Receiver Guidelines – On-board [ESSP-TN-25931]
- SBAS L1 Receiver Guidelines – Trackside [ESSP-TN-26038]
- SBAS DFMC Receiver Guidelines – On-board [ESSP-TN-26136]
- SBAS DFMC Receiver Guidelines – Trackside [ESSP-TN-26137]

1.2 References

1.2.1.1 The following documents are references in this document:

PERSPECTIVE	ERA, "Report on ERTMS Longer Term Perspective," 18/12/2015.
[SS041]	UNISIG, "ERTMS/ETCS – Performance Requirements for Interoperability – SUBSET-041 Issue 3.2.0." 2015.
[SS091]	UNISIG, "ERTMS/ETCS – Safety Requirements for the Technical Interoperability of ETCS in Levels 1 & 2 – SUBSET-091 Issue 3.6.0." 2016.
[EUG-20E087]	EUG, "GNSS Augmentation for ERTMS/ETCS – Interface Control Document for GA-OB / GA-TS (Airgap). Version 0f." 2022.
[EUG-20E086]	EUG, "GNSS Augmentation for ERTMS/ETCS – System Functional Hazard Analysis. Version 0f." 2022.
[EN50159]	CENELEC, "Railway applications – Communication, signalling and processing systems – Safety-related communication in transmission systems – EN 50159." CENELEC, Brussels, Belgium, 2010.
[ESSP-TN-25931]	ESSP, "SBAS L1 Receiver Guidelines for Railway – On-board Unit. Issue 01-00." 2020.
[ESSP-TN-26038]	ESSP, "SBAS L1 Receiver Guidelines for Railway – Trackside Unit. Issue 01-00." 2020.

[ESSP-TN-26136]	ESSP, "SBAS DFMC Receiver Guidelines for Railway – On-board Unit. Issue 01-00." 2020.
[ESSP-TN-26137]	ESSP, "SBAS DFMC Receiver Guidelines for Railway – Trackside Unit. Issue 01-00." 2020.
[DO-229]	RTCA, "DO-229F – Minimum Operational Performance Standards for Global Positioning System/Satellite Based Augmentation System Airborne Equipment." RTCA Inc., Washington D.C., USA, 2020.
[ED-259]	EUROCAE, "ED-259A (v0.12) – Minimum Operational Performance Standard for Galileo / Global Positioning System / Satellite-based Augmentation System Airborne Equipment." Saint-Denis, France, 2022.
[IS-GPS-200]	GPS Directorate, "Interface Specification – NAVSTAR GPS Space Segment / Navigation User Segment User Interfaces – IS-GPS-200. Rev. M." 2021.
[IS-GPS-705]	GPS Directorate, "Interface Specification – NAVSTAR GPS Space Segment / User Segment L5 Interfaces – IS-GPS-705. Rev. H." 2021.
[GAL-OS-SIS-ICD]	European Commission, "European GNSS (Galileo) Open Service – Signal-in-Space Interface Control Document. Issue 2.0." 2021.

1.3 Terms and Abbreviations

1.3.1.1 The following terms and abbreviations are used in this document:

APDU	Application Protocol Data Unit
ATPL	Along Track Protection Level
CDF	Cumulative Distribution Function
CED	Clock and Ephemeris Data
CEI	Clock, Ephemeris, Integrity (data set)
CONOPS	Concept of Operations
CPF	Central Processing Facility
CRC	Cyclic Redundancy Check
CSD	Circuit Switched Data
DFC	Dual Frequency Correction
DFMC	Dual Frequency Multiple Constellation
DFRE	Dual Frequency Range Error (dual frequency UDRE)
DFRECI	Dual Frequency Range Error Change Indicator
DFREI	Dual Frequency Range Error Indicator
ECAC	European Civil Aviation Conference
EEIG	European Economic Interest Group
EGNOS	European Geostationary Navigation Overlay Service (SBAS developed by the European Union)
EGPRS	Enhanced GPRS
EIRP	Effective Isotropic Radiated Power
ENT	EGNOS Network Time
ERA	European Union Agency for Railways (formerly European Railway Agency)
ERTMS	European Rail Traffic Management System
ESA	European Space Agency
ESSP	European Satellite Services Provider
ETCS	European Train Control System
EUG	EEIG ERTMS Users Group

EVLF	Enhanced Vehicle Localisation Function
FFFIS	Form-Fit Functional Interface Specification
FIS	Functional Interface Specification
FMEA	Failure Modes and Effects Analysis
FRMCS	Future Railway Mobile Communication System
GA	GNSS Augmentation
GAC	GNSS Augmentation Channel
GADF	GNSS Augmentation Dissemination Function
GAM	GNSS Augmentation Message
GANT	GNSS Augmentation Network Time
GA-OB	GNSS Augmentation On-board
GAS	GNSS Augmentation System
GATF	GNSS Augmentation Trackside Function
GA-TS	GNSS Augmentation Trackside
GEO	Geostationary Earth Orbit
GIVE	Grid Ionospheric Vertical Error
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSA	European GNSS Agency
GSM-R	Global System for Mobile Communications – Railway
HAL	Horizontal Alert Limit
HLDC	High Level Data Link Control
HMI	Hazardous Misleading Information
HPL	Horizontal Protection Level
HR	Hazard Rate
IC	Interoperability Constituent
IOD	Issue of Data
IODC	Issue of Data Clock
IODE	Issue of Data Ephemeris
IODF	Issue of Data Fast Corrections

IODG	Issue of Data used for matching MT39/40 pair in DFMC service
IODI	Issue of Data Ionospheric
IODN	Issue of Data Navigation Data (Galileo E1 I/NAV and E5a F/NAV)
IODM	Issue of Data Mask
IODP	Issue of Data PRN Mask
IODS	Issue of Data Service
IP	Internet Protocol
LPV	Localizer Performance with Vertical Guidance
MAC	Message Authentication Code
MCC	Mission Control Centre
MI	Misleading Information
MOPS	Minimum Operation Performance Standard
MT	Message Type
NLES	Navigation Land Earth Station
NLOS	Non-Line-Of-Sight
OBAD	Old But Active Data
OBU	On-Board Unit
OS	Open Service
PDM	Position Domain Monitor
PRN	Pseudo-Random Noise
PS	Packet Switched
PSD	Packet Switched Data
RAIM	Receiver Autonomous Integrity Monitoring
RAM	Reliability, Availability and Maintainability
RBC	Radio Block Centre
RFI	Radio Frequency Interference
RIMS	Range and Integrity Monitoring Stations
RSS	Root-Sum-Square
RTCA	Radio Technical Commission for Aeronautics
SaPDU	Safety Protocol Data Unit

SARPs	Standards and Recommended Practices
SBAS	Satellite Based Augmentation System
SDCM	System for Differential Corrections and Monitoring (SBAS developed by Russian Federation)
SDD	Service Definition Document
SIL	Safety Integrity Level
SIS	Signal in Space
SoL	Safety of Life
SoM	Start of Mission
SV	Satellite Vehicle
TBC	To Be Confirmed
TEC	Total Electron Content
THR	Tolerable Hazard Rate
TTA	Time To Alert
UDRE	User Differential Range Error
UDREI	User Differential Range Error Indicator
UIRE	User Ionospheric Range Error
UIC	Union Internationale des Chemins de fer (international union of railways)
UNIFE	Union des Industriels Ferroviaires Européennes (union of European railway industries)
UTC	Universal Time Coordinate
VAL	Vertical Alert Limit
VPL	Vertical Protection Level
xAL	Horizontal or Vertical Alert Limit
xPL	Horizontal or Vertical Protection Level

2 GNSS Augmentation (GA) for ERTMS/ETCS

2.1 Overview

2.1.1.1 The GNSS Augmentation capability for ERTMS/ETCS has been designed as an agnostic framework supporting GNSS augmentation systems that meet an agreed set of mission requirements for Railway SoL Services and are based on compatible principles (i.e., provision of a pseudorange domain integrity service). This ensures a future-proof approach that can support services as they evolve and provide different interfaces, additional capabilities, and additional commitments.

2.1.1.2 To guarantee interchangeability of GNSS augmentation systems, technical interoperability of on-board equipment is essential. The GNSS receiver in the EVLF would need to conform to requirements on critical receiver parameters (common between supported GNSS augmentation systems), ensuring the same on-board equipment can operate with different GNSS augmentation sources. The principles of GNSS augmentation for ERTMS/ETCS are described in Annex A.

2.1.2 GA Reference Functional Architecture

2.1.2.1 Figure 2-1 illustrates the high-level reference functional architecture of GNSS Augmentation for ERTMS/ETCS, which is comprised of three functions:

- a) The Enhanced Vehicle Localisation Function (EVLF)
- b) The GNSS Augmentation Dissemination Function (GADF); and
- c) The GNSS Augmentation Trackside Function (GATF).

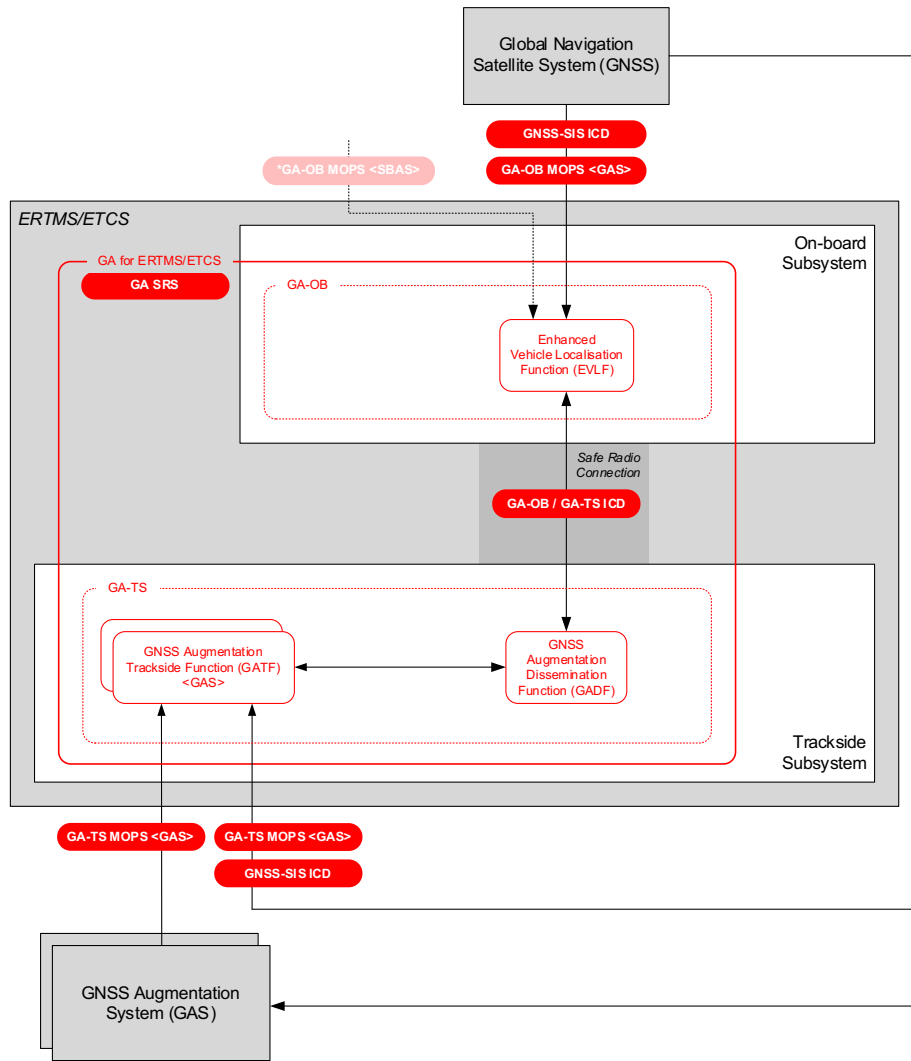


Figure 2-1. GNSS Augmentation Reference Functional Architecture for ERTMS/ETCS

2.1.2.2 The Enhanced Vehicle Localisation Function (EVLf) utilises GNSS augmentation to improve position accuracy and derive a statistical bounding (at the required level of confidence) on position errors through the application of corrections and residual pseudorange error models. The GNSS receiver implemented within the EVLf shall implement the specific Minimum Operational Performance Standards (MOPS) of the GNSS augmentation service, which addresses requirements on GNSS signal and message processing, the specificities of GAS message processing and computation of pseudorange error bounds for the specific GNSS augmentation type and service (e.g., EGNOS Legacy and DFMC Railway SoL Services¹). In addition to reception of GNSS augmentation information via the trackside, the EVLf may have an interface supporting direct reception of SBAS messages via the SBAS GEO SIS; however, principles for use of this interface are not currently defined in this version of the SRS and will be addressed in a future release. It should be noted that information from EGNOS received by the EVLf via the GADF and via the SBAS GEO SIS cannot be mixed in a single GNSS processing channel.

¹ For MOPS addressing EGNOS legacy and DFMC railway SoL services for the EVLf, refer to [ESSP-TN-25931] and [ESSP-TN-26136].

2.1.2.3 The GNSS Augmentation Dissemination Function (GADF) is responsible for the dissemination of GA messages containing correction and integrity information to the EVLF. The GADF can also provide GNSS navigation data to the EVLF to support faster start-up time, especially in difficult start-up environments (e.g., where there is significant obscuration of GNSS satellites).

The ICD for GA-OB / GA-TS [EUG-20E087] defines interoperability-relevant messages, packets and variables exchanged between the GNSS Augmentation On-board (GA-OB) and GNSS Augmentation Trackside (GA-TS).

2.1.2.4 The GNSS Augmentation Trackside Function (GATF) is responsible for the interface between the GA-TS and the GNSS Augmentation System (GAS). The GATF timestamps and encapsulates GA messages in GAM packets, leaving the in-built message protections (e.g., CRC) intact. While the GA-TS performs some message processing (e.g., in support of maintaining active data sets), by encapsulating GA messages, the complexity of the function is greatly reduced, and assumptions related to inbuilt defences against message-level hazards that are assumed by the GNSS augmentation service and its respective integrity commitments are maintained.

In addition, the GATF is responsible for obtaining navigation data from the Global Navigation Satellite System (GNSS), which is repackaged in packets optimised to provide essential CED parameters to the EVLF. This includes GNSS navigation data for constellations supported by the GAS (e.g., for EGNOS: GPS L1, L5; Galileo E1-B/C, E5a).

An ICD for the interface between the GADF and GATF(s) is not currently defined as it is not considered relevant for interoperability.

2.1.2.5 The Safe Radio Connection between the GA-OB and GA-TS is intentionally left undefined; for example, it could potentially be the EURORADIO channel between the on-board and RBC or a dedicated GNSS augmentation radio channel between the GA-OB and GA-TS.

2.1.3 Basic Functions

2.1.3.1 GNSS Augmentation for ERTMS/ETCS is comprised of the following basic functions:

Enhanced Vehicle Localisation Function (EVLF) [GA-relevant functionality only]:

- Reception of GA messages from GADF
- Reception of GA active data sets² from GADF
- Reception of GNSS navigation data from GADF
- Transmission and reception of GA session management messages and acknowledgements
- Timestamping of GA messages received from GADF

² Active data sets are sets of GA messages containing data that is valid (i.e., has not yet timed out). Reception of an active data set consisting of last received valid GA messages by the trackside reduces the amount of time needed before a valid combination of active data is available to the EVLF.

- Supervision and management of TTA
- Supervision of GA message content timeout
- GA message processing
- GNSS signal processing
- GNSS pseudorange determination and use
- Computation and application of GA corrections to smoothed pseudorange
- Computation and application of GNSS pseudorange error models

GNSS Augmentation Dissemination Function (GADF):

- Transmission of GA message streams to EVLF
- Transmission of GA active data sets to EVLF
- Transmission of GA active alerts to EVLF
- Transmission of GNSS navigation data sets to EVLF
- Transmission and reception of GA session management messages and acknowledgements
- Reception of GA messages from GATF
- Reception of GA active data sets from GATF
- Reception of GA active alerts from GATF
- Reception of GNSS navigation data sets from GATF
- Transmission and reception of GADF-GATF session management messages and acknowledgements
- Selection of GA service and channel compatible with services supported by EVLF
- Resumption of suspended GA message streams

GNSS Augmentation Trackside Function (GATF):

- Reception of messages from GAS
- Transmission of GA messages to GADF for each service / GAC
- Transmission of requested GA active data sets to GADF
- Transmission of requested GNSS navigation data sets to GADF
- Transmission and reception of GADF-GATF session management messages and acknowledgements
- Selection of GACs
- Maintain GA active data set for each GAC

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- Maintain GA active alerts for each GAC
- Timestamping reception of messages from GAS
- Encapsulation of messages received from GAS in GAM packets
- Maintain GNSS navigation data sets
- GNSS signal processing
- Processing of GAS messages to support GATF functions

Note: EVLF functionality related to reception of SBAS messages from the SBAS GEO SIS is not addressed in this document and will be addressed in a future release.

2.2 GA Functions

2.2.1 GA Session Management

2.2.1.1 The EVLF can request a GNSS augmentation (GA) session when a safe radio connection has been established with the trackside.

2.2.1.2 A GA session shall be established according to the following steps:

- a) The EVLF shall send *Message 170: Initiate GA Session* to the GADF with Packet 50, containing the GA versions supported by the EVLF. The GA version refers to the version of the GA-OB / GA-TS (refer to Section 2.2.25 on GA version management).
- b) The GADF shall respond as follows:
 - If the GADF can provide a GA session compatible with the GA versions supported by the EVLF, it shall respond with *Message 60: GA Session Established* (with M_GAVER = the GA version to be used). The GADF requires this message to be acknowledged by the EVLF.
 - If the GADF cannot provide a session compatible with supported GA versions, it shall respond with *Message 66: GA Session Error* (with M_GAERR=0, *no compatible GA version supported by on-board*).

2.2.1.3 Once an GNSS augmentation session is established, the EVLF can request allocation of a GA message stream (stream of GNSS augmentation messages from the GA-TS) or resumption of a previously suspended GA message stream (refer to Section 2.2.2).

2.2.1.4 To request allocation of a GA message stream, the EVLF shall send *Message 174: Allocate GA Message Stream* with the GA message stream identifier (NID_GAMS) and Packet 51, containing the GA services supported by the EVLF. Valid GA message stream identifiers are:

- NID_GAMS = 0, Primary GA message stream (shall be supported by the EVLF)
- NID_GAMS = 1, Secondary GA message stream (may optionally be supported by the EVLF)

2.2.1.5 The GADF shall respond as follows:

- a) If the GADF can provide a GA message stream with a service compatible with GA services supported by the EVLF, it shall respond with *Message 61: GA Message Stream Allocated / Resumed* with the following information:
 - GA message stream identifier (NID_GAMS)
 - GA service provider identifier (NID_GAP)
 - GA service identifier (NID_GAS)
 - GA channel identifier (NID_GAC)
 - GA service version (M_GASVER)
 - Packet 210: GA service national values.
- b) The GADF requires this message to be acknowledged by the EVLF before starting to send *Message 62: GA Messages* associated with the allocated GA message stream.
- c) If a GA message stream has already been allocated, the GADF shall allocate a GA message stream for a different GA channel from the same service provider or from a different service provider for a service compatible with GA services supported by the EVLF.

- d) If the GADF cannot provide a GA message stream compatible with supported GA services, it shall respond with *Message 66: GA Session Error* (with M_GAERR=1, no compatible GA service supported by on-board).

2.2.1.6 Packet 210 contains the following National Values for the GA service:

- GA maximum TTA (T_NVGAMAXTTA)
- GA maximum system TTA budget (T_NVGAMAXSYSTTA)
- GA broadcast update rate (T_NVGAMBUR)

2.2.1.7 *Message 62: GA Message* contains the following information:

- GA message stream identifier (NID_GAMS)
- Packet 212, which contains GA message type (Q_GAMT), GA time reference qualifier (Q_GAT), timestamp of the end of GA message reception by the GATF (T_GAM) and the GA message (M_GAM).

2.2.1.8 The GADF shall continue sending messages of type 62 associated with the allocated GA message stream(s) to the EVLF until terminated by:

- A request from EVLF to suspend a GA message stream;
- Termination of the GA session by the EVLF or GADF; or
- Termination of the underlying safe radio connection between the trackside and on-board.

2.2.1.9 The EVLF can suspend a GA message stream by sending *Message 176: Suspend GA Message Stream* with the GA message stream identifier (NID_GAMS). The GADF shall respond with *Message 68: GA Message Stream Suspended*.

2.2.1.10 The EVLF can terminate a GA session (and any active GA message streams) by sending *Message 173: Terminate GA Session*. The GADF shall respond with *Message 67: GA Session Terminated* (with M_ACK=0).

2.2.1.11 If the GADF terminates a GA session, it shall send *Message 67: GA Session Terminated* (with M_ACK=1), requiring the message to be acknowledged by the EVLF.

2.2.1.12 An example of establishing and terminating a GA session is illustrated by the sequence diagram in Figure 2-2.

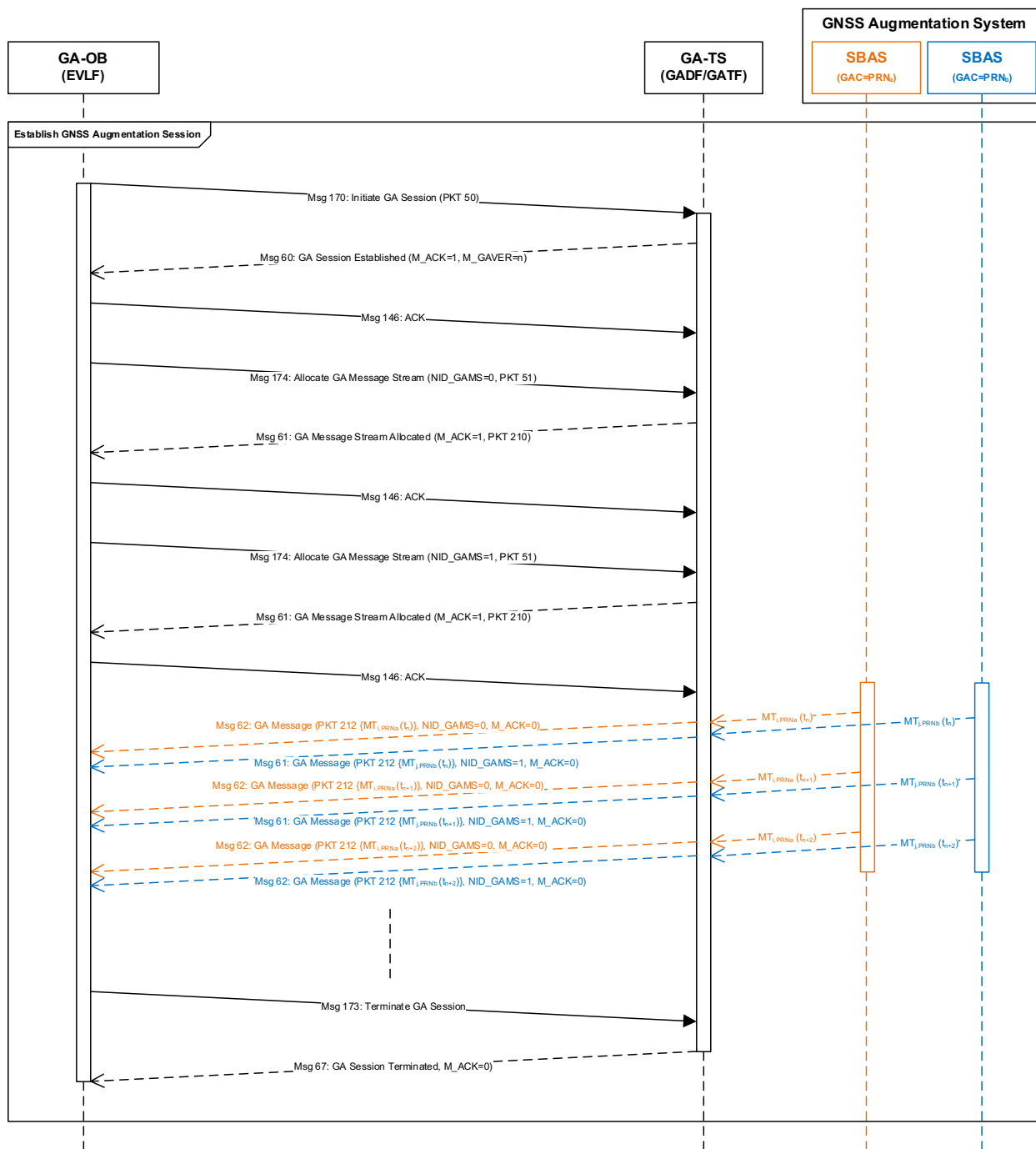


Figure 2-2. Establishing and terminating a GA Session

2.2.2 Resuming a GA Message Stream

2.2.2.1 The *resume GA message stream* function is provided to minimise impact from temporary disruption to the safe radio connection, including announced radio holes, which may result in an intervention if timer T_GATIMEOUT expires, which results in all GA integrity data for the GA message stream becoming unavailable. The *resume GA message stream* function allows the EVLF to restore integrity data that have not timed out (particularly relevant for integrity data with long update intervals and timeouts) by ensuring any active alerts (i.e., alerts that have not timed out) are processed by the EVLF before the GA message stream is resumed.

2.2.2.2 Under nominal conditions, the GA data timeout mechanism provides resilience against message loss and ensures through the application of degradation parameters, that for any valid combination of active data, residuals are bounded at the specified level of confidence. In the case of non-nominal conditions, where the GNSS augmentation system has erroneously broadcast integrity data not bounding the residuals at the required level of confidence, an alert sequence is transmitted by the GNSS augmentation system.

2.2.2.3 To restore integrity data that have not timed out, it is necessary to ensure transmission of alerts (GA messages with Q_GAMT=1) or “do not use for safety applications” (GA messages with Q_GAMT=2) have not been missed during the period from the last GA message received by the EVLF to the time of resumption of the GA message stream.

- If the timestamp of the last GA message received from the GA message stream to be resumed is known, then the GADF shall provide the on-board with all active alerts received from the timestamp of the last GA message to the time the GA message stream is resumed.
- If timestamp (T_GAM) of the last GA message received from the GA message stream to be resumed is not available / unknown, the EVLF shall not restore integrity data and shall resume processing GA messages from the state where all integrity data have timed out.

Justification: In the case of SBAS, UDREI and DFREI data has a timeout of 12 seconds; the impact of timing-out this data in the event of disruption of the GA message stream on availability and continuity is minimal due to the high update rate of the information once the GA message stream is resumed. In the case of the SBAS Legacy service, GIVEI data has a maximum update rate of 300 seconds and a timeout of 600 seconds and therefore timing-out this data has a significant impact on availability and continuity. The risk of not timing out this data is that during an outage, an alert may have been missed by the EVLF (e.g., in the case of a coverage hole in a tunnel); as this data is still active (i.e., has not timed out) when the communications link is restored, the missed alerts may result in hazardous misleading information (i.e., errors that are not bounded at the required level of confidence).

2.2.2.4 Assuming the EVLF already has an active GA session (otherwise new GA session needs to be established), it shall send a *Message 175: Resume GA Message Stream* to the GADF requesting the message stream (identified by NID_GAMS) to be resumed. Message 175: Resume GA Message Stream contains the following information:

- GA message stream identifier (NID_GAMS)
- GA reference time for T_GAM (Q_GAT)

- Timestamp from last GA message received from the GA message stream (T_GAM)

2.2.2.5 The GADF shall respond as follows:

- a) If the GADF can resume the GA message stream, it shall respond to the EVLF with *Message 61: GA Message Stream Allocated / Resumed*, requiring acknowledgement, with the following information:
 - GA message stream identifier (NID_GAMS)
 - GA service provider identifier (NID_GAP)
 - GA service identifier (NID_GAS)
 - GA channel identifier (NID_GAC)
 - GA service version (M_GASVER)
 - Packet 210: GA service national values.
- b) Once Message 61 has been acknowledged, the GADF shall send *Message 62: GA Message* to the EVLF, requiring acknowledgement, containing all active alerts covering the period from the last GA message received to the time of resumption of the GA message stream. This message shall be acknowledged by the EVLF prior to the GADF resuming the GA message stream.
- c) If there were no alerts during this period, the GADF resumes sending messages of type *Message 62: GA Message* associated with the GA message stream without acknowledgement.
- d) If the GADF cannot resume the message stream:
 - The GADF shall respond with *Message 66: GA Session Error* (with M_GAERR=2, unable to resume primary GA message stream; or M_GAERR=3, unable to resume secondary GA message stream).
 - The on-board equipment shall cease using and discard any ranging data associated with the GA message stream and all GA message types obtained from the GA message stream.

2.2.2.6 An example of resuming a GA session is illustrated by the sequence diagram in Figure 2-3.

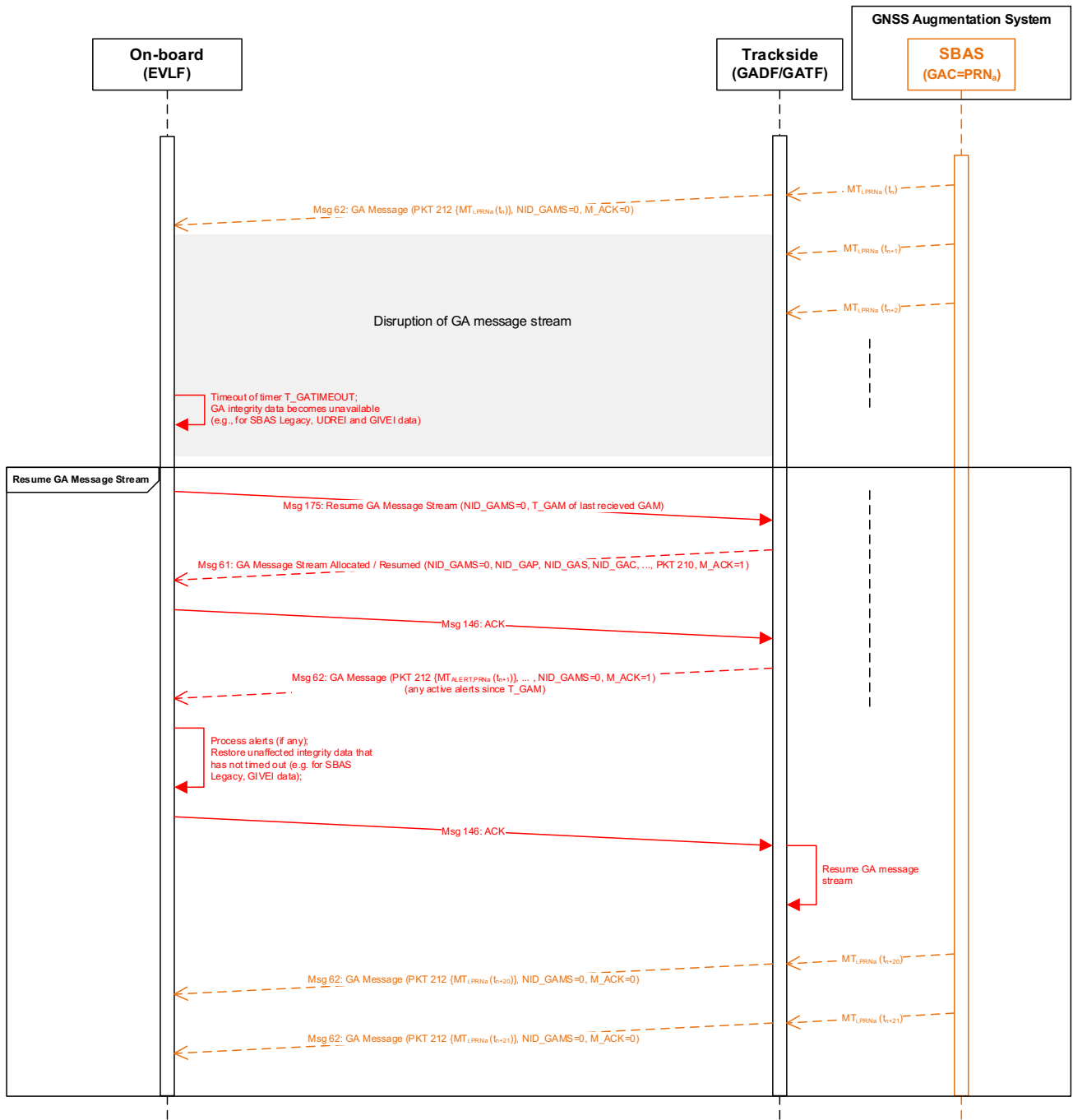


Figure 2-3. Resume GA message stream (SBAS example)

2.2.3 Provision of GA Active Data Sets to the EVLF

2.2.3.1 Once a GA session is established and a GA message stream allocated, the EVLF can make a request to the GADF for GA active data, which is comprised of a set of GA messages containing the most recent active data (i.e., data most recently received by trackside that has not yet timed out). This reduces the amount of time the EVLF needs to wait before a valid combination of active data is available allowing the GNSS channel to enter a state of availability with integrity.

2.2.3.2 GA active data shall be provided to the EVLF according to the following steps:

- a) A GA session must have already been established and a GA message stream allocated, with the EVLF processing GA messages from the GA message stream.
- b) The EVLF shall send *Message 171: GA Active Data Request* to the GADF with the GA message stream identifier (NID_GAMS).
- c) The GADF shall respond as follows:
 - If GA active data is available on the GA-TS, it shall respond with the first of n messages of *type 63: GA Active Data Set*. The GADF requires each *Message 63: GA Active Data Set* to be acknowledged by the EVLF (see below).
 - If GA active data is not available to the GA-TS, it shall respond with an empty *Message 63: GA Active Data Set* not requiring acknowledgement by the EVLF.

2.2.3.3 The GADF shall ensure that the maximum ETCS message length is not exceeded, splitting the set of packets that comprise the active data over multiple *type 63: GA Active Data Set* messages.

2.2.3.4 Each message shall be acknowledged by the EVLF, indicating to the GADF to send the next message until all n messages have been sent to and acknowledged by the EVLF.

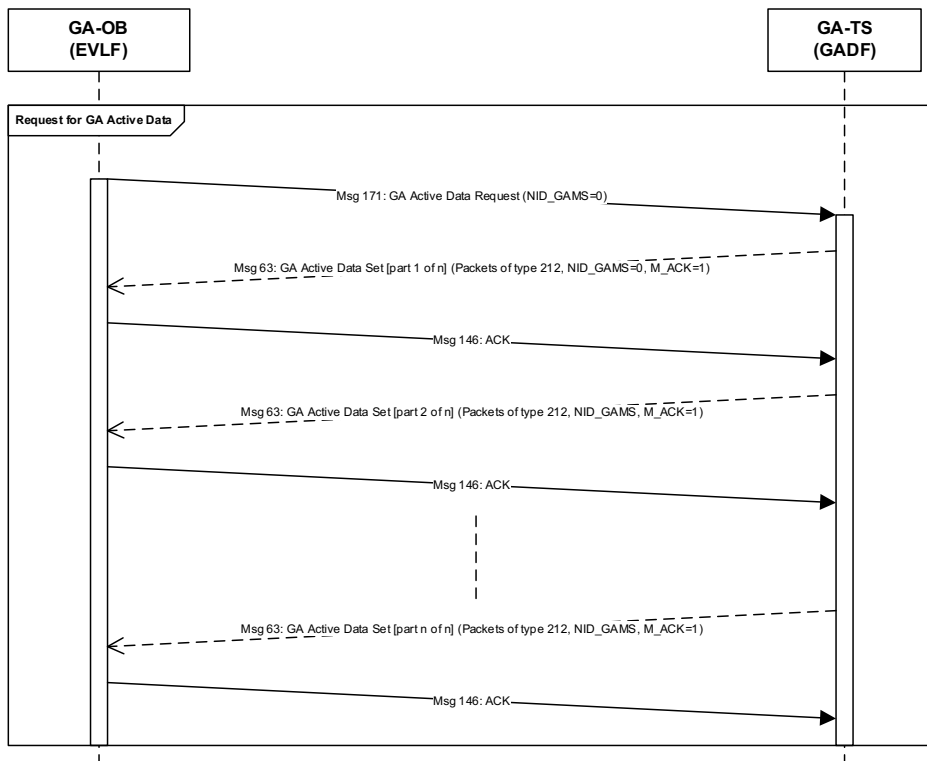


Figure 2-4. Requesting GA Active Data

2.2.3.5 If the GADF does not receive an acknowledgement message within T_GAADSRTIMEOUT seconds for one of the messages of *type 63: GA Active Data Set*, the GADF shall retransmit the unacknowledged message. Once the number of unsuccessful retransmissions reaches N_GAADSMAXRETRIES, the GADF shall abort providing *GA Active Data Set* messages.

2.2.3.6 The EVLF shall discard any GA messages provided in *GA Active Data Set* messages if the timestamp of the GA message is older than the timestamp of the same GA message type received from the GA message stream.

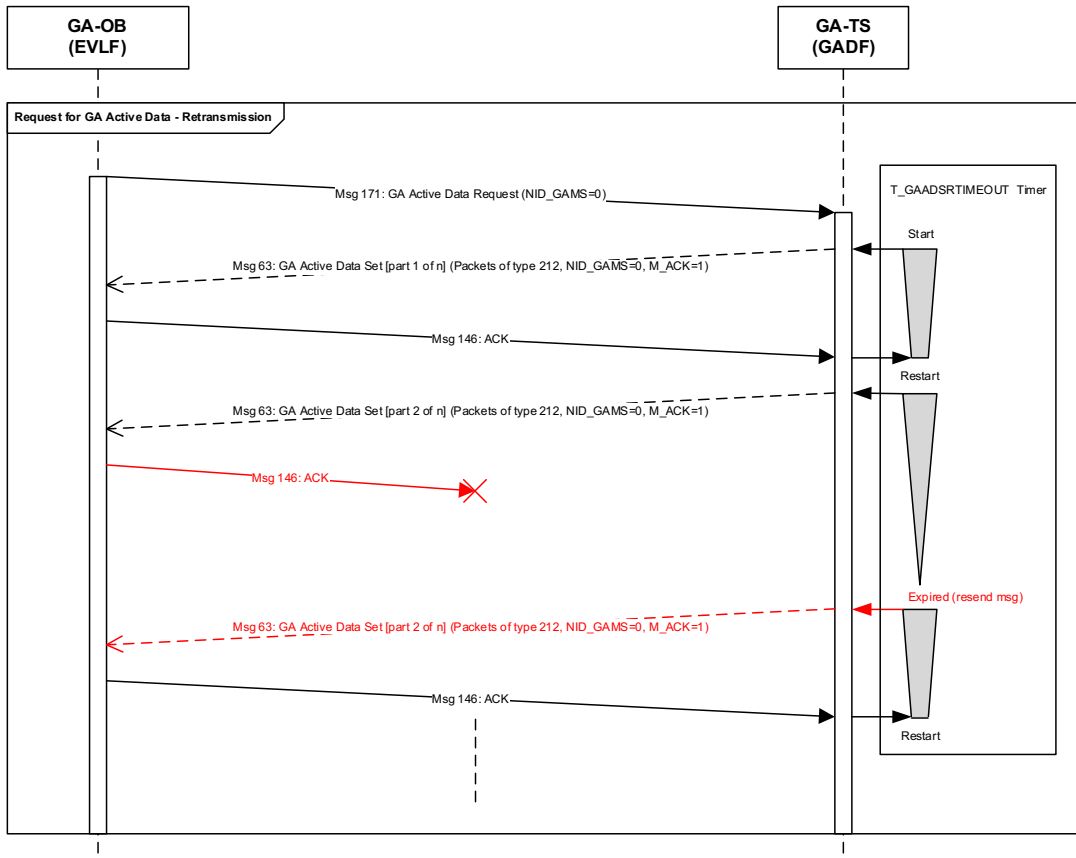


Figure 2-5. Requesting GA Active Data – Retransmission mechanism

2.2.4 Provision of GNSS Navigation Data Sets to the EVLF

2.2.4.1 Once a GA session is established, the EVLF can make a request to the GADF for GNSS navigation data. This reduces the time at start-up for the demodulation of GNSS navigation data, especially in difficult start-up environments (e.g., where there is significant obscuration of GNSS satellites).

2.2.4.2 GNSS navigation data shall be provided to the EVLF equipment according to the following steps:

- a) An GA session must have already been established.

- b) The EVLF shall send the Message 172: GNSS Navigation Data Request to the GADF with Packet 51 indicating the requested navigation datasets. Packet 51 supports multiple data requests, where for each dataset requested the following information is required:
- Satellite mask identifying the the satellites for which the navigation data is required (M_GSVMASK). The SV mask slot numbers are assigned to satellites in the order of a satellite's identifier within a given constellation (e.g., for GPS, PRN numbers; for Galileo SV identifiers). Refer to the ICD for GA-OB / GA-TS (Airgap) [EUG-20E087] for definition of packets and variables, including definition of the satellite mask;
 - The requested navigation data set (Q_GNSSNDT); and
 - The number of last broadcast sets of the requested navigation data to be provided (N_LASTND). This is to ensure the issue of data (IOD) in the GA corrections matches the IOD associated with one of the last N_LASTND different navigation datasets.
- c) The GADF shall respond as follows:
- If the requested GNSS navigation data is available on the GA-TS, it shall respond with the first of n messages of *type 64: GNSS Navigation Data Set*. The GADF requires each *Message 64: GNSS Navigation Data Set* to be acknowledged by the EVLF equipment (see below).
 - If only a partial set of the requested GNSS navigation is available on the GA-TS, the partial set shall be provided.
 - If the requested GNSS navigation data is not available to the GA-TS, it shall respond with an empty *Message 64: GNSS Navigation Data Set* not requiring acknowledgement by the EVLF.

2.2.4.3 The GADF shall ensure that the maximum ETCS message length is not exceeded, splitting the set of packets that comprise the GNSS navigation data over multiple *type 64: GNSS Navigation Data Set* messages.

2.2.4.4 Each message shall be acknowledged by the EVLF, indicating to the GADF to send the next message until all n messages have been sent to and acknowledged by the EVLF.

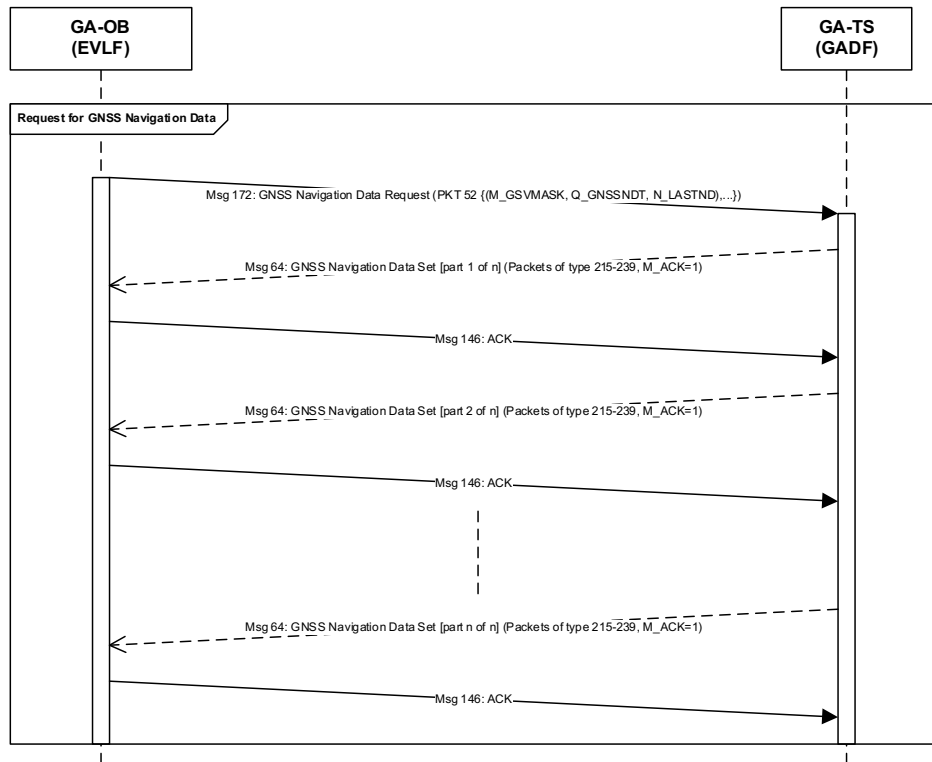


Figure 2-6. Requesting GNSS navigation data

2.2.4.5 If the GADF does not receive an acknowledgement message within T_GNSSNDSRTIMEOUT seconds for one of the messages of *type 64: GNSS Navigation Data Set*, the GADF shall retransmit the unacknowledged message. Once the number of unsuccessful retransmissions reaches N_GNSSNDSMAXRETRIES, the GADF shall abort providing *GNSS Navigation Data Set* messages.

2.2.5 GATF/GADF Management of Alerts

2.2.5.1 Under nominal conditions, the GADF shall send unacknowledged (M_ACK=0) GA messages of *type Message 62: GA Message* to the EVLF. The timeout mechanism and application of degradation parameters of messages received from the GAS ensure that integrity is guaranteed under nominal conditions for any valid combination of active data with resilience against message loss.

2.2.5.2 There are several conditions (non-nominal) where the GADF shall require acknowledgement by the EVLF:

- a) Reception of an alert from the GAS
 - The GADF shall send a *Message 62: GA Message* to the EVLF requiring acknowledgement (M_ACK=1), with Packet 212 encapsulating the alert message with Q_GAMT = 1 (GA alert message).
- b) Reception of a message from the GAS indicating service not to be used for safety applications

- The GADF shall send a *Message 62: GA Message* to the EVLF requiring acknowledgement (M_ACK=1), with Packet 212 and Q_GAMT = 2 (DNU GA message stream) indicating that the EVLF shall no longer use the GA message stream.
- In the case of SBAS, this is reception of MT0 (Do Not Use for Safety Applications); Packet 212 would encapsulate the MT0 message. MT0/0 could be received if SBAS ground system determined that there was a problem in the signals or data already transmitted. This message applies to a particular PRN signal, not the satellite itself as there could be more than one signal broadcast by an SBAS satellite; or during testing MT0/2 (Legacy) and MT0/3X (DFMC) may also be broadcast by an SBAS satellite, where the contents of MT2 or MT3X are broadcasted in each MT0.

c) GATF-GAS communications link failure

- In the case of a communications link failure between the GATF and GAS, the GADF shall send a *Message 62: GA Message* to the EVLF requiring acknowledgement (M_ACK=1), with Packet 212 and Q_GAMT = 2 (DNU GA message stream) indicating that the EVLF shall no longer use the GA message stream.
- In the case of SBAS (link between GATF and SBAS via SIS), a communications link failure is indicated when no valid SBAS message has been received for 4 consecutive seconds. Packet 212 would encapsulate a MT63 (SBAS L1 or L5 null message).

d) Other GA-TS (GADF/GATF) error conditions / failures

- The GADF shall send a *Message 62: GA Message* to the EVLF requiring acknowledgement (M_ACK=1), with Packet 212 and Q_GAMT = 2 (DNU GA message stream) indicating that the EVLF shall no longer use the GA message stream.
- In the case of SBAS, Packet 212 would encapsulate a MT63 (SBAS L1 or L5 null message).

2.2.5.3 When the GADF sends messages of *type 62: GA Message* with Packet 212 and Q_GAMT = 1 (GA alert message) to the EVLF:

- a) The GADF shall suspend the relevant GA message stream until the *GA Message* is acknowledged by EVLF (i.e., acknowledgement received by trackside).
- b) If the message is not acknowledged within T_GAMRTIMEOUT seconds, the GADF shall re-send the *type 62: GA Message* until acknowledged or the safe radio connection is terminated (i.e., due to expiry of T_NVCONTACT).
- c) Once acknowledged, the GADF shall:
 - Ensure any additional alert messages (different alert sequences) received during suspension of the message stream are sent to the EVLF in a *type 62: GA Message* requiring acknowledgement.
 - Resume the suspended GA message stream.

2.2.5.4 When the GADF sends messages of *type 62: GA Message* with Packet 212 and Q_GAMT = 2 (DNU GA message stream) to the EVLF:

- a) The GADF shall suspend the relevant GA message stream.

- b) If the message is not acknowledged within $T_GAMRTIMEOUT$ seconds, the GADF shall re-send the *type 62: GA Message* until acknowledged or the safe radio connection is terminated (i.e., due to expiry of $T_NVCONTACT$).

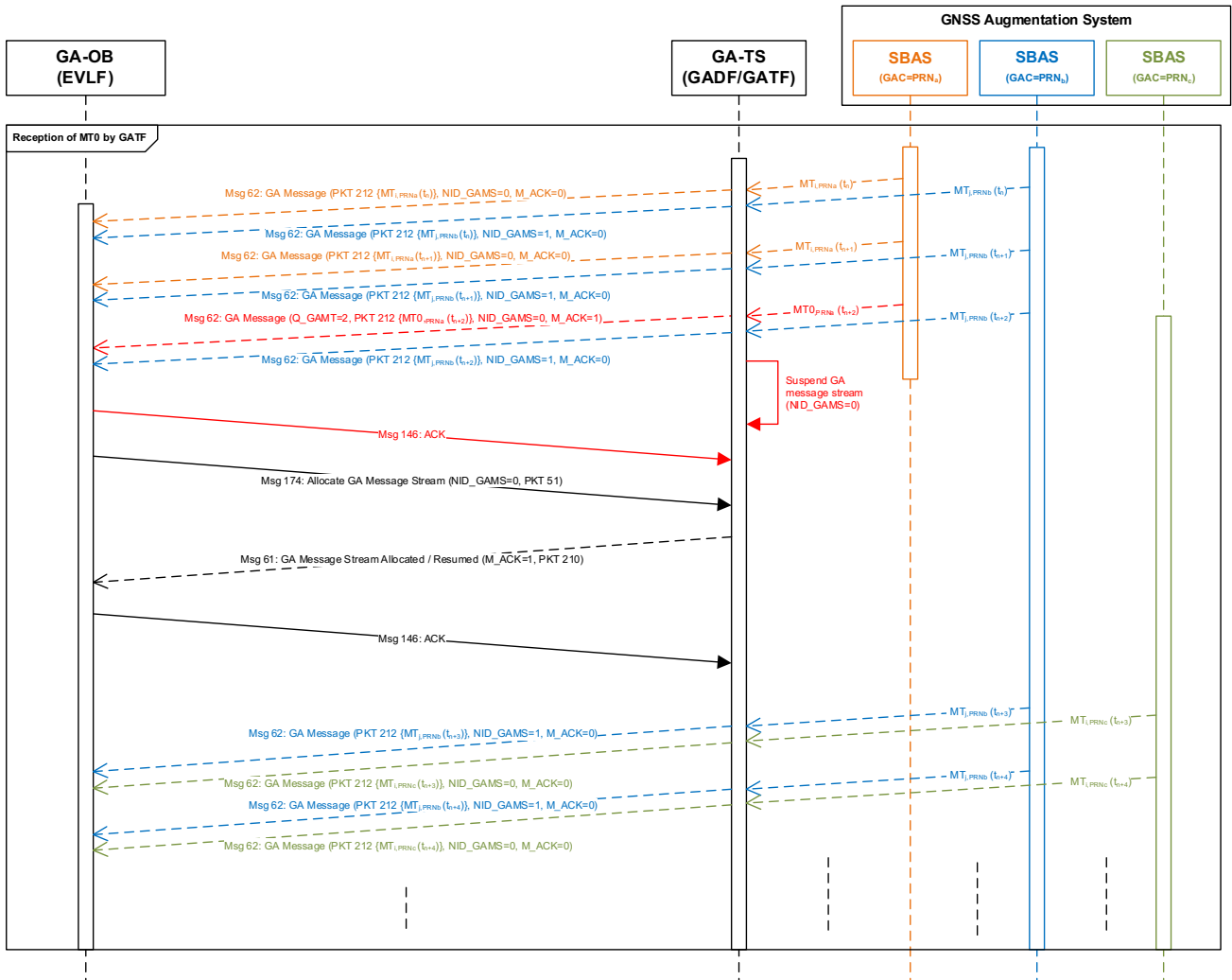


Figure 2-7. Reception of a SBAS MT0 by GATF (SBAS example)

2.2.6 Reception of a GA Message Indicating DNU GA Message Stream by EVLF

2.2.6.1 If a message *type 62: GA Message Stream* with Packet 212 and $Q_GAMT = 2$ (DNU GA message stream) is received by the EVLF:

- a) The EVLF shall acknowledge receipt of the message
- b) The EVLF shall cease using and discard any ranging data and GA data obtained from the GA message stream identified by the GA message
- c) In the case of SBAS,
 - For the SBAS L1 Legacy Service, the EVLF shall cease using and discard any ranging data and all message types 1-7, 9-10, 18, and 24-28 obtained from the GA message stream identified by the GA message.

- For the SBAS DFMC Service, the EVLF shall cease using and discard any ranging data and all message types 31, 34, 35, 36, 32, 39, 40, 37, and 42 obtained from the SBAS message stream identified by the GA message.

2.2.6.2 For EVLF capable of multi-channel GA processing (i.e., implementing two channels, each processing a different GA message stream in parallel):

- Assuming one GA message source is still healthy, the EVLF shall ensure the healthy source is selected. If the lane processing the unhealthy source is currently selected, the EVLF shall switch to the channel processing the healthy GA message stream. A GA message source is defined as healthy when it is broadcasting valid messages and no “do not use” indication has been received (i.e., for SBAS reception of MT0).
- The EVLF shall request a new GA message stream allocation to the GADF by sending *Message 174: Allocate GA Message Stream*. If a new message stream can be allocated (i.e., another healthy GA message source is available to the GADF), the EVLF shall start processing the new GA message stream after having discarded any GNSS ranging data and GA data as detailed above.

2.2.6.3 For EVLF with single-channel SBAS processing (i.e., implementing a single processing channel):

- The EVLF shall request a new GA message stream allocation to the GADF by sending *Message 174: Allocate GA Message Stream*. If a new message stream can be allocated (i.e., another healthy GA message source is available to the GADF), the EVLF shall start processing the new GA message stream after having discarded any GNSS ranging data and GA data as detailed above.
- To minimise the time the GNSS integrity is unavailable due to processing of GA messages from an initial state, the EVLF can make a request to the GADF for GA active data (refer to Section 2.2.3) to reduce the time required for the GNSS channel to enter a state of availability with integrity.

2.2.7 EVLF Supervision and Management of Alerts and Time To Alert (TTA)

2.2.7.1 Under nominal conditions, the GNSS Augmentation System (GAS) shall guarantee integrity for any valid combination of active data. Resilience against message loss is provided through timeouts for message content and the application of degradation parameters.

2.2.7.2 In the case of an alert condition, integrity is ensured with a reactive fail-safe design, where the TTA is the time elapsed from the onset of the alert condition to its detection and negation in the EVLF. An alert condition occurs when the GAS has erroneously broadcast integrity data not bounding the residuals (i.e., orbit and clock correction and ionosphere residual errors) at the required confidence level.

2.2.7.3 Figure 2-8 provides a concrete example of the timing relationships of the TTA in terms of non-train and train events for GNSS augmentation based on SBAS.

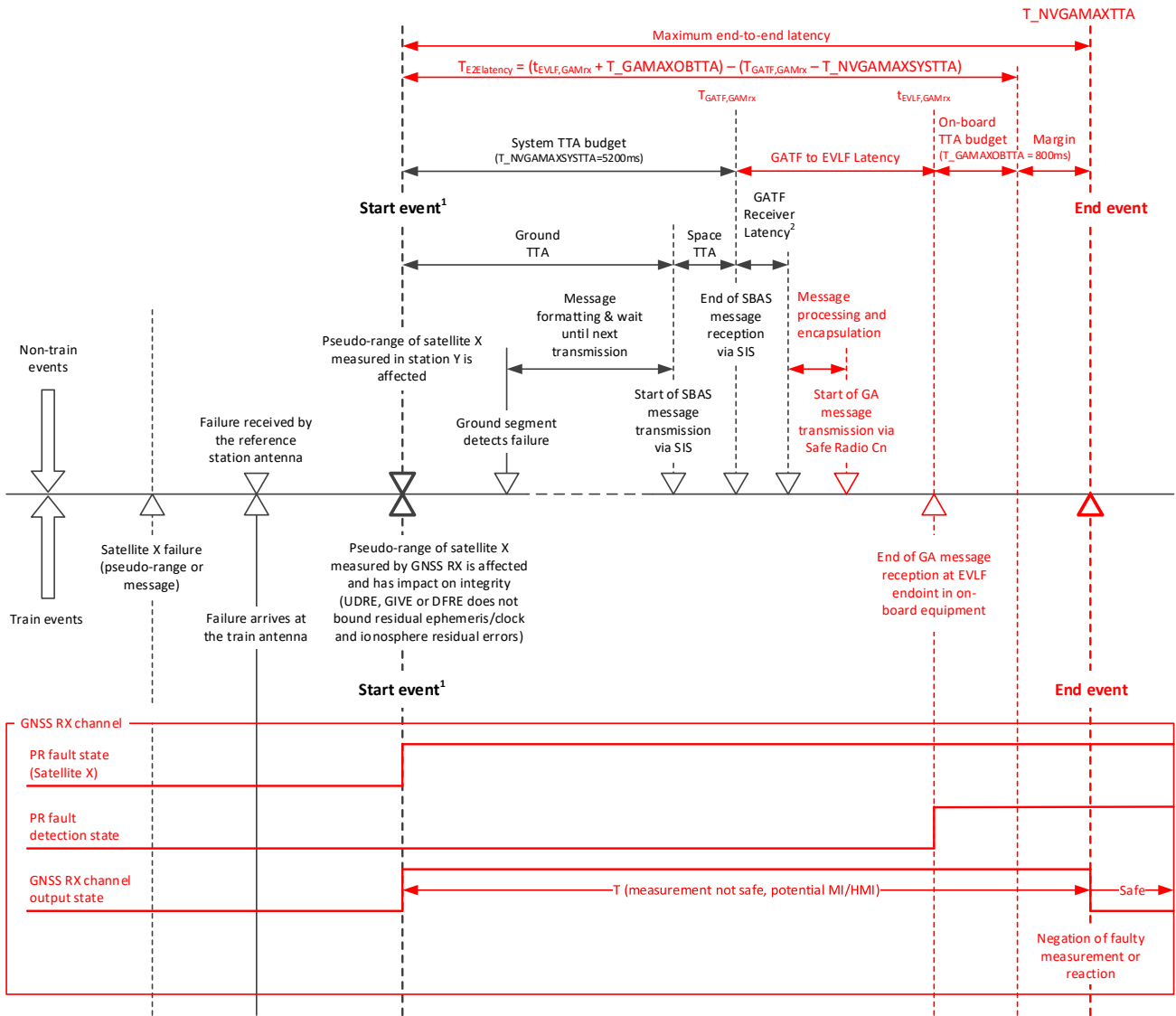


Figure 2-8. TTA example for SBAS (for reception of SBAS SIS at GATF and dissemination to EVLF via Safe Radio Connection)

Note 1.— Both events are considered as simultaneous. This is not strictly the case because of difference of performance between specific receivers. There is a slight difference due to receiver processing between the time the pseudo-range measurement is affected, and the erroneous data are displayed. For practical reasons, this is not reflected in this diagram.

Note 2.— The GATF receiver latency is related to the output of SBAS messages from the GNSS/SBAS receiver in the SBAS GATF.

2.2.7.4 A detailed breakdown of the allocations in the SBAS example illustrated in Figure 2-8 is provided in the table below:

Budget	Allocation	Remarks
Ground TTA budget	3900 ms	5200 – Space TTA = 3900 ms
Space TTA budget	1300 ms	1300 = uplink time (150 ms) + SBAS message length (1000 ms) + downlink time (150 ms)
SBAS System TTA budget	$T_NVGMAXSYSTTA = 5200$ ms	System TTA requirement for SBAS supporting precision approach from SARPs [7] (when last bit of an SBAS message arrives at the antenna port)
GATF to On-board latency	$t_{EVLF,GAMrx} - T_{GATF,GAMrx}$	Latency between the end of reception of SBAS message by the GATF GNSS receiver (when last bit of an SBAS message arrives at antenna port) and the end of reception of GA message at EVLF endpoint in the on-board

		equipment. This includes latency introduced by message processing on the GA-TS / encapsulation in ETCS packets and messages and transmission via Safe Radio Connection. It is assumed that the uncertainty of GATF and EVLF timestamps < 1ms.
On-board TTA budget	T_GAMAXOBTTA = 800 ms	Budget for processing latency from end of reception of GA message at EVLF endpoint in the on-board equipment to raising an alert (negation of fault).
End-to-End Latency	T _{E2Elatency}	(t _{EVLF,GAMrx} + T_GAMAXOBTTA) – (T _{GATF,GAMrx} – T_NVGAMAXSYSTTA)

Note: The EVLF endpoint refers to the function within the on-board equipment. For example, GA communication channel could include forwarding on an internal bus of the on-board equipment (e.g., Profibus) to the EVLF, the endpoint.

2.2.7.5 It is assumed that the GA system TTA budget (T_NVGAMAXSYSTTA) is guaranteed by the GAS to its interface in the GATF (e.g., in the case of SBAS, the SBAS/GNSS receiver in the GATF). Considering additional latencies introduced by dissemination of GA messages to the EVLF via Safe Radio Connection, additional mechanisms are required for supervising GA message latency to ensure it is below the configured end-to-end TTA threshold (T_NVGAMAXTTA) or in the case the threshold is exceeded, that the GNSS channel is transitioned into a safe state (i.e., GNSS integrity unavailable).

2.2.7.6 The maximum GA message latency (T_NVGAMAXTTA) has been defined as a national value that is specific to the GNSS augmentation system, allowing for optimisation / tuning of performances. The dimensioning of this value shall take into consideration the following:

- GA System TTA budget (e.g., for SBAS, T_NVGAMAXSYSTTA = 5200 ms);
- Latency of GATF/GADF processing (including encapsulation of GA message);
- GA-TS to GA-OB transfer delay over Safe Radio Connection;
- On-board equipment maximum TTA budget (fixed value T_GAMAXOBTTA = 800 ms [TBC]); and
- Margin to cope with variations in safe radio connection performance taking into consideration track to train radio communication system (e.g., GSM-R CSD, GSM-R GPRS, FMRCS) availability, configuration, and coverage.

Note: this is a national value and is configured by the infrastructure manager taking into consideration the performance and dimensioning of the Safe Radio Connection. This variable is used by the EVLF to determine T_GATIMEOUT for supervision of the GA message stream and to ensure correct assumptions are made within the EVLF regarding time to detect and negate faulty measurements caused by GNSS errors or anomalies detected by the GAS.

2.2.7.7 For each GA message stream in the GA session, the EVLF shall supervise when no valid GA message has been received for T_GATIMEOUT seconds (refer to Figure 2-9). If Timer T_GATIMEOUT expires, the EVLF shall ensure all GA integrity data for the GA message stream become unavailable. The resume GA message stream function is used to restore

integrity data that would not have timed out (especially for integrity data with long update intervals and timeouts) by ensuring any missed alerts are processed by the EVLF – refer to Section 2.2.2).

2.2.7.8 If TTA supervision is unavailable (e.g., due to unavailability of the GNSS Augmentation Time reference on the EVLF as indicated by Q_GAT in the GAM packet, unavailability of the GAT reference on the GATF for timestamping), the EVLF shall ensure all GA integrity data for affected GA message streams become unavailable.

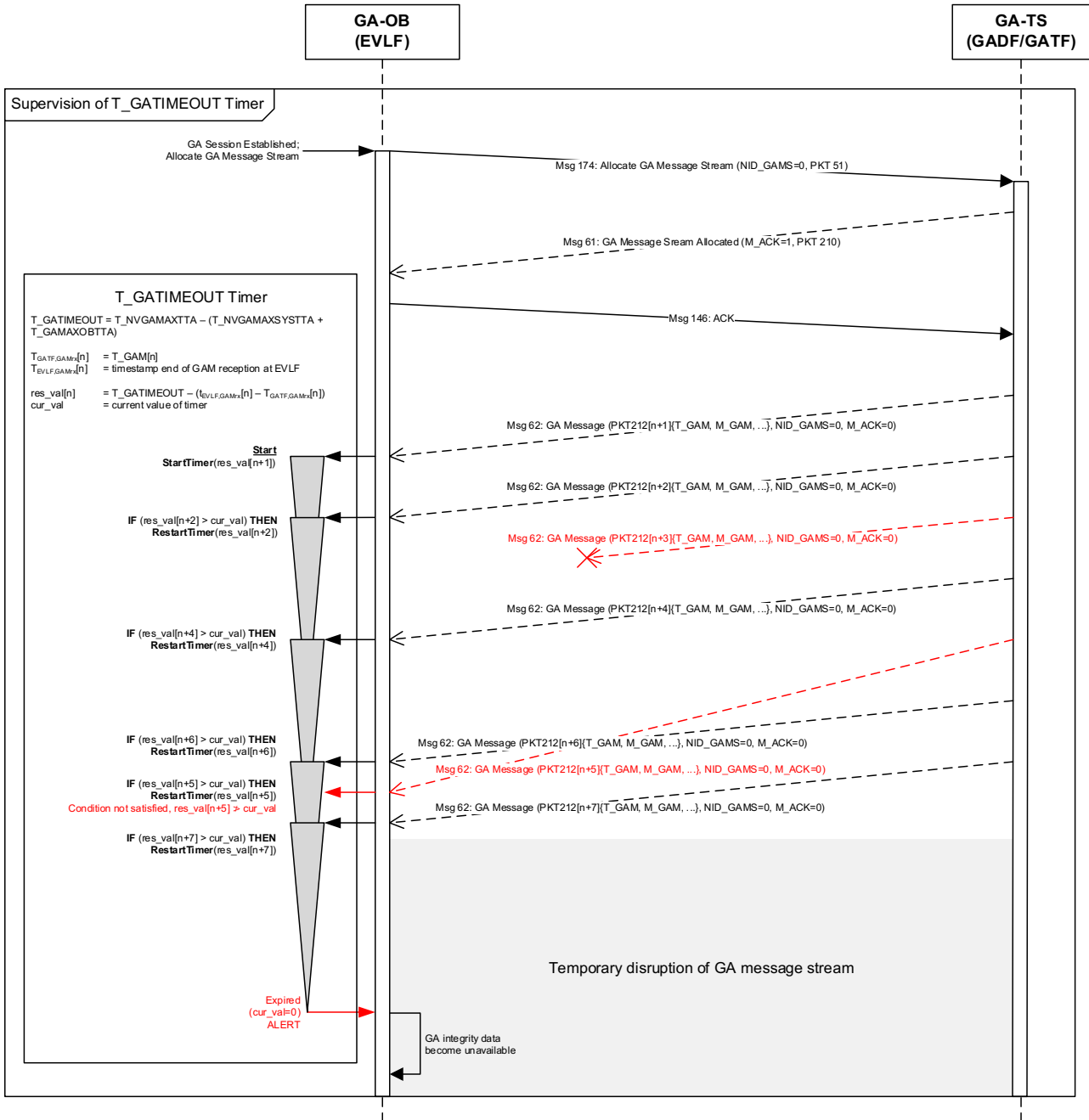


Figure 2-9. Supervision of Timer T_GATIMEOUT

2.2.7.9 The supervision of Timer T_GATIMEOUT assumes continuity of signal (i.e., the rate of GA messages broadcast within a GA message stream of at least one message every T_NVGAMBUR milliseconds). The GATF shall ensure continuity of signal by providing a GA message for each GAC at least every T_NVGAMBUR milliseconds:

- If a message is not available from the GAS, the GATF shall provide a Packet 212 encapsulating an empty / null message.
- In the case of SBAS, T_NVGAMBUR = 1000 ms; continuity of signal is guaranteed for the SBAS L1 and L5 signal. The SBAS null message (MT63) is used as a filler message if no other message is available for broadcast for the one-second time slot.

2.2.7.10 The management of alerts for the EVLF is based on the use of a positive acknowledgement paradigm over the Safe Radio Connection between the GA-TS and GA-OB.

2.2.7.11 When an alert condition occurs, the GAS alerts the user (GATF) of the alert condition. The GADF forwards the alert to the EVLF encapsulated in a GA message that requires acknowledgement. The GA message stream is suspended until the alert is acknowledged by the EVLF.

2.2.7.12 Figure 2-10 and Figure 2-11 illustrate management of alerts for the EVLF considering GAS based on SBAS as an example. Figure 2-11 illustrates the case of reception of an alert with disruption of the Safe Radio Connection. In Figure 2-10, suspension and resumption of GA message stream occurs before timeout of timer T_GATIMEOUT.

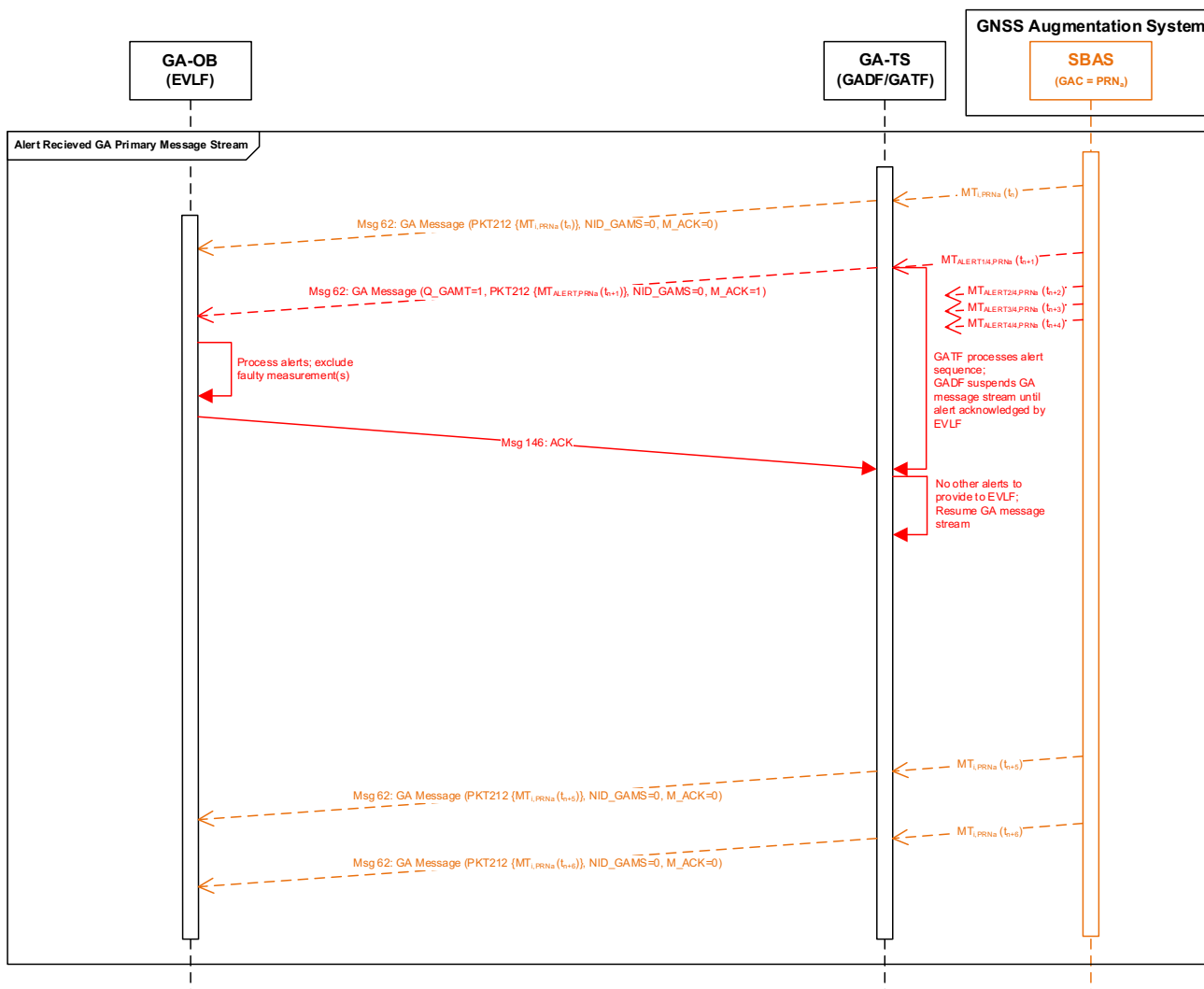


Figure 2-10. Reception of an alert (SBAS example)

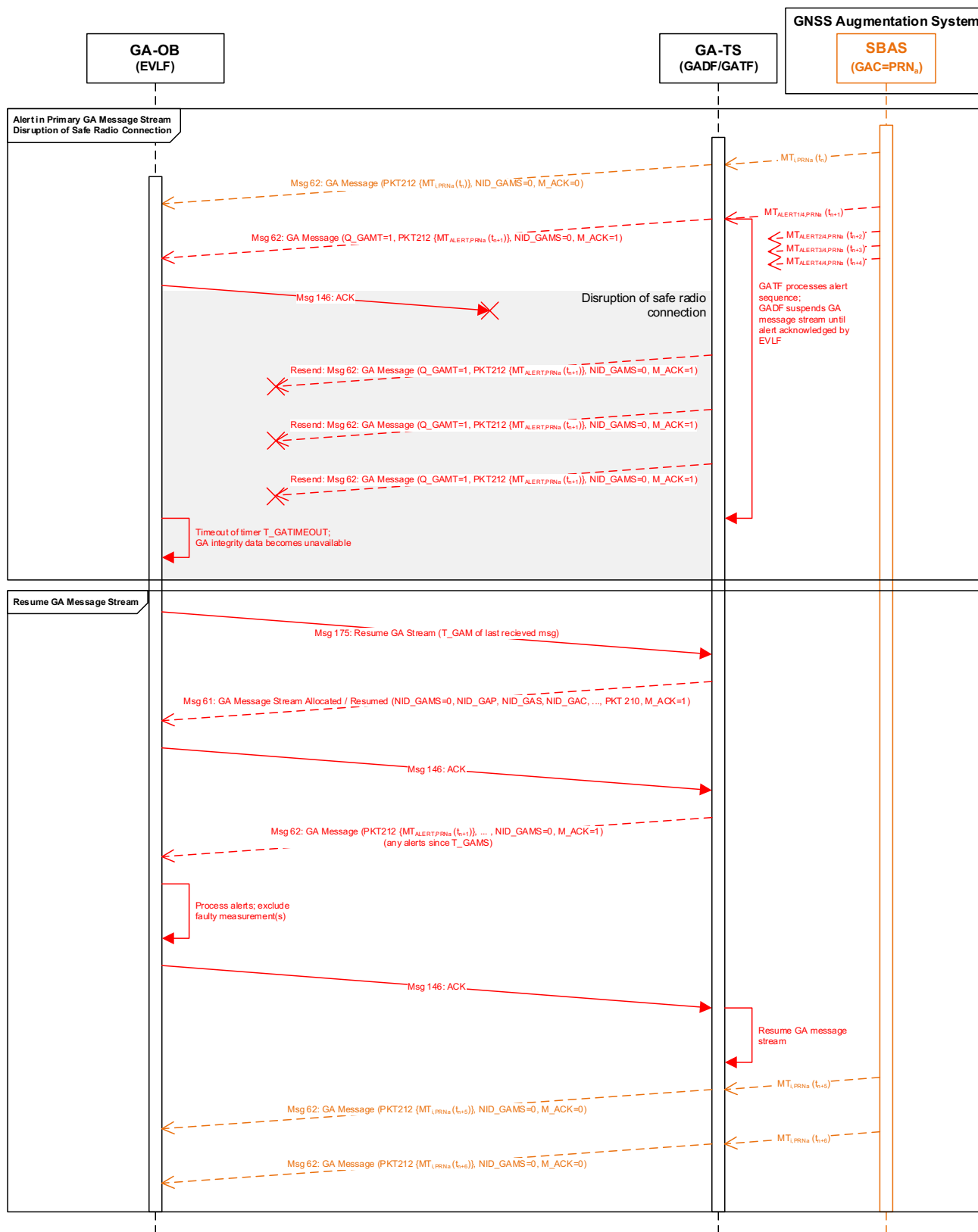


Figure 2-11. Reception of an alert with disruption of safe radio connection (SBAS example)

2.2.8 EVLF Supervision of GA Message Content Timeout

- 2.2.8.1 The EVLF equipment shall only use broadcast GA data within the current valid time interval. Timeout supervision shall be performed such that GA message content is valid when:

$$t_{\text{EVLF,now}} - T_{\text{GATF,GAMrx}} \leq \text{timeout}(\text{GA message content})$$

where: $t_{\text{EVLF,now}}$ is the current time of the EVLF in milliseconds, $T_{\text{GATF,GAMrx}}$ is the time of the end of reception of the GA message by the GATF in milliseconds, and $\text{timeout}(\text{GA message content})$ is the timeout interval for GA message content in milliseconds.

Note: $T_{\text{GATF,GAMrx}}$ is provided by the variable T_GAM in Packet 212 included in messages of type 62: *GA Message* sent by the GADF to the EVLF. The reference time of T_GAM is indicated by the qualifier Q_GAT in Packet 212.

- 2.2.8.2 The EVLF shall ensure that $t_{\text{EVLF,now}}$ and $T_{\text{GATF,GAMrx}}$ have the same reference time (e.g., in the case of SBAS, both times shall be in SBAS Network Time).
- 2.2.8.3 Wrap around (rollover) of the timestamps $t_{\text{EVLF,now}}$ and $T_{\text{GATF,GAMrx}}$ can occur during a GA session and shall have no impact on system behaviour (i.e., EVLF correcting for rollover if needed).
- 2.2.8.4 If GA message content timeout supervision is unavailable (e.g., due to unavailability of the GNSS Augmentation Time reference on the EVLF as indicated by Q_GAT in the GAM packet, unavailability of the GAT reference on the GATF for timestamping), GA message content (i.e., message from GAS encapsulated in GAM packet) shall be discarded by the EVLF.
- 2.2.8.5 Refer to the relevant GA-OB-MOPS for definition of timeouts for GA message content.

2.2.9 Management of Announced Radio Holes

- 2.2.9.1 In an announced radio hole, supervision of the loss of the safe radio connection by the on-board equipment is temporarily stopped. As long as the train front end is inside an announced radio hole, the ERTMS/ETCS on-board equipment shall stop the supervision of the safe radio connection. The supervision is restored when the train front end leaves the radio hole, comparing the current on-board time with the on-board time when the train front end left the radio hole (instead of the time stamp of the latest consistent received message) until a new consistent message has been received.
- 2.2.9.2 If radio contact is lost, the GA session is terminated by the trackside. Once radio contact is restored, the EVLF shall establish a new GA session. The EVLF can attempt to resume the GA message stream(s) by sending a *Message 175: Resume GA Message Stream* to the GADF for each stream to be resumed.
- 2.2.9.3 If the GA message stream cannot be resumed, the EVLF can request allocation of GA message stream(s) by sending a *Message 174: Allocate GA Message Stream* to the GADF for each stream to be allocated. To minimise the time GNSS integrity is unavailable, the EVLF can request GA active data from the GADF (refer to Section 2.2.3).

2.2.10 EVLF Timestamping of GA Messages Received from GADF

- 2.2.10.1 Timestamp $t_{\text{EVLF,GAMrx}}$ shall be within 1ms of end of reception of GA message at EVLF endpoint in the on-board equipment.
- 2.2.10.2 Wrap around (rollover) of the timestamp can occur during a GA session and shall have no impact on system behaviour.
- 2.2.10.3 The EVLF endpoint refers to the function within the on-board equipment. For example, the GA communication channel could include reception of GA messages by another function within the on-board and forwarding on the internal bus (e.g., Profibus) to the EVLF, the endpoint.
- 2.2.10.4 The EVLF shall ensure that $t_{\text{EVLF,GAMrx}}$ and $T_{\text{GATF,GAMrx}}$ have the same reference time. $T_{\text{GATF,GAMrx}}$ is provided by the variable T_GAM in Packet 212 included in messages of *type 62: GA Message* sent by the GADF to the EVLF. The reference time of T_GAM is indicated by the qualifier Q_GAT in Packet 212.

2.2.11 EVLF GA Message Processing

- 2.2.11.1 The EVLF shall support at least one GA message stream and may optionally support two GA message streams (a primary and secondary stream). A GA session can support up to two GA message streams.
- 2.2.11.2 Justification for support of two GA message streams:
- Considering for example, GNSS augmentation based on SBAS: processing of two PRNs is specified in the aviation MOPS and is linked to unavailability of the GEO itself as well as the unavailability of the Navigation Land Earth Stations (NLES). The NLES switching may lead to a GEO SIS outage. Having a parallel processing of at least two SBAS GEOs avoids a service outage if the on-board receiver has two channels capable of processing SBAS message streams from two PRNs with fast switching between channels in case of an unexpected service outage. Note: it is not mandatory for the on-board to support processing of two message streams.
- 2.2.11.3 GA message processing requirements for the EVLF are provided in the GA-OB-MOPS for the specific GA service.
- 2.2.11.4 In the case of the EGNOS Railway SoL Service, the GA-OB-MOPS are provided by the following documents:
- SBAS L1 Receiver Guidelines for Railway – On-board Unit [ESSP-TN-25931]; and
 - SBAS DFMC Receiver Guidelines for Railway – On-board Unit [ESSP-TN-26136].

2.2.12 EVLF GNSS Signal Processing

- 2.2.12.1 GNSS signal processing requirements for the EVLF are provided in the GA-OB-MOPS for the specific GA service.
- 2.2.12.2 In the case of the EGNOS Railway SoL Service, the GA-OB-MOPS are provided by the following documents:

- SBAS L1 Receiver Guidelines for Railway – On-board Unit [ESSP-TN-25931]; and
- SBAS DFMC Receiver Guidelines for Railway – On-board Unit [ESSP-TN-26136].

2.2.13 EVLF Pseudorange Determination and Use

2.2.13.1 Requirements on pseudorange determination and use for the EVLF are provided in the GA-OB-MOPS for the specific GA service.

2.2.13.2 In the case of the EGNOS Railway SoL Service, the GA-OB-MOPS are provided by the following documents:

- SBAS L1 Receiver Guidelines for Railway – On-board Unit [ESSP-TN-25931]; and
- SBAS DFMC Receiver Guidelines for Railway – On-board Unit [ESSP-TN-26136].

2.2.14 EVLF Compute and Apply GA Corrections to Smoothed Pseudorange

2.2.14.1 Requirements on computation and application of GA correction to smoothed pseudoranges are provided in the GA-OB-MOPS for the specific GA service.

2.2.14.2 In the case of the EGNOS Railway SoL Service, the GA-OB-MOPS are provided by the following documents:

- SBAS L1 Receiver Guidelines for Railway – On-board Unit [ESSP-TN-25931]; and
- SBAS DFMC Receiver Guidelines for Railway – On-board Unit [ESSP-TN-26136].

2.2.15 EVLF Compute and Apply Pseudorange Error Models

2.2.15.1 Requirements on computation and application of pseudorange error models for the EVLF are provided in the GA-OB-MOPS for the specific GA service.

2.2.15.2 In the case of the EGNOS Railway SoL Service, the GA-OB-MOPS are provided by the following documents:

- SBAS L1 Receiver Guidelines for Railway – On-board Unit [ESSP-TN-25931]; and
- SBAS DFMC Receiver Guidelines for Railway – On-board Unit [ESSP-TN-26136].

2.2.16 GATF Reception and Processing of Messages from GAS

2.2.16.1 Reception and message processing requirements for the GATF are provided in the GA-TS-MOPS for the specific GA service.

2.2.16.2 In the case of the EGNOS Railway SoL Service, the GA-TS-MOPS are provided by the following documents:

- SBAS L1 Receiver Guidelines for Railway – Trackside Unit [ESSP-TN-26038]; and
- SBAS DFMC Receiver Guidelines for Railway – Trackside Unit [ESSP-TN-26137].

2.2.17 GATF Selection of GACs

2.2.17.1 The GATF shall select GNSS Augmentation Channels (GACs) for compatible services from authorised GNSS Augmentation System (GAS) providers. These are service providers for which use of the railway SoL service has been approved by the service provider.

2.2.17.2 Other criteria for selection of GACs is addressed in the relevant GA-TS MOPS (e.g., in the case of an EGNOS railway SoL service provided via the GEO SIS, selection of GEO signals broadcasting valid messages, passing CRC, no reception of MT0, etc.).

2.2.18 GATF Maintain GA Active Data for each GAC

2.2.18.1 The GATF shall maintain a set of GA active data (data most recently received that has not timed out) for each GAC of supported GA service to enable transmission of active data sets to the EVLF when requested.

2.2.19 GATF Maintain GA Active Alerts for each GAC

2.2.19.1 The GATF shall maintain GA active alerts for each GAC of supported GA services to support resuming of a GA message stream, allowing the EVLF to restore integrity data that have not timed out by ensuring active alerts (i.e., alerts that have no timed out) are processed by the EVLF before the GA message stream is resumed.

2.2.20 GATF Timestamping Reception of Messages from GAS

2.2.20.1 The GATF shall timestamp the end of reception of GNSS Augmentation Messages (GAMs) received from the GNSS Augmentation System (GAS).

2.2.20.2 The timestamp (T_GAM) shall have a resolution of 1ms and is a 32-bit value containing the timestamp (time of week with a maximum value of 604799999 ms) in the reference time indicated by the qualifier Q_GAT. For example, in the case of EGNOS, Q_GAT = 0: SNT (SBAS Network Time).

2.2.20.3 The timestamp (T_GAM) shall be within 1ms [TBC] of the end of reception of GA message by GATF. The GADF shall not change the time reference frame of the GA corrections. Q_GAT shall only be used for timestamping of messages from the GAS.

2.2.20.4 Wrap around (rollover) of the timestamp can occur during a GA session and shall have no impact on system behaviour.

2.2.20.5 Figure 2-12 illustrates the timestamping of GA messages by the GATF.

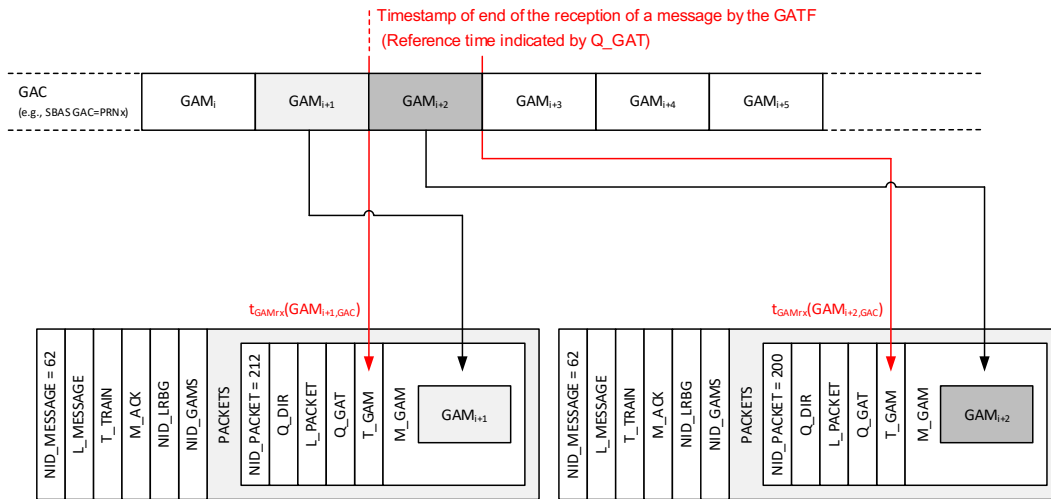


Figure 2-12. Timestamping of GA Messages by GATF

2.2.20.6 Justification for approach:

- The proposed solution supports timestamping with different reference times (indicated by Q_GAT). While UTC can be used, flexibility in supporting GA message timestamping using the reference time of the GNSS Augmentation System was considered in the proposed approach due to the increased complexity of providing UTC time offset parameters in the context of safety-related applications.
- For example, in the case of EGNOS, the timestamping mechanism cannot rely on the UTC timing information provided in SBAS MT12. The provision of a real-time EGNOS Network Time (ENT) offset to UTC is secondary function of EGNOS and is not relevant to the navigation service (i.e., not considered as critical for the primary mission). As such, the SBAS MT12 cannot be used as the EGNOS safety case only considers the use of EGNOS as a navigation system and does not provide any analysis of safety of life applications that may rely on the timing service. For this reason, timestamping in the case of EGNOS shall be in SNT (SBAS Network Time).
- It is noted that, when using GA corrections, the EVLF’s solution for time will be with respect to the GA Network Time. In the case of SBAS, SNT shall be within 50 nanoseconds of GPS system time.

2.2.21 GATF Encapsulation of Messages Received from GAS in GAM Packets

2.2.21.1 The GATF shall encapsulate messages received from the GNSS Augmentation System (GAS) in packets of type 212, with a timestamp of the end of reception of the message from the GAS (T_GAM) and an indication of the reference time of the timestamp (Q_GAT).

2.2.22 GATF Maintain GNSS Navigation Data Sets

2.2.22.1 The GATF shall maintain the last four different sets of GNSS navigation data for each visible satellite of the core constellations (GPS and Galileo) to enable transmission of navigation data sets to the EVLF when requested.

2.2.22.2 The GATF shall optionally maintain a set of GNSS navigation data for visible satellites from other constellations (e.g., BEIDOU, GLONASS, etc.) as needed to support specific GA services or degraded modes of operation of the EVLF.

2.2.23 GATF GNSS Signal Processing

2.2.23.1 Requirements on GNSS signal processing for the GATF are provided in the GA-TS-MOPS for the specific GA service and by the relevant GNSS-SIS-ICD.

2.2.23.2 In the case of the EGNOS Railway SoL Service, the GA-TS-MOPS are provided by the following documents:

- SBAS L1 Receiver Guidelines for Railway – Trackside Unit [ESSP-TN-26038]; and
- SBAS DFMC Receiver Guidelines for Railway – Trackside Unit [ESSP-TN-26137].

2.2.24 Safe Radio Connection Message Consistency

2.2.24.1 Note: The Safe Radio Connection between the GA-OB and GA-TS is currently undefined (including protocol); to be defined in a future specification. GA application messages are defined in the GA ICD [EUG-20E087]).

2.2.24.2 The GA-OB shall discard a message transmitted by the GA-TS if it is not consistent.

2.2.24.3 The GA-TS shall discard a message transmitted by the GA-OB if it is not consistent.

2.2.24.4 A radio message is consistent when the following checks have been passed:

- Protocol level checks have passed (e.g., verification of CRC, safety code using secret key, etc.);
- Message timestamp checks have passed (i.e., with respect to T_TRAIN); and
- Messages are complete and variables in messages do not have invalid values (refer to GA ICD [EUG-20E087]).

2.2.24.5 Messages shall be timestamped by the GA-TS with a value corresponding to the time of transmission.

2.2.24.6 Message sequence supervision shall be performed using the message timestamp (T_TRAIN). If the timestamp of the last received message is less than or equal to the former one, it shall be discarded. There shall always be a timestamp increment between consecutive messages.

2.2.25 GA Version Management

2.2.25.1 The GA version refers to the version of the GA for ERTMS/ETCS framework supporting dissemination of GNSS augmentation information to the EVLF (GA-OB / GA-TS).

2.2.25.2 The GA for ERTMS/ETCS framework shall have a version number (M_GAVER) to support backwards compatibility. The version has a major and minor version number, where major versions increase in the case of non-compatible changes and minor versions increase in the case of compatible changes.

2.2.25.3 GA-OB and GA-TS with the same major version are compatible.

2.2.25.4 The EVLF, when initiating a GA session, shall send the major GA versions with the highest supported minor version.

2.2.25.5 The GADF responds with the highest major version supported by both GA-OB and GA-TS. If no major version is supported by both GA-TS and GA-OB, the GADF responds with *Message 66: GA session Error* (with M_GAERR=0, No compatible GA version supported by on-board).

2.2.26 GA Service Version Management

2.2.26.1 The GA service version refers to the version of a GNSS augmentation service.

2.2.26.2 Each GA service shall have a version number (M_GASVER) to support backwards compatibility. The version has a major and minor version number, where major versions increase in the case of non-compatible changes and minor versions increase in the case of compatible changes.

2.2.26.3 GA services with the same major version are compatible.

2.2.26.4 The EVLF, when requesting allocation of a GA message stream, shall send the major versions with the highest supported minor version for each supported GA service.

2.2.26.5 The GADF selects a service to allocate from the GA services that are compatible. If no services are compatible, the GADF responds with *Message 66: GA session Error* (with M_GAERR=1, No compatible GA service supported by on-board).

2.3 EVLF Operational States

2.3.1.1 Operational states of the on-board Enhanced Vehicle Localisation Function (EVLF) are described in this section.

2.3.1.2 The EVLF shall support at least one GA message stream and may optionally support two GA message streams (a primary and secondary stream). A GA session can support up to two GA message streams, where operational states GN, GR and GO are related to each GA message stream of the session.

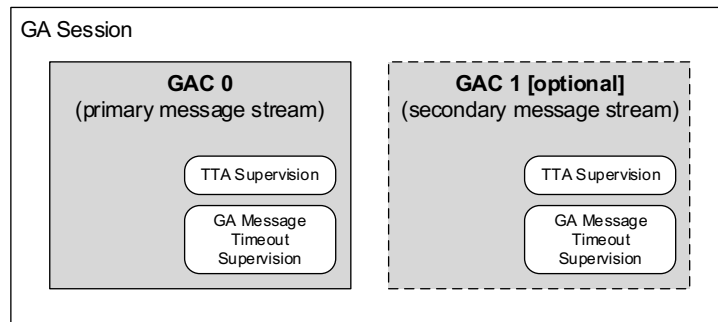


Figure 2-13. EVLF GA Session and GA Message Streams

2.3.2 No Power (NP)

2.3.2.1 The EVLF is in NP state when switched off.

2.3.3 Standby (SB)

2.3.3.1 This is the default state entered when the EVLF is switched on.

2.3.3.2 In this state, the EVLF can initiate a GA session with the GADF.

2.3.4 GAC Not Available (GN)

2.3.4.1 In this state, the GNSS augmentation channel (GAC) is not available. The EVLF has an active GA session, and the GA message stream has not been allocated.

2.3.4.2 The EVLF can request the following from the GADF:

- GNSS navigation data
- Allocation GA message stream
- Termination of GA session

2.3.5 GAC Ready (GR)

2.3.5.1 In this state, the GNSS augmentation channel (GAC) is ready for operation. The EVLF has an active GA session and GA message stream has been allocated. TTA supervision is active,

supervision of GA message content timeout is active, and the GA message stream may be suspended or receiving GA messages.

2.3.5.2 If transition to this state was caused by timeout of timer T_GATIMEOUT (TTA supervision), all GA integrity data are unavailable.

2.3.5.3 The EVLF can request the following from the GADF:

- GA active data set for the allocated GA message stream
- GNSS navigation data
- Resumption of the GA message stream
- Suspension of the GA message stream

2.3.6 GAC Operational (GO)

2.3.6.1 In this state, the GNSS augmentation channel (GAC) is operational. The EVLF has an active GA session and GA message stream has been allocated. The GA message stream is receiving GA messages, TTA supervision is active, and supervision of GA message content timeout is active.

2.3.6.2 If transition to this state was caused by resumption of the GA message stream, GA integrity data may be restored if conditions allow (i.e., GA integrity data have not timed out and any missed alerts have been processed).

2.3.6.3 The EVLF can request the following from the GADF:

- GA active data set for the allocated GA message stream
- GNSS navigation data
- Suspension of the GA message stream

2.3.7 EVLF failure (FA)

2.3.7.1 The EVLF enters the FA state for detected faults / error conditions that prevents GA functions from being performed.

2.3.8 Transition Between States

2.3.8.1 This section defines the transitions between EVLF GA states and the transition conditions.

2.3.8.2 Note the following conventions are used for the transition table:

- “>n” indicates that condition [n] must be fulfilled to trigger transition from the state identified in the column to the state identified by the arrow “>”
- Each transition from a given state is given a priority order indicated by “-px-”, where x is the priority order. The priority is provided to avoid a conflict between different transitions when they occur at the same time (i.e., in the same clock cycle). P1 has a higher priority than P2.

- Some transitions are given the same priority when it has been determined that these transitions cannot occur at the same time and can never lead to a conflicting situation.

Table 2-1. EVLF transition table

NP	<10 -p1-	<10 -p1-	<10 -p1-	<10 -p1-	<10 -p1-
1> -p1-	SB	<8,9 -p3-	<8,9 -p3-	<8,9 -p3-	
	2> -p3-	GN	<7 -p4-		
			GR	<6 -p5-	
		3> -p4-	4> -p5-	GO	
	5> -p2-	5> -p2-	5> -p2-	5> -p2-	FA

Table 2-2. Transition conditions table

Condition ID	Transition conditions
[1]	EVLF is powered on
[2]	GA session established (EVLF initiates GA session, providing GADF with GA versions supported by on-board; GADF confirms establishment of GA session with GA version to be used by EVLF)
[3]	GA message stream allocated (EVLF requests GADF to allocate GA message stream, providing GADF with GA services supported by EVLF; GADF confirms allocation of GA message stream with details of GA provider, service, channel, and service version; GADF starts sending GA messages)
[4]	(EVLF acknowledges alert (<i>Message 62: GA Message</i> requiring acknowledgement) AND timer T_GATIMEOUT (TTA supervision) has not timed out) OR (GA message stream resumed (EVLF requests GADF to resume GA message stream, providing the GADF with timestamp of last received GM message for the stream to be resumed; GADF sends any missed alert messages and resumes sending GA messages))
[5]	EVLF detects a fault / error condition that prevents GA functions from being performed
[6]	(Timeout of timer T_GATIMEOUT (TTA supervision)) OR (Reception of an alert (<i>Message 62: GA Message</i> with Packet 212 and Q_GAMT = 1)) OR (Reception of a DNU message stream (<i>Message 62: GA Message</i> with Packet 212 and Q_GAMT = 2))

[7]	GA message stream cannot be resumed
[8]	EVLF sends termination request to GADF, which responds by sending a <i>GA session terminated</i> message to EVLF
[9]	GADF detects fault / error condition that impacts the GA session; GADF terminates session by sending <i>GA session terminated</i> message to EVLF
[10]	EVLF is powered off

2.3.9 EVLF Active Functions Table

2.3.9.1 Note: the active functions table only addresses interoperability-relevant functions of the EVLF for GNSS augmentation.

2.3.9.2 The following conventions are used for the active functions table:

- X = functions shall be active
- Empty case = function shall be inactive
- O = optional (function not required for interoperability, but is not forbidden)

EVLF Functions	Related Requirement	NP	SB	GN	GR	GO	FA
EVLF / GADF Communication							
Reception of GA messages from GADF	SRS §2.2.1				X	X	
Reception of GA active data sets from GADF	SRS §2.2.3				X	X	
Reception of GNSS navigation data from GADF	SRS §2.2.4			X	X	X	
Transmission and reception of GA session management messages and acknowledgements	SRS §2.2.1, 2.2.2, 2.2.3, 2.2.4, 2.2.6, 2.2.7, 2.2.9		X	X	X	X	
GA Functions							
Timestamping of GA messages received from GADF	SRS §2.2.10				X	X	
Supervision and management of TTA	SRS §2.2.7				X	X	
Supervision of GA message content timeout	SRS §2.2.8				X	X	
GA message processing	GA-OB MOPS				X	X	
GNSS signal processing							
GNSS pre-correlation signal processing	GA-OB MOPS		X	X	X	X	O
Acquisition and tracking of GNSS signals	GA-OB MOPS		X	X	X	X	O
Navigation data demodulation and FEC decoding	GNSS-SIS-ICD ³		X	X	X	X	O
Navigation data processing	GA-OB MOPS, GNSS-SIS-ICD		X	X	X	X	O
GNSS pseudorange determination and use							

³ Examples of GNSS signal-in-space ICDs: GPS: [IS-GPS-200] and [IS-GPS-705]; Galileo: [GAL-OS-SIS-ICD]

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Carrier smoothing on pseudorange measurements	GA-OB MOPS		X	X	X	X	O
Measurement quality monitoring	GA-OB MOPS		X	X	X	X	O
Pseudorange determination	GA-OB MOPS		X	X	X	X	O
GNSS satellite selection (use criteria)	GA-OB MOPS		X	X	X	X	
Compute and apply GA corrections to smoothed pseudorange	GA-OB MOPS				X	X	
GNSS pseudorange error models (GA-provided integrity)							
Compute and apply model for correction residual error	GA-OB MOPS				X	X	
Compute and apply model for residual ionospheric error	GA-OB MOPS				X	X	

2.4 GADF Operational States

2.4.1.1 Operational states of the trackside GNSS Augmentation Dissemination Function (GADF) are described in this section.

2.4.2 No Power (NP)

2.4.2.1 The GADF is in NP state when switched off.

2.4.3 Standby (SB)

2.4.3.1 This is the default state entered when the GADF is switched on.

2.4.3.2 In the SB state, the GADF can initiate a session with the GATF. The GADF cannot accept requests for a GA session from EVLFs.

2.4.4 Operational (OP)

2.4.4.1 In the OP state, the GADF is operational and can accept requests for a GA session from EVLFs. In this state, the GADF is responsible for:

- Providing GA message stream(s) to the EVLF, which are compatible with the GA services supported by the EVLF
- Providing GA active data sets on request to the EVLF
- Providing GNSS navigation data sets on request to the EVLF
- Facilitating resumption of GA message streams by providing past alerts to the EVLF

2.4.5 GADF Failure (FA)

2.4.5.1 The GADF enters FA state for detected faults / error conditions that prevent GADF functions from being performed.

2.4.6 Transition Between States

2.4.6.1 This section defines the transitions between GADF states and the transition conditions.

2.4.6.2 Note the following conventions are used for the transition table:

- “>n” indicates that condition [n] must be fulfilled to trigger transition from the state identified in the column to the state identified by the arrow “>”
- Each transition from a given state is given a priority order indicated by “-px-”, where x is the priority order. The priority is provided to avoid a conflict between different transitions when they occur at the same time (i.e., in the same clock cycle). P1 has a higher priority than P2.
- Some transitions are given the same priority when it has been determined that these transitions cannot occur at the same time and can never lead to a conflicting situation.

Table 2-3. GADF transition table

NP	<6 -p1-	<6 -p1-	<6 -p1-
1> -p1-	SB	<4,5 -p3-	
	2> -p3-	OP	
	3> -p2-	3> -p2-	FA

Table 2-4. Transition conditions table

Condition ID	Transition conditions
[1]	GADF is powered on
[2]	(GADF-GATF session established (GADF initiates a session with GATF; GATF confirms establishment of GADF-GATF session) AND (one or more GA services are available))
[3]	GADF detects a fault / error condition that prevents GADF functions from being performed
[4]	GA services(s) become unavailable, and no GA services are available (e.g., in the case of SBAS, reception of an MT0)
[5]	GATF detects fault / error condition that impacts the GADF-GATF session; GATF terminates session
[6]	GADF is powered off

2.4.7 GADF Active Functions Table

2.4.7.1 The following conventions are used for the active functions table:

- X = functions shall be active
- Empty case = function shall be inactive
- O = optional (function not required for interoperability, but is not forbidden)

GADF Functions	Related Requirement	NP	SB	OP	FA
GADF / EVLF Communication					
Transmission of GA message streams to EVLF	SRS §2.2.1			X	

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Transmission of GA active data sets to EVLF	SRS §2.2.3			X	
Transmission of past alerts to EVLF	SRS §2.2.5			X	
Transmission of GNSS navigation data sets to EVLF	SRS §2.2.4			X	
Transmission and reception of GA session management messages and acknowledgements	SRS §2.2.1, 2.2.2, 2.2.3, 2.2.4, 2.2.6, 2.2.7, 2.2.9			X	
GADF / GATF Communication					
Reception of GA messages from GATF				X	
Reception of GA active data sets from GATF				X	
Reception of GA past alerts from GATF				X	
Reception of GNSS navigation data sets from GATF				X	
Transmission and reception of GADF-GATF session management messages and acknowledgements			X	X	
GADF Functions					
Selection of GA service and channel (GA message source) compatible with services supported by EVLF	SRS §2.2.1			X	
Resumption of suspended GA message streams	SRS §2.2.2			X	

2.5 GATF Operational States

2.5.1.1 Operational states of the trackside GNSS Augmentation Trackside Function (GATF) are described in this section.

2.5.1.2 Note: the GATF is defined generically to interface to any GNSS Augmentation System (GAS). The GATF active functions table has been provided for the generic function. Refer to Annex B: B.4.3 for the EGNOS-specific GATF active functions table.

2.5.2 No Power (NP)

2.5.2.1 The GATF is in NP state when switched off.

2.5.3 Standby (SB)

2.5.3.1 This is the default state entered when the GATF is switched on.

2.5.3.2 In the SB state, the GATF is not connected to the GNSS Augmentation System.

2.5.3.3 The GATF is responsible for:

- Connecting to GNSS Augmentation System
- Accepting requests from the GADF for a GADF-GATF session

2.5.4 Operational (OP)

2.5.4.1 In the OP state:

- The GATF is connected to the GNSS Augmentation System and is receiving valid GA messages
- The GATF is monitoring GA messages for management of active alerts and active data sets
- The GATF is demodulating navigation data for visible GNSS satellites

2.5.4.2 The GATF is responsible for:

- Processing of GAS messages (may include processing of GAS signals as is required for SBAS L1 and L5 signals to obtain L1 legacy and L5 DFMC messages)
- Timestamping the reception of GA messages
- Maintaining GA active alerts
- Maintaining GA active data sets
- Encapsulating GA messages in GA message packets
- Processing of GNSS signals and navigation data
- Maintaining GNSS navigation data sets

2.5.5 GATF Failure (FA)

2.5.5.1 The GATF enters FA state for detected faults / error conditions that prevent GATF functions from being performed.

2.5.6 Transition Between States

2.5.6.1 This section defined the transitions between GATF states and the transition conditions.

2.5.6.2 Note the following conventions are used for the transition table:

- “>n” indicates that condition [n] must be fulfilled to trigger transition from the state identified in the column to the state identified by the arrow “>”
- Each transition from a given state is given a priority order indicated by “-px-”, where x is the priority order. The priority is provided to avoid a conflict between different transitions when they occur at the same time (i.e., in the same clock cycle). P1 has a higher priority than P2.
- Some transitions are given the same priority when it has been determined that these transitions cannot occur at the same time and can never lead to a conflicting situation.

Table 2-5. GATF transition table

NP	<5 -p1-	<5 -p1-	<5 -p1-
1> -p1-	SB	<4 -p3-	
	2> -p3-	OP	
	3> -p2-	3> -p2-	FA

Table 2-6. Transition conditions table

Condition ID	Transition conditions
[1]	GATF is powered on
[2]	Valid GA messages received from at least one GA service with correction and integrity information available for a minimum number of satellites
[3]	GATF detects a fault / error conditions that prevents GATF functions from being performed

[4]	Valid GA messages NOT available for at least one GA service with correction and integrity information not available for a minimum number of satellites
[5]	GATF is powered off

2.5.7 GATF<Generic> Active Functions Table

2.5.7.1 The following conventions are used for the active functions table:

- X = functions shall be active
- Empty case = function shall be inactive
- O = optional (function not required for interoperability, but is not forbidden)

GATF Functions	Related Requirement	NP	SB	OP	FA
GATF / GAS Communication					
Reception of GA messages from GAS			X	X	
GATF / GADF Communication					
Transmission of GA messages to GADF for each service / GAC				X	
Transmission of requested GA active data sets to GADF				X	
Transmission of requested GNSS navigation data sets to GADF				X	
Transmission and reception of GADF-GATF session management messages and acknowledgements			X	X	
GATF Functions					
Selection of GACs	GA-TS MOPS		X	X	
Maintain GA active data set for each GAC	SRS §2.2.18			X	
Timestamping reception of messages from GAS	SRS §2.2.20			X	
Encapsulation of messages received from GAS in GAM packets	SRS §2.2.21			X	
Maintain GNSS navigation data sets	SRS §2.2.22			X	
GAS message processing (may include processing of GAS signals if applicable)	GA-TS MOPS		X	X	
GNSS signal processing					
Acquisition and tracking of GNSS signals	GNSS-SIS-ICD		X	X	
Navigation data demodulation and FEC decoding	GNSS-SIS-ICD		X	X	
Navigation data processing	GA-TS MOPS, GNSS-SIS-ICD		X	X	

3 GA-TS Configuration Management

3.1.1.1 The following table provides a preliminary list of configuration items related to the GA-TS.

Table 3-1. Configuration items

Ref	Configuration Items	Description
1	M_GAVER	Applicable GA version
2	M_GASVER	Applicable GA service versions
3	T_NVGAMAXSYSTTA	GA service maximum system TTA
4	T_NVGAMAXTTA	GA service maximum TTA
5	T_NVGAMBUR	GA service broadcast update rate
6	Configuration parameters for GA service selection	Parameters relating to prioritisation of GA services compatible with EVLF to be selected for allocation to GA message streams
7	Configuration parameters for GAC selection	Parameters relating to selection of GACs for a given GA service

Annex A GNSS Augmentation Principles for ERTMS/ETCS

A.1.1.1 The proposed GNSS augmentation framework for ERTMS/ETCS has been designed to be agnostic to GNSS augmentation systems that meet an agreed set of mission requirements for a Railway SoL service and are based on compatible GNSS augmentation principles (i.e., provision of a pseudorange domain integrity service), ensuring the solution is “future proof”.

A.1.1.2 The GNSS augmentation framework has been designed to support interoperability and interchangeability:

- *Technical interoperability* of on-board equipment means GNSS equipment from different suppliers can safely operate with a given GNSS Augmentation System (GAS) assuming the GNSS equipment conforms to requirements of the relevant Minimum Operational Performance Specification (MOPS). These requirements include constraints on receiver design (i.e., range of critical receiver parameters) to limit complexity and ensure assumptions are met by the ground monitoring subsystem of the GAS.
- *Interchangeability* refers to the possibility to utilise the same on-board equipment with different GNSS Augmentation Systems. This requires that GAS' support a compatible range of critical receiver parameters. In aviation, SBAS and GBAS were designed with commonality for these critical parameters, enabling the use of a single set of navigational equipment on aircraft for both SBAS and GBAS approaches from different suppliers / service providers. A similar approach is foreseen for railway, enabling a single set of on-board equipment to operate with EGNOS and other GNSS augmentation solutions for markets outside the EGNOS service area.

A.1.1.3 The GNSS receiver implemented within the EVLF would need to implement the specific Minimum Operational Performance Standards (MOPS) of the GNSS augmentation service, which addresses the specificities of message processing and computation of pseudorange error bounds for the specific GNSS augmentation type (e.g., SBAS, GBAS, etc.).

A.2 Mission Requirements for GNSS Augmentation Systems

A.2.1.1 To ensure Railway SoL Services based on EGNOS and other GNSS augmentation systems are interchangeable, mission requirements defining assumptions and performance requirements for the Railway SoL Service are needed. The mission requirements would address the following:

External Assumptions

- GNSS constellation and performance
 - a) GPS Standard Positioning Service (SPS) Performance Standard
 - b) Galileo OS Service Definition Document
 - c) Other GNSS constellations...
- Assumption of users compliant to relevant MOPS

Signal in Space Performance Requirements – Railway SoL Service

- *Pseudorange Accuracy [UNSTABLE]*: Pseudorange accuracy requirement excluding receiver noise and local effects (e.g., multipath, NLOS, RFI).
- *Pseudorange Integrity Risk*: Pseudorange integrity requirement excluding receiver noise and local effects (e.g., multipath, NLOS, RFI). As service provides commitments in pseudorange domain, pseudorange integrity risk is considered in terms of:
 - a) Pseudorange error bound integrity risk, i.e., bounded residual correction and vertical ionospheric errors (considering a specific definition of a mapping function for computing ionospheric slant range delay and model variance for slant range ionospheric error); and
 - b) SIS / ground integrity risk, i.e., detection and exclusion of fault conditions that are not bounded.
- *Time to Alert (GAS to GATF)*: The maximum duration accepted between the occurrence of an alert condition and the time the alert is received by the GATF of the GA-TS. The time to detect the alert condition is included in this duration. An alert condition occurs when the GNSS augmentation system has erroneously broadcast integrity data not bounding the correction residuals or vertical ionospheric error at the specified confidence level for any valid combination of active data. Note: this is not the end-to-end TTA, which is the duration between the occurrence of an alert condition and the time the alert is received at the endpoint⁴
- *Continuity Risk [UNSTABLE]*: This requirement is potentially linked to:
 - a) Minimum set of constraints at GNSS SIS constellation level and GNSS augmentation RAM level; and
 - b) Probability that variance of correction residuals and variance of vertical ionosphere error (for single frequency users) does not exceed defined thresholds over a given period of time.
- *Availability [UNSTABLE]*: This requirement is potentially linked to:
 - a) GNSS SIS constellation availability and GNSS augmentation RAM-related availability; and
 - b) Availability of variances of correction residuals and vertical ionospheric error below a given threshold for the service volume.

Note: Tropospheric error is not actively monitored by the GNSS augmentation system (tropospheric refraction is a local phenomenon, where water vapour associated with precipitation, thunderstorms and bad weather is a significant contributor to tropospheric delay). The proposed tropospheric correction and residual tropospheric error model is the model defined in [DO-229] and [ED-259A], which is a blind model that has been validated

⁴ Endpoint refers to the ELVF within the on-board equipment. For example, this may include forwarding of GA messages on an internal bus (e.g., Profibus) to the endpoint.

using historical data for use in the aviation SoL service. (Refer to open point 1 – Validation of tropospheric model for railway in Annex C).

- A.2.1.2 The proposed integrity requirements for the Railway SoL Service, illustrated in Table A-1, are consistent with integrity requirements for CAT-I precision approach (integrity risk = 2×10^{-7} in any approach (150s), TTA = 6s). Precision approach services are associated with the most stringent level of integrity performance that is provided by the current and next generation of SBAS. While non-precision approach (NPA) meets a higher level of integrity in the position domain (integrity risk = 10^{-7} / hour, TTA = 10s, with an alert limit of 556m), NPA integrity is not committed by EGNOS in the pseudorange domain as all the barriers are designed against the *Precision Approach* services (i.e., for NPA service, the case of position domain impact analysis needs to be explicitly addressed).
- A.2.1.3 In EGNOS for *Precision Approach* services, a conservative assumption is made that under fault-free conditions a violation of integrity in the pseudorange domain would result in a violation of integrity in the position domain with a probability of 1; therefore,
- an integrity risk allocation of 10^{-7} / 150s is allocated to bounding of residual errors in the pseudorange domain under fault-free conditions (i.e., no extreme ionosphere / scintillation conditions; includes ground station nominal multipath, interference, cycle slips, etc.); and
 - another allocation of 10^{-7} / 150s is made for detection of fault conditions (i.e., presence in the system of any feared events or any events beyond the defined fault-free conditions).
- A.2.1.4 For railway applications, the integrity risk of 2×10^{-7} / 150s is translated to a one-hour exposure time. The justification for this exposure period is related to safety analyses and the apportionment to constituents in the European Train Control System (ETCS), which is undertaken against a definition of the role of that constituent and its related hazards in a representative one-hour journey.
- A.2.1.5 There are 24×150 second periods in one hour, resulting in an integrity requirement of 4.8×10^{-6} / hour, equally allocated between pseudorange error bound integrity risk (fault-free) and SIS integrity risk.

Table A-1. Proposed Railway SoL Service performance requirements

Performance	Requirement	Railway SoL Service (short to medium-term) ^e	Railway SoL Service (future) ^f
Pseudorange Accuracy	(to be defined in the future) ^a		X
Pseudorange Integrity Risk	4.8×10^{-6} / hour	X ^{b,c,d}	X
Time to Alert (GAS – GATF)	6 seconds	X	X
Continuity Risk	(to be defined in the future) ^a		X
Availability	(to be defined in the future) ^a		X

The following conventions are used for the above table:

- X = supported (with caveats – refer to notes)
- Empty case = not supported
- Short to medium-term refers to before 2030; future refers to beyond 2030

- a) Currently there is no agreed definition for these requirements in the pseudorange domain. While there may be limitations for making commitments on these requirements for EGNOS, in the case of other GNSS augmentation systems, it may be possible to fulfil such requirements.
- b) For EGNOS V2, although the system has been designed with integrity in the pseudorange domain (for the precision approach service), requirements for integrity in the pseudorange domain are not specified. To enable service declaration for a railway SoL service, additional EGNOS subsystem level activities may be required. A railway SoL service concept and roadmap is to be confirmed by EUSPA.
- c) For EGNOS V3 (i.e., EGNOS V3.1 Legacy, EGNOS V3.2 Legacy + DFMC), there are requirements on integrity in the pseudorange domain and therefore commitments on integrity in the pseudorange domain may be possible. A railway SoL service concept and roadmap is to be confirmed by EUSPA.
- d) In terms of interoperability with other SBAS service providers, currently they have not provided formal commitments on integrity in the pseudorange domain, which may be a constraint in exporting the concept.
- e) Refers to requirements for which commitments in the pseudorange domain may be possible considering a future (long-term) evolution of EGNOS with additional features / commitments for a Railway SoL Service.

A.3 Use of GNSS Augmentation Services and Prescriptions on the GNSS Receiver

A.3.1.1 To use the service, there are a minimum set of requirements and constraints that must be fulfilled for commitments on pseudorange domain integrity to be valid. A *Minimum Operational Performance Standard for GNSS Augmentation On-board Equipment (GA-OB MOPS)* is needed for each type of GNSS augmentation, addressing essential EVLF GNSS receiver requirements including:

- GNSS Signal processing
- Critical parameters of the user receiver configuration space
- Augmentation message processing
- Computation of pseudorange error bounds (i.e., variance of correction residuals and slant range ionospheric error)

A.3.1.2 It is expected that a demonstration of conformance of the EVLF GNSS receiver to the specific GA-OB MOPS will be required in addition to evidence of safe integration of the receiver into the relevant safe positioning elements in ERTMS/ETCS for use of a GNSS augmentation service by the implementing equipment to be authorised.

A.3.1.3 Constraining the receiver implementation through prescription of critical parameters of the user receiver configuration space is necessary to enable technical interoperability between receivers from different manufacturers and to limit the complexity of the GNSS augmentation ground monitoring subsystem. These critical parameters directly influence how each point in the threat space for each fault mode translate to an error in the differentially corrected smoothed pseudorange.

A.3.1.4 The design of GNSS augmentation ground monitors considers the error that would be induced in the corrected smoothed pseudorange given the full range of critical parameters that comprise the user receiver configuration space for each fault mode to be protected by the GNSS augmentation system.

A.3.1.5 For example, the current SARPs identifies the signal deformation threats (EWF anomalies) and defines the SQM function that allows them to be mitigated for both SBAS and GBAS. As noted in the SARPs [SARPS, Attachment D-43, Section 8]:

The signal effects that might cause a GBAS or SBAS to output MI can be categorised into three different effects on the correlation function as follows:

- a) *Dead zones: If the correlation function loses its peak, the receiver's discriminator function will include a flat spot or dead zone. If the reference receiver and aircraft receiver settle in different portions of this dead zone, MI can result.*
- b) *False peaks: If the reference receiver and aircraft receiver lock to different peaks, MI could exist.*
- c) *Distortions: If the correlation peak is misshapen, an aircraft that uses a correlator spacing other than the one used by the reference receivers may experience MI.*

A.3.1.6 The SARPs defines three threat models and the SQM function to detect these anomalies through characterisation of the correlation peak. The critical user receiver parameters for the signal distortion threat are:

- *Smoothing filter type*. The fault condition will appear as a step in raw code measurement both for user and ground receivers. The step is filtered by the smoothing filter in the ground and user receivers, impacting detection threshold and whether the increasing pseudorange error exceeds limit for protection before detection threshold is reached.
- *Correlator type* (Early-Late (E-L) or Double Delta (DD))
- *Correlator spacing*
- *GNSS signal bandwidth* (from reception at antenna through RF, IF, and A/D conversion)
- *Group delay* (from reception at antenna through RF, IF, and A/D conversion)

A.3.1.7 The user receiver must conform with the prescribed critical parameters for the ground monitor to protect users against the defined threat models.

A.3.1.8 In aviation, SBAS and GBAS were designed with commonality for these critical parameters, enabling the use of a single set of navigational equipment on aircraft for both SBAS and GBAS approaches from different suppliers / service providers.

A.3.1.9 A similar approach is considered for railway, where the EVLF with a GNSS receiver conforming to the prescribed critical parameters, can support different GNSS augmentation services through implementations of GA-specific software modules that address GA-OB MOPS-compliant message processing and computation of pseudorange error bounds specific to the GAS.

A.4 Use of Pseudorange and Error bounding with GNSS Augmentation

A.4.1.1 The residual errors for pseudorange measurements for fault-free satellites are modelled by root-sum-squaring the error components (under the assumption of zero-mean normal distributions).

A.4.1.2 It is foreseen that a generic Railway SoL Service (pseudorange domain integrity service), would provide bounding of correction residuals and slant range ionospheric error. Equation

A-1 illustrates the error components provided by a generic Railway SoL Service, with mappings to examples for specific GNSS augmentation systems:

$$\sigma_i = \sqrt{\sigma_{i,CRE}^2 + \sigma_{i,iono}^2} \quad \text{A-1}$$

Where:

$\sigma_{i,CRE}^2$ is the variance of the correction residual error for satellite i :

- For SBAS L1, $\sigma_{i,CRE}^2$ is the model variance for the residual error when SBAS L1 corrections (long term, fast and range rate) are applied, and the degradation model is used ($\sigma_{i,flt}^2$).
- For SBAS DFMC, $\sigma_{i,CRE}^2$ is the model variance for the residual error after application of SBAS L5 dual-frequency corrections ($\sigma_{i,DFC}^2$).
- For GBAS GAST-C, $\sigma_{i,CRE}^2$ is the variance of the total post correction fault-free noise term provided by the ground function (σ_{i,pr_gnd}^2).

$\Sigma_{i,iono}^2$ is the variance of the residual ionospheric error for satellite i :

- For SBAS L1, $\sigma_{i,iono}^2$ is the model variance for the slant range ionospheric error when applying SBAS L1 ionospheric corrections ($\sigma_{i,UIRE}^2$).
- For SBAS DFMC, $\sigma_{i,iono}^2$ is the model variance describing the residual ionospheric error (including ionospheric higher-order effects, ray bending and excess TEC) when applying the ionosphere-free dual-frequency L1/L5 combination.
- For GBAS GAST-C, $\sigma_{i,iono}^2$ is the variance for the residual ionospheric delay due to spatial decorrelation uncertainty.

A.4.1.3 Error components related to troposphere, receiver noise and multipath would also need to be included in the fault-free residual measurement error σ_i (as illustrated in Equation A-2); however,

- models for bounding residual errors related to receiver errors in the railway environment (e.g., receiver noise and multipath) are the responsibility of the manufacturer perimeter; and
- model for residual error related to troposphere is based on the DO-229 / ED-259A tropospheric model (refer to Open Point 1 – Validation of tropospheric model for railway in Annex C).

$$\sigma_i = \sqrt{\sigma_{i,CRE}^2 + \sigma_{i,iono}^2 + \sigma_{i,rail}^2 + \sigma_{i,tropo}^2} \quad \text{A-2}$$

Where:

$\sigma_{i,rail}^2$ is the model variance for receiver errors in the railway environment:

$$\sigma_{i,rail}^2 = \sigma_{i,noise}^2 + \sigma_{i,MP\&AGDV}^2 + \sigma_{i,divg}^2 \quad \text{A-3}$$

- $\sigma_{i,noise}^2$ is the model variance that bounds the errors in the tails associated with the receiver for satellite i , including receiver noise, thermal noise, interference, inter-channel biases, extrapolation, time since smoothing filter initialisation, and processing errors for smoothed pseudoranges.
- $\sigma_{i,MP\&AGDV}^2$ is the model variance for multipath and antenna group delay variation error.
- $\sigma_{i,divg}^2$ includes residual ionospheric error caused by the difference between the implemented smoothing filter and the reference smoothing filter given an ionospheric code-carrier divergence during the transient phase (i.e., before filter reaches steady-state) for L1 single frequency measurements smoothed with the time variant reference smoothing filter, applying SBAS L1 ionospheric corrections; after steady state $\sigma_{i,divg}^2 = 0m$.

Not applicable for SBAS DFMC (i.e., ionosphere free dual-frequency measurements)

Not applicable for GBAS, as it requires (nearly) matched smoothing filters in ground and on-board to limit sensitivity to ionospheric divergence (SBAS can implement smoothing filters with a longer weighting function time constant as it removes divergence on ground using GPS L2 measurements).

and $\sigma_{i,tropo}^2$ is the model variance of the zero-mean normal distribution describing the tropospheric correction residual errors.

A.4.1.4 While translation of the variance of the residual measurement errors for satellites (pseudorange domain error bounds) to position domain error bounds is outside the scope of the Railway SoL Service, it is expected that guidance could be provided for the computation of protection levels (along-track and horizontal) within the Railway SoL Service MOPS for the specific GNSS augmentation system. It is expected that track-constrained along-track and horizontal protection levels would be defined, although definition of a track-constrained ATPL is dependent on the definition of an interoperable digital track map.

A.4.1.5 It should be noted that SBAS and GBAS have different equations for computation of protection levels:

- In the case of SBAS, protection level calculations assume fault-free conditions where pseudorange and position domain errors are modelled under the assumption of zero-mean normal distributions (i.e., errors assumed to be Gaussian in the tails). Fault conditions are managed by SBAS (i.e., detected and excluded).
- In the case of GBAS, pseudorange and position domain errors under fault-free (nominal) conditions are modelled under the assumption of zero-mean normal distributions; however, under faulted conditions, a known bias (B-value) due to the failure of a single satellite or ground reference receiver is added to the zero-mean normal distribution with the same sigma. As such, protection levels are computed for: H_0 : nominal conditions, H_1 : single ground reference receiver failure, and part of H_2 : all other conditions, related to ephemeris failures, i.e.,

$$xPL = \max\{xPL_{H_0}, xPL_{H_1}, xPB_e\}$$

A-4

Where:

- $xPL_{H1} = \max\{xPL_{H1}[j]\}$ and $xPB_e = \max\{xPB_e[k]\}$.
- nominal conditions are bounded by xPL_{H0} ;
- single ground receiver fault conditions are bounded by $xPL_{H1}[j]$ for all $j(1 \text{ to } \max\{M[i]\})$, where $M[i]$ is the number of ground reference receivers whose pseudorange measurement was used to determine the differential correction for the i^{th} ranging source used in the position solution; and
- single satellite ephemeris fault conditions are bounded by $xPB_e[k]$ for the k^{th} ranging source used in the position solution.

A.5 Considerations on Responsibility and Critical User Receiver Parameters

- A.5.1.1 The Railway SoL Service is a pseudorange domain integrity service quasi-independent of the user concept of operations, with a limited set of assumptions, allowing for the use of GNSS augmentation in a technology-neutral manner, also facilitating a simplification of service provision requirements and operations.
- A.5.1.2 It provides on-board equipment manufacturers with the flexibility to integrate GNSS augmentation into their solutions without a high-level of prescription on the design of the GNSS localisation equipment, hybridisation approach, etc.
- A.5.1.3 The pseudorange domain integrity service protects users from system feared events and provides bounding on the correction residuals and ionospheric error at the required level of confidence for any valid combination of active data. The on-board equipment perimeter, however, would be responsible for protecting the user from local feared events, bounding residual errors due to receiver and local environment, and the translation of range domain error bounds to position domain error bounds.
- A.5.1.4 It is understood some of the MOPS-compliant critical user receiver parameters such as the smoothing filter type may be impacted by local effects of the railway environment (e.g., carrier phase discontinuities) and as such, may result in poor performance.
- A.5.1.5 For cases such as this, where a deviation from the requirements may be necessary, it is proposed for a future iteration of this specification that guidance is provided on how to deviate from prescribed critical user receiver parameters in a controlled manner to ensure integrity requirements are met.
- A.5.1.6 The guidance could be included in an informative annex and would address:
- Definition of minimum constraints.
 - Information on the effects / impact (if can be determined) of not implementing the prescribed parameters.
 - Guidance on how to deviate in a controlled manner. For example, in the case of the smoothing filter, guidance on how to justify that integrity assumptions are not violated considering differences of the implemented smoothing filter with respect to the response of the reference smoothing filter, addressing:

- a) The transient function of the error during convergence time of the filter (i.e., elapsed time since smoothing filter re-initialisation until in the steady state).
- b) Inflation of $\sigma_{MP\&AGDV}$ in the case of a smoothing filter with a weighting function time constant < 100 seconds (i.e., in the steady state).
- c) For single frequency users, residual ionospheric error caused by the difference between the implemented filter and the reference filter caused by ionospheric divergence during the transient phase.

A.6 A Note on EGNOS and the use of Kalman Filters

- A.6.1.1 In the case of snapshot weighted least squares (WLS), integrity is guaranteed when the pseudorange error is bounded for all measurements.
- A.6.1.2 If Kalman filters are used, applicability of the UDRE/DFRE (and GIVE) may not be suitable if the effect of the biases and the time-correlation of the remaining error distribution after corrections are not accounted for properly. Protection levels computed from the Kalman filter-estimated covariance may not bound position errors at the required level of confidence as assumptions on errors being uncorrelated (i.e., errors related to ephemeris/clock and ionosphere are correlated in time) and error distributions being zero-mean Gaussian are not valid. It is the responsibility of the manufacturer perimeter to address such issues and ensure the safety of the Enhanced Vehicle Localisation Function.
- A.6.1.3 EGNOS currently does not provide commitments on error decorrelation or provide bias values. Such features may be investigated for a future Railway SoL service but are not foreseen in the short / medium term.

Annex B EGNOS-based GA for ERTMS/ETCS

B.1 Introduction

B.1.1 The European Geostationary Navigation Overlay Service (EGNOS)

- B.1.1.1 EGNOS, the European Satellite Based Augmentation System (SBAS), is a system designed to augment Global Navigation Satellite Systems (GNSS) by providing users with ephemeris, clock and ionospheric error corrections, and integrity information broadcasted via geostationary satellites. Currently EGNOS V2 augments GPS L1 signals only; however, EGNOS V3 will provide a Dual Frequency Multi Constellation (DFMC) service augmenting GPS and Galileo L1/E1 and L5/E5a signals, in addition to the legacy GPS L1 service.
- B.1.1.2 The EGNOS ground segment is comprised of a network of monitoring stations (RIMS) that are used to collect measurements, which are elaborated by the Central Processing Facility (CPF). The CPF computes ephemeris corrections, clock corrections, and a model for ionospheric errors, valid for the defined service area, improving positioning accuracy for users within this area.
- B.1.1.3 The CPF estimates residual error variances (assuming application of corrections broadcast by the system) – the User Differential Range Error (UDRE) and Grid Ionospheric Vertical Error (GIVE) for single frequency users, and the Dual Frequency Range Error (DFRE) for dual frequency users. These residual error variances are used in the determination of a protection level, a statistical bounding of the position error that meets the integrity requirement for a given operation (e.g., for LPV-200 service level that supports approach operations based on SBAS with a minimum decision height of 200 feet, integrity requirement is $1-2 \times 10^{-7}$ in any approach). The CPF can detect when errors exceed certain thresholds or anomalies in the GPS, Galileo or SBAS systems themselves. In these cases, the user must be alerted within the Time to Alert (TTA).

B.1.2 EGNOS Railway Safety of Life Service Concept

- B.1.2.1 The EGNOS Railway Service concept is expected to be quasi-independent of the user concept of operations (CONOPS), with a limited set of assumptions, allowing for use of GNSS augmentation in a technology-neutral manner, also facilitating a simplification of service provision requirements and operations. It would provide on-board equipment manufacturers with the flexibility to integrate EGNOS into their solutions without a high-level of prescription on the design of the enhanced localisation equipment, hybridisation approach, etc.
- B.1.2.2 On this basis, the on-board equipment perimeter would be responsible for:
- Protecting user from local feared events;
 - Bounding of residual errors due to receiver and local environment; and
 - Translation of pseudorange domain error bounds to position domain error bounds.
- B.1.2.3 Details of service commitments shall be provided in an EGNOS Railway Safety of Life Service Definition Document.

B.2 Overview of GA for ERTMS/ETCS based on EGNOS

B.2.1.1 Figure B-1 provides a high-level reference architecture of GNSS Augmentation based on EGNOS for ERTMS/ETCS, illustrating the interface of the GATF to EGNOS via the EGNOS signal-in-space (SIS).

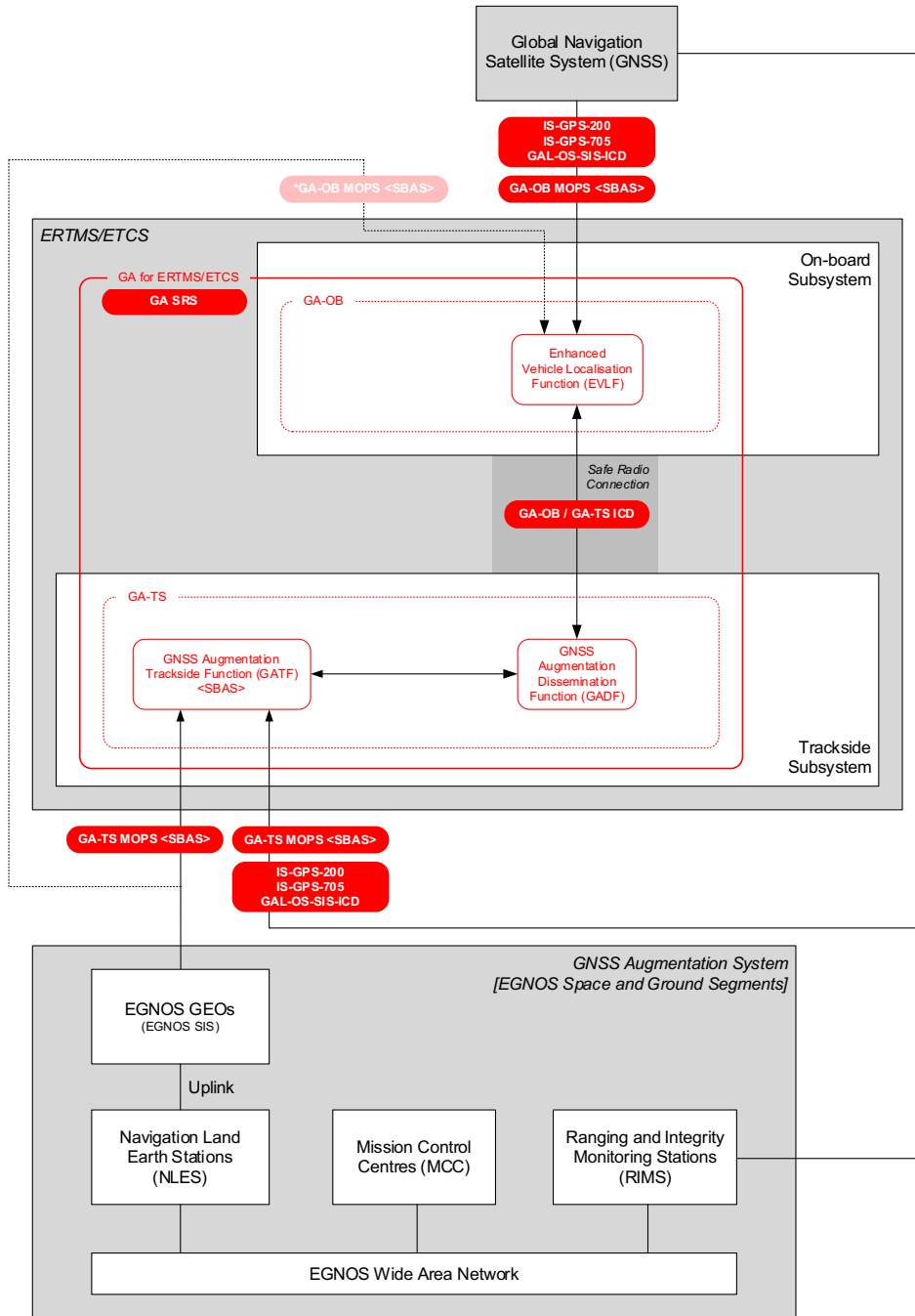


Figure B-1. GNSS Augmentation Functional Reference Architecture with EGNOS-based GA

B.2.1.2 The functional reference architecture includes the possibility for reception of SBAS messages directly by the EVLF from the SBAS GEO SIS. Note that this interface is SBAS-

specific and is to be developed further in the next iteration of this document⁵. This mode of operation is expected to have a low availability due to obscuration of signals, especially in the railway environment. For this reason, on-board reception of EGNOS augmentation information via the GA-TS is considered as the primary means to ensure a high availability of augmentation information to the on-board.

Note: it is conceivable that an EGNOS railway-specific dissemination channel(s) via terrestrial or other means (e.g., including possible future concepts including SBAS E5b / signals from IGSOs (inclined geosynchronous orbits)) could be considered in the future.

B.3 EGNOS-Specific EVLF Functions

B.3.1.1 This section provides some EGNOS-specific considerations related to the EVLF functions.

B.3.2 SBAS Network Time (SNT)

B.3.2.1 $T_{GATF,GAMrx}$ is the timestamp (time of week) of the end of GA message reception by the GATF, provided by the variable T_GAM in Packet 212 included in messages of *type 62: GA Message* sent by the GADF to the EVLF. The reference time of T_GAM is indicated by the qualifier Q_GAT in Packet 212.

B.3.2.2 For EGNOS, $Q_GAT = 0$, SBAS Network Time. The EVLF time $t_{EVLF,now}$ for EGNOS services (time of week) shall be in SBAS Network Time.

B.3.2.3 SBAS Network Time (SNT) is defined as that which is maintained, after corrections, to GPS system time, within the overall SBAS performance requirements. Data blocks will maintain synchronism with the GPS data blocks to within the same performance requirements. It is noted that, when using corrections, the user's solution for time will be with respect to the SBAS Network Time, and not with respect to GPS System Time. SBAS Network Time will be within 50 nanoseconds of GPS system time.

B.3.3 Time of Applicability

B.3.3.1 It is assumed that the time of applicability of the differential information in the SBAS signal-in-space is the start of transmission from the SBAS GEO of the 1-second message block containing that information. The start of transmission is synchronized to the beginning of the corresponding SBAS Network Time (SNT) second.

B.3.4 Message Timeout Periods

B.3.4.1 The beginning of the timeout interval for message content timeout supervision is the end of the reception of a message by the SBAS/GNSS receiver in the GATF. This timestamp is provided in GA messages (T_GAM) to allow the EVLF to supervise message content timeouts with respect to its current time $t_{EVLF,now}$.

⁵ This interface is reserved for supporting reception of the SBAS GEO SIS by the EVLF. In a future release of the SRS, principles for use of this interface will be defined. It should be noted that information from EGNOS received by the EVLF via the GADF and via the SBAS GEO SIS cannot be mixed in a single GNSS processing channel.

B.3.4.2 The following tables provide SBAS message content broadcast intervals and timeout for the proposed Railway SoL Service, which is assumed to be based on the SBAS precision approach operation – refer to Annex A: A.2)

Table B-1. Message content broadcast intervals and timeout (SBAS L1 Legacy)

Data	Associated Message Types	Maximum Update Interval (seconds)	Railway SoL Service Timeout (seconds)*
PRN Mask	1	120	600
UDREI	2 to 6, 24	6	12
Fast Corrections	2 to 5, 24	(see Table B-2)	(see Table B-2)
Long Term Corrections	24, 25	120	240
Fast Correction Degredation	7	120	240
Degradation Parameters	10	120	240
Ionospheric Grid Mask	18	300	1200
Ionospheric Corrections	26	300	600
Service Level	27	300	86400
Clock-Ephemeris Covariance Matrix	28	120	240

*Note: Railway SoL Service (L1 Legacy) timeout values are equivalent to those defined for LNAV/VNAV, LP and LPV approach [DO-229].

Table B-2. Fast corrections degradation factor and user timeout interval evaluation (SBAS L1 Legacy)

Fast Corrections Degredation Factor Indicator (ai)	Fast Corrections Degredation Factor (ai) (m/s ²)	Railway SoL Service Timeout Interval for Fast Corrections (seconds)*	Maximum Fast Correction Update Interval (seconds)
0	0.00000	120	60
1	0.00005	120	60
2	0.00009	102	51
3	0.00012	90	45
4	0.00015	90	45
5	0.00020	78	39
6	0.00030	66	33
7	0.00045	54	27
8	0.00060	42	21
9	0.00090	30	15
10	0.00150	30	15
11	0.00210	18	9
12	0.00270	18	9
13	0.00330	18	9
14	0.00460	12	6
15	0.00580	12	6

*Note: Railway SoL Service (L1 Legacy) timeout intervals for fast corrections are equivalent to those defined for LNAV/VNAV, LP and LPV approach [DO-229].

Table B-3. Message content broadcast intervals and timeout (SBAS L5 DFMC)

Contents	Associated Message Types	Maximum Update Intervals (seconds)	Railway SoL Service Timeout (seconds)*
Do Not Use for Safety Applications	0	6	N/A
Satellite mask	31	120	600
Integrity information (DFREI and DFRECI)	34	6	12
	35		
	36		
	32		
	40		
Satellite Clock-Ephemeris error corrections and covariance matrix	32	$0.5 \times (I_{VALID})_{MT32}$ (defined in MT 37)	$(I_{VALID})_{MT32}$ (defined in MT 37)
Ephemeris and Clock covariance matrix of SBAS broadcasting satellites	39	$0.5 \times (I_{VALID})_{MT39/40}$ (defined in MT 37)	$(I_{VALID})_{MT39/40}$ (defined in MT 37)
	40		
OBAD parameters and DFREI scale table	37	120	600
Time Reference Identifier	37	120	600
SBAS provider ID	47	120	600

*Note: Railway SoL Service (L5 DFMC) timeout values are equivalent to those defined for LNAV/VNAV, LP and LPV approach [DO-229].

B.4 EGNOS-Specific GATF Functions

B.4.1.1 This section provides some EGNOS-specific considerations related to the GATF functions.

B.4.2 Maintain GA Active Data Set for Each GAC

B.4.2.1 The GATF shall maintain an active GA data set for each GAC by temporarily storing the last received SBAS messages for SBAS message types, ensuring stored messages are consistent in terms of IOD (see Figure B-1).

B.4.2.2 The GATF shall maintain GA active data sets for multiple IODs, providing the EVLF with the most recent complete active data set (i.e., with IOD consistency) when requested.

B.4.2.3 SBAS messages are temporarily stored until a new SBAS message is received for the same IOD or for the duration of the validity of the message content (i.e., until message content times out).

B.4.2.4 Note: Upon transmission of new clock and ephemeris data from GNSS satellites, the SBAS will continue to broadcast corrections and covariance matrix with respect to the old clock and ephemeris data for a period of time enabling all SBAS users to acquire the new GNSS data.

B.4.2.5 Message types with a short timeout and high update rate are not included in the active data set, as it is assumed that these messages can be received by the EVLF via the GA message stream.

B.4.2.6 Figure B-1 and Figure B-2 illustrate the relationships between message types that are broadcast on SBAS L1 and SBAS L5 respectively, including IOD-related dependencies.

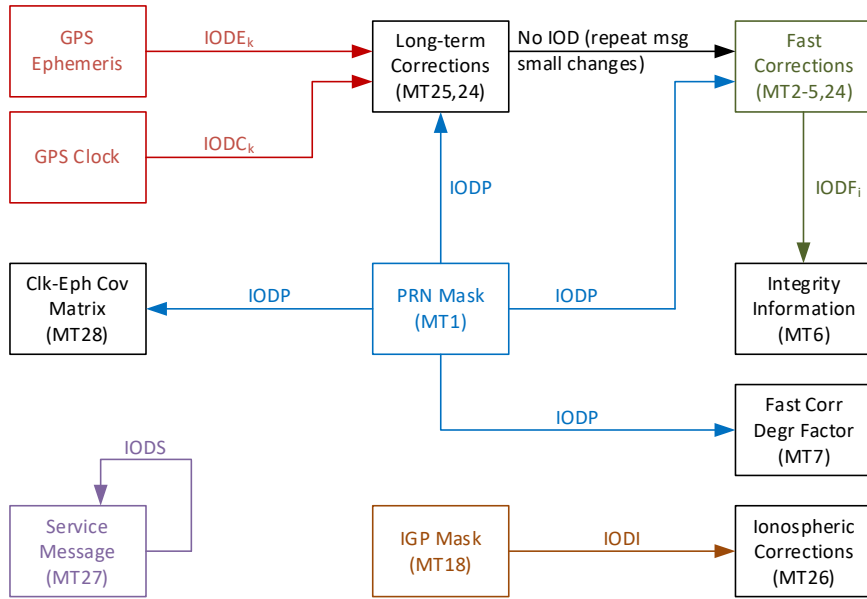


Figure B-1. Relationships between SBAS message types (Legacy GPS L1)

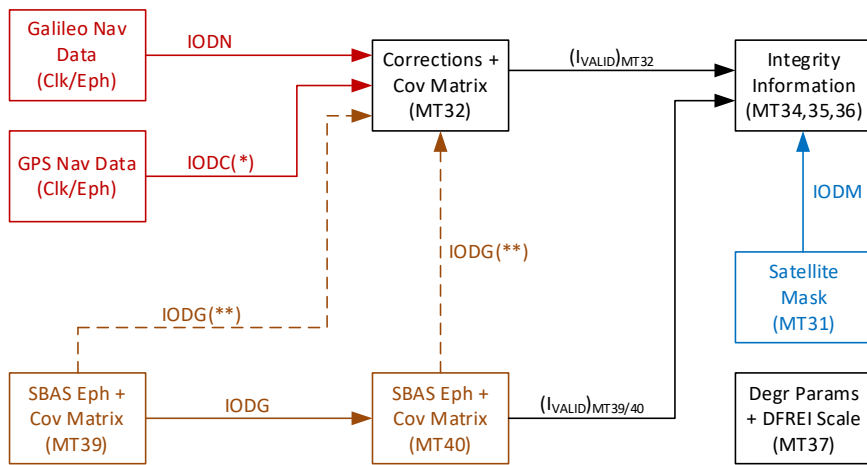


Figure B-2. Relationships between SBAS message types (DFMC)

(*) Once the IODC/IODE consistency is checked, the IODC is used to identify the applicable set of clock and ephemeris data when applying SBAS L5 corrections.

(**) IODG links between MT39/40 and MT32 are used when the MT32 is broadcast for an SBAS satellite.

B.4.2.7 The composition of the SBAS messages comprising the active data set shall be configurable for each service to accommodate:

- Differences in message scheduling between different SBAS’;

- Changes to message scheduling for a given SBAS; and
- Changes to service area (i.e., related to ionospheric bands / blocks for Legacy service).

Note: maintaining GA active data sets requires the processing of SBAS messages.

B.4.3 GATF Active Functions Table

B.4.3.1 The following conventions are used for the active functions table:

- X = functions shall be active
- Empty case = function shall be inactive
- O = optional (function not required for interoperability, but is not forbidden)

GATF Functions	Related Requirement	NP	SB	OP	FA
GATF / GAS Communication					
<i>Reception of GA messages from GAS</i>					
Reception of SBAS Legacy messages from EGNOS L1 SIS from each GEO	SRS §TBA		X	X	
Reception of SBAS DFMC messages from EGNOS L5 SIS from each GEO	SRS §TBA		X	X	
GATF / GADF Communication					
<i>Transmission of GA messages to GADF for each service / GAC</i>					
Transmission of SBAS Legacy messages to GADF for each EGNOS PRN in operational mode (i.e., no MT0)	SRS §TBA			X	
Transmission of SBAS DFMC messages to GADF for each EGNOS PRN in operational mode (i.e., no MT0)	SRS §TBA			X	
Transmission of requested GA active data sets to GADF	SRS §TBA			X	
Transmission of requested GNSS navigation data sets to GADF	SRS §TBA			X	
Transmission and reception of GADF-GATF session management messages and acknowledgements	SRS §TBA		X	X	
GATF Functions					
<i>Selection of GACs</i>					
EGNOS Legacy Satellite Selection (at least 2 available SBAS L1 GEO signals broadcasting valid messages – passing CRC, no MT0)	SRS §TBA, EGNOS TS Railway MOPS		X	X	
EGNOS DFMC Satellite Selection (at least 2 available SBAS L5 GEO signals broadcasting valid messages – passing CRC, no MT0)	SRS §TBA, EGNOS TS Railway MOPS		X	X	
Maintain GA active data set for each GAC	SRS §TBA			X	

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Timestamping reception of messages from GAS					
Timestamping end of reception of SBAS Legacy / DFMC messages from SBAS SIS by GNSS/SBAS receiver	SRS §TBA			X	
Encapsulation of messages received from GAS in GAM packets					
Encapsulation of SBAS Legacy messages in GAM packets	SRS §TBA			X	
Encapsulation of SBAS DFMC messages in GAM packets	SRS §TBA			X	
Maintain GNSS navigation data sets	SRS §TBA			X	
SBAS signal processing					
Acquisition and tracking of SBAS signals (L1 and L5)	EGNOS TS Railway MOPS		X	X	
SBAS L1 data demodulation and FEC decoding	EGNOS TS Railway MOPS		X	X	
SBAS L5 data demodulation and FEC decoding	EGNOS TS Railway MOPS		X	X	
SBAS L1 message processing (minimum required to support GATF functions)	EGNOS TS Railway MOPS		X	X	
SBAS L5 message processing (minimum required to support GATF functions)	EGNOS TS Railway MOPS		X	X	
GNSS signal processing					
Acquisition and tracking of GNSS signals	GNSS-SIS-ICD		X	X	
Navigation data demodulation and FEC decoding	GNSS-SIS-ICD		X	X	
Navigation data processing	EGNOS TS Railway MOPS, GNSS-SIS-ICD		X	X	

Annex C Open Points to be Addressed in Future Iterations of the Specification

C.1.1.1 The following table provides a list of open points related to the SRS to be addressed in future iterations of the specification.

Table C-1. Open points list

Ref	Description	Solution / Workstream	Status / Notes
1	Validation of tropospheric model for railway	Currently being investigated by ESA / EUSPA; activity may be required to perform additional validation work if determined necessary.	<p>Open.</p> <p>Currently under investigation, awaiting access to data from validation of Galileo tropospheric model and comparison with DO-229 / ED-259A model.</p> <p>Key points from investigation to date:</p> <ul style="list-style-type: none"> No need to validate in railway environment, model is a blind model independent of any local phenomena. Historical data is sufficient for validation. Variability comes from water vapour and pressure, with water vapour being the significant contributor (i.e., associated with precipitation, bad weather, thunderstorms). Mapping function anomalies from blind model are concentrated below 10 degrees of elevation; usage conditions of model requiring application of masking < 10 degrees would significantly reduce anomalies. Repetition of extreme events is rare, few data points. The model requires further consolidation to assess its validity under bad weather conditions.
2	GATF specification for EGNOS	Working group to be allocated (support from ESA / EUSPA)	<p>Open.</p> <p>Specification to be developed once details of Railway SoL service and its commitments are confirmed by EUSPA.</p> <p>Specification includes aspects such as:</p> <ul style="list-style-type: none"> GAC selection (selection of GACs for authorised services / service providers) Barriers / diagnostic capabilities to address possible cybersecurity threats related to open SBAS transmission channel Allocation of processing to the trackside: additional elaboration on the trackside could be considered to reduce the amount of data to be transferred to the on-board subsystem without impacting its ability to apply models for degradation of data (e.g., quantity of information related to ionospheric corrections to be transferred to the on-board subsystem can be reduced for SBAS Legacy service, by only providing the vertical delays and errors (GIVEs) for relevant Ionospheric Grid Points (IGPs).
3	Development of guidance on how to deviate from prescribed critical user receiver parameters in a controlled manner to ensure integrity requirements	Activity to be defined (led by ESA / EUSPA)	<p>Open.</p> <p>Guidance addressing critical user receiver parameters such as:</p> <ul style="list-style-type: none"> Carrier smoothing filter (length, non-stationary state)

	are met (refer to Annex A: A.3 and A.5)		<ul style="list-style-type: none"> Correlator type, spacing, GNSS signal bandwidth, group delay
4	Development of guidance on the computation of protection levels (along-track and horizontal)	Activity to be defined (led by ESA / EUSPA)	Open.
5	Update of EGNOS railway receiver guidelines (MOPS) for GA-OB and GA-TS	To be performed by ESSP with support from EUSPA/ESA.	Open. Update of documents / alignment with updated SRS and SFHA.
6	GA and GAS versioning	To be addressed by JWG	<p>Open.</p> <p>Issue raised in review: GA and GAS versioning paradigms are opposite of ETCS versioning paradigm, where on-board receives system version from trackside.</p> <p>In GA SRS, on-board sends supported GA versions to trackside, trackside responds with version to be used by on-board. Similarly in the case of on-board requesting allocation of a GA message stream, GA services and versions supported by on-board are provided to trackside; trackside allocates a message stream based on the supported on-board versions.</p> <p>Motivation for different paradigm is that trackside would be expected to support different versions of augmentation.</p> <p>Note that this paradigm is also used by ATO over ERTMS (SUBSET-125/126) (handshake request, with on-board sending ATO versions supported to trackside)</p>
7	Degraded modes	To be addressed by JWG	<p>Open.</p> <p>Issue raised in review: behaviour when the trackside cannot provide a compatible GNSS augmentation service to the on-board. What is the impact on ECVF function / how to handle (e.g., through definition of degraded modes / special modes)?</p>
8	GATF processing time	To be addressed by JWG (with support by ESA / EUSPA)	<p>Open.</p> <p>Issue raised in review: requirement for maximum GATF processing time has not been allocated as it had been considered that it may be GAS-specific. The latency is to be considered in the end-to-end TTA (T_NVGMAXTTA) but an upper bound may need to be considered.</p>
9	Requirement for at least 2 available SBAS GEO signals for selection of GAC	To be addressed by JWG (with support by ESA / EUSPA)	<p>Open.</p> <p>Issue raised in review: in Annex B, for EGNOS-specific GATF, selection of GACs based on at least 2 available SBAS L1 and L5 GEO signals broadcasting valid messages, passing CRC and no MT0. Is it necessary to require at least 2 available SBAS GEOs? Relates to support for 2 message streams.</p>
10	Support for more than 2 GA message streams	To be addressed by JWG (with support by ESA / EUSPA)	<p>Open.</p> <p>Issue raised in review: although stakeholders indicated that 2 channels should not be mandatory, it needs to be confirmed whether support should be provided for more than two parallel message streams. Currently 2 streams are supported, but not required. For example, there are cases where more than 2 would be needed to avoid discontinuity when transitioning between two service areas, where 2 streams are allocated for each service.</p>

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11	Support for reception of SBAS SIS directly by EVLF	To be addressed by JWG (with support by ESA / EUSPA)	Open. EVLF has an interface supporting direct reception of SBAS messages via the SBAS GEO SIS; however, principles for use of this interface are not currently defined in this version of the SRS. To be addressed in a future release of SRS.
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