Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

Issue Three December 2015
Rail Industry Guidance Note

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Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

**Issue record**

<table>
<thead>
<tr>
<th>Issue</th>
<th>Date</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>December 2008</td>
<td>Original document</td>
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<tr>
<td>Two</td>
<td>September 2011</td>
<td>Replaces issue one Small scale change amendment to include new section 6.4.2.9, and change to colour coding in Figure 3. Also, new Appendix D – Locator Interface Specification</td>
</tr>
</tbody>
</table>
| Three | December 2015 | Replaces issue two The document has been restructured throughout and the following key changes have been incorporated:  
- Title has been changed to align with the scope of the document.  
- Updated Figure 1 of issue two, to illustrate locator interfaces to applications both on board and at trackside, and to clarify the boundary between the guidance note and other documents.  
- Clarification of the definition of the locator and its classifications.  
- The capability of the Class B locator.  
- Incorporating previous Appendix D on standard interface into the main body.  
- Additional guidance on defining requirements, choice and procurement of the locator.  
- Providing an overview of location dependent applications within the Great Britain (GB) railway.  
- Example applications are provided in the Appendix A to illustrate use of a locator.  
- The technology overview in Appendix A of issue two has been removed. |

Revisions have not been marked by a vertical black line in this issue because the document has been revised throughout.

**Superseded documents**

The following Railway Industry Guidance Note is superseded, either in whole or in part as indicated:

<table>
<thead>
<tr>
<th>Superseded documents</th>
<th>Sections superseded</th>
<th>Date when sections are superseded</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE/GN8578 issue two Guidance on the Use of Satellite Navigation</td>
<td>All</td>
<td>05 December 2015</td>
</tr>
</tbody>
</table>

GE/GN8578 issue two Guidance on the Use of Satellite Navigation is withdrawn as of 05 December 2015.
Supply

The authoritative version of this document is available at www.rssb.co.uk/railway-group-standards. Enquiries on this document can be forwarded to enquirydesk@rssb.co.uk.
## Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

### Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part 1</strong> Introduction</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>G 1.1</td>
<td>Purpose of this document</td>
<td>6</td>
</tr>
<tr>
<td>G 1.2</td>
<td>Copyright</td>
<td>6</td>
</tr>
<tr>
<td>G 1.3</td>
<td>Approval and authorisation of this document</td>
<td>6</td>
</tr>
<tr>
<td><strong>Part 2</strong> Overview</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>G 2.1</td>
<td>Scope</td>
<td>7</td>
</tr>
<tr>
<td>G 2.2</td>
<td>Why the guidance is needed</td>
<td>8</td>
</tr>
<tr>
<td>G 2.3</td>
<td>Structure of the document</td>
<td>9</td>
</tr>
<tr>
<td>G 2.4</td>
<td>How to use this document</td>
<td>9</td>
</tr>
<tr>
<td>G 2.5</td>
<td>Location dependent applications within GB railway</td>
<td>10</td>
</tr>
<tr>
<td>G 2.6</td>
<td>Related documents</td>
<td>13</td>
</tr>
<tr>
<td><strong>Part 3</strong> On-Train Locator</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>G 3.1</td>
<td>Definition of a locator</td>
<td>14</td>
</tr>
<tr>
<td>G 3.2</td>
<td>Locator architecture</td>
<td>14</td>
</tr>
<tr>
<td>G 3.3</td>
<td>Locator quality of service</td>
<td>16</td>
</tr>
<tr>
<td>G 3.4</td>
<td>Quality of service parameters</td>
<td>17</td>
</tr>
<tr>
<td>G 3.5</td>
<td>Service classes</td>
<td>19</td>
</tr>
<tr>
<td>G 3.6</td>
<td>Design options</td>
<td>20</td>
</tr>
<tr>
<td><strong>Part 4</strong> Locator External Interfaces</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>G 4.1</td>
<td>Introduction</td>
<td>25</td>
</tr>
<tr>
<td>G 4.2</td>
<td>External interface overview</td>
<td>25</td>
</tr>
<tr>
<td>G 4.3</td>
<td>Interface A: locator position data output</td>
<td>26</td>
</tr>
<tr>
<td>G 4.4</td>
<td>Interface B: antennas</td>
<td>29</td>
</tr>
<tr>
<td>G 4.5</td>
<td>Interface C: power</td>
<td>33</td>
</tr>
<tr>
<td>G 4.6</td>
<td>Interface D: control and command interface</td>
<td>34</td>
</tr>
<tr>
<td><strong>Part 5</strong> Implementation and Installation</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>G 5.1</td>
<td>Defining requirements</td>
<td>36</td>
</tr>
<tr>
<td>G 5.2</td>
<td>Choice of locator</td>
<td>38</td>
</tr>
<tr>
<td>G 5.3</td>
<td>Procurement of GNSS equipment</td>
<td>39</td>
</tr>
<tr>
<td>G 5.4</td>
<td>System integration</td>
<td>42</td>
</tr>
<tr>
<td>G 5.5</td>
<td>Equipment installation</td>
<td>43</td>
</tr>
<tr>
<td>G 5.6</td>
<td>EMC considerations</td>
<td>46</td>
</tr>
<tr>
<td><strong>Appendices</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appendix A</td>
<td>Example Applications</td>
<td>48</td>
</tr>
</tbody>
</table>

### Definitions | 51

### Abbreviations and Acronyms | 54

### References | 56
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

<table>
<thead>
<tr>
<th>Tables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
</tr>
<tr>
<td>Table 2</td>
</tr>
<tr>
<td>Table 3</td>
</tr>
<tr>
<td>Table 4</td>
</tr>
<tr>
<td>Table 5</td>
</tr>
<tr>
<td>Table 6</td>
</tr>
<tr>
<td>Table 7</td>
</tr>
<tr>
<td>Table 8</td>
</tr>
<tr>
<td>Table 9</td>
</tr>
<tr>
<td>Table 10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
</tr>
<tr>
<td>Figure 2</td>
</tr>
<tr>
<td>Figure 3</td>
</tr>
<tr>
<td>Figure 4</td>
</tr>
<tr>
<td>Figure 5</td>
</tr>
<tr>
<td>Figure 6</td>
</tr>
<tr>
<td>Figure 7</td>
</tr>
<tr>
<td>Figure 8</td>
</tr>
<tr>
<td>Figure 9</td>
</tr>
</tbody>
</table>
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

Part 1 Introduction

G 1.1 Purpose of this document

G 1.1.1 This document gives guidance on the use of satellite positioning technology for location dependent railway applications. This document does not set out mandatory requirements.

G 1.1.2 This document gives guidance on good practice for the specification, selection, implementation and installation of on-train satellite positioning technology based equipment (the ‘locator’), in support of applications requiring train position, speed and time (PVT).

G 1.1.3 This document gives guidance to:
   a) Users of the locator for position dependent railway applications; this includes Train Operating Companies (TOCs), Freight Operating Companies (FOCs), Rolling Stock Operating Companies (ROSCOs) and infrastructure managers.
   b) Satellite positioning equipment manufacturers.
   c) System integrators.
   d) Train builders.

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G 1.3 Approval and authorisation of this document

G 1.3.1 The content of this document was approved by Control Command and Signalling Standards Committee on 01 October 2015.

G 1.3.2 This document was authorised by RSSB on 28 October 2015.
Part 2 Overview

G 2.1 Scope

G 2.1.1 The scope of this document is the on-train arrangements that include the locator and its external interfaces.

G 2.1.2 Interfaces of the on-train locator to on-board and on-shore applications, assuming the train is fitted with a common on-board databus and a Mobile Communications Gateway (MCG) are shown in Figure 1. The MCG provides a gateway for data communications between the train and the trackside. Guidance on the implementation of data communications between the train and the trackside is given in GE/GN8579. Guidance on train rooftop antenna is given in GK/GN0602.

G 2.1.3 The guidance is applicable to all Global Navigation Satellite Systems (GNSSs) based positioning technology. GNSS includes the Global Positioning System (GPS), GLONASS (the system of the Russian Federation) and GALILEO (the European global satellite navigation system under development to provide Europe independence and greater robustness).

Figure 1  On-train locator interfaces to on-shore and on-board applications
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

G 2.2 Why the guidance is needed

G 2.2.1 There is, potentially, a wide range of position dependent applications, from safety-related applications and asset management, to on-board passenger information. The implementation of these applications could provide substantial operations, commercial and safety benefits to the railway. Satellite positioning technology is one of the technologies which has the potential to support these applications.

G 2.2.2 Global Navigation Satellite Systems is already being used extensively within the Great Britain (GB) rail industry to provide common time and position information for managing the assets and operations across the rail network. However, the current pattern of deployment is on an ad hoc case-by-case basis, with little appreciation of the type of GNSS technology being used. Furthermore, what works for one operator may not work for another operator due to the topography of the route and the layout of stations and surroundings.

G 2.2.3 Most purchases of GNSS equipment to-date are not through direct GNSS equipment procurements, but through larger on-train systems that already incorporate GNSS equipment within their system architectures (for example, On Train Monitoring Recorder (OTMR), closed-circuit television (CCTV), Selective Door Operation (SDO), Passenger Information Service (PIS) and Eco-driving). As a result, several discreet GNSS systems could be fitted to one train, which are adequate for the intended application, but their ability to add new functionality is limited as they are not specified to meet the needs of other applications.

G 2.2.4 It follows that, when the train operator or infrastructure manager identifies a new need for GNSS, a new GNSS based system is usually procured and installed. Furthermore, it is evident that existing deployments do not embrace the latest GNSS technology and the selection of the GNSS equipment is naturally governed by the cost factor, with little consideration of future-proofing the investment.

G 2.2.5 An alternative single locator approach is promoted by this document, especially to support applications requiring high quality GNSS positioning information that is not achievable by low cost equipment. Using a single locator, together with an MCG to provide standard communications services between the train and the trackside, will allow application designers to focus on the applications themselves and justify those applications on the marginal benefits of each application, rather than the application having to bear separately the full costs of a supporting infrastructure.

G 2.2.6 This document gives guidance on:

a) One antenna being shared between as many radio frequency receivers as is reasonably practicable.

b) One locator accommodating the requirements for as many applications as is reasonably practicable, with a definition of the common interfaces.

G 2.2.7 The single locator approach facilitates effective life cycle management of the equipment, as follows:

a) It provides for the upgrading of the locator by straightforward replacement, with minimum impact on the applications. This makes it easier to support migration to future applications.

b) It limits the proliferation of multiple equipment providing similar functions, with the potential to compromise performance.

G 2.2.8 This document also gives guidance on how to facilitate the achievement of a level of system performance in these applications commensurate with their needs. It aims to provide a foundation for users to establish best practice and hence to use these positioning technologies to meet the needs of the rail industry more effectively.
G 2.3 Structure of the document

G 2.3.1 This document is structured as follows:

Part 1 Introduction
This part sets out the purpose of the guidance and for whom it is intended.

Part 2 Overview
This part explains the scope of the guidance, why the guidance is needed and how to use the guidance.

Part 3 On-train locator
This part introduces the concept of a locator, service classes, performance requirements and design options for a locator.

Part 4 Locator interfaces
This part sets out the standard external interfaces for the locator.

Part 5 Implementation and installation
This part gives guidance on defining requirements, choice of locator, receiver procurement, system integration, equipment installation and other practical issues of implementation.

G 2.3.2 Appendix A sets out a summary of five applications with their performance requirements and a potential locator that can be used to achieve the requirements.

G 2.4 How to use this document

G 2.4.1 This document informs industry of the performance of the satellite positioning technology based on-train locator, as well as providing practical advice about applying the technology, and pointers to where more detailed technical information may be found.

G 2.4.2 As this document is not intended to set mandatory requirements, readers should consider it to be a framework which enables better judgement of what can be expected from a satellite positioning technology-based on-train locator and the design options for different classes of locators.

G 2.4.3 For all potential users of the GNSS positioning technology within the rail domain, the users should consider what is required from their applications, and how they intend to use satellite positioning technology. Section G 5.1 proposes attributes and performance parameters of applications to be considered before choosing a locator.

G 2.4.4 Train operators and ROSCOs can use the guidance given in Parts 3, 4 and section 5.1 when considering and specifying application requirements. They can also refer to G 5.2 and G 5.3 when considering how equipment may be selected to achieve different levels of service, and to G 4.3 to check what data outputs are expected from the locator, in order to purchase the relevant GNSS equipment.

G 2.4.5 Infrastructure managers can use Part 3 of this document, to assist their assessment on how an on-train locator contributes to the overall solution, and G 4.3 on what data could be made available from the locator.

G 2.4.6 For suppliers of satellite positioning equipment, section G 2.5 and Part 3 can help them to gain an overview of the potential applications for the railway and align their products to the classes of locators, in order to serve the rail market more effectively. Parts 4 and 5 of this document provide train builders and potential system integrators with practical advice on interfaces, and on implementation and installation of a locator on a train.
G 2.5 **Location dependent applications within GB railway**

G 2.5.1 RSSB research report T892 provides an overview of the scope and a diverse range of location dependent applications in the rail domain. The document consists of a catalogue of applications at various stages of development, ranging between those fully operational and those which are not yet in any formal plans. The description of each application includes its purpose, a high level summary of how it is expected to work, and how PVT information contributes.

G 2.5.2 An on-train locator can be used as the sole train position solution for multiple on-train applications. The output from a locator may also be combined with other on-train or trackside train positioning information, to provide a more robust solution for some applications, including safety applications.

G 2.5.3 The applications have been classified into five groups:

a) Signalling and control.

b) Operations.

c) Customer.

d) On-train monitoring and diagnosis.

e) Infrastructure.

G 2.5.4 The following tables set out the applications identified by RSSB research report T892_D1.1. Descriptions for each application can be found in T892_D1.1, which is available on the SPARK website provided by RSSB, for the rail industry to share and find key information, and help drive innovation.

G 2.5.5 A list of signalling and control applications is set out in Table 1. These applications are typically safety critical or safety related. The locator technology could be used to contribute to the positioning solution, thus reducing the cost of implementing the applications. Guidance on how to use an on-train locator for safety related applications is given in G 3.6.3 and G 5.3.4.

<table>
<thead>
<tr>
<th>ID</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Automatic Train Protection (ATP)</td>
</tr>
<tr>
<td>1.2</td>
<td>On-train ERTMS Interface</td>
</tr>
<tr>
<td>1.3</td>
<td>Train Awakening</td>
</tr>
<tr>
<td>1.4</td>
<td>Cold Movement Detector</td>
</tr>
<tr>
<td>1.5</td>
<td>Train Integrity and Train Length Monitoring</td>
</tr>
<tr>
<td>1.6</td>
<td>Location of GSM-R Reports</td>
</tr>
<tr>
<td>1.7</td>
<td>User Worked Crossings</td>
</tr>
<tr>
<td>1.8</td>
<td>Secondary Line Signalling</td>
</tr>
<tr>
<td>1.9</td>
<td>Trackside Personnel Protection</td>
</tr>
<tr>
<td>1.10</td>
<td>Possessions Management</td>
</tr>
<tr>
<td>1.11</td>
<td>Track Circuit Diversity During Leaf Fall</td>
</tr>
</tbody>
</table>
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

<table>
<thead>
<tr>
<th>ID</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.12</td>
<td>Alternative Temporary Block Working</td>
</tr>
<tr>
<td>1.13</td>
<td>Diverse Positioning Systems (COMPASS)</td>
</tr>
<tr>
<td>1.14</td>
<td>Detonator Replacement (‘Virtual Detonator’)</td>
</tr>
<tr>
<td>1.15</td>
<td>Tilting Trains</td>
</tr>
</tbody>
</table>

**Table 1**  
Signal and control applications

G 2.5.6 A list of operation related applications is set out in Table 2. These applications cover both normal as well as degraded modes of operation and typically deliver benefits in terms of performance and efficiency.

<table>
<thead>
<tr>
<th>ID</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Centralised Clock</td>
</tr>
<tr>
<td>2.2</td>
<td>Traffic Management &amp; Regulation</td>
</tr>
<tr>
<td>2.3</td>
<td>Eco-Driving</td>
</tr>
<tr>
<td>2.4</td>
<td>Driver Advisory Systems</td>
</tr>
<tr>
<td>2.5</td>
<td>Track Discrimination</td>
</tr>
<tr>
<td>2.6</td>
<td>Automatic Train Operation</td>
</tr>
<tr>
<td>2.7</td>
<td>Driverless Trains</td>
</tr>
<tr>
<td>2.8</td>
<td>Temporary Speed Restrictions &amp; Emergency Speed Restrictions</td>
</tr>
<tr>
<td>2.9</td>
<td>Fleet Management</td>
</tr>
<tr>
<td>2.10</td>
<td>Cargo Monitoring</td>
</tr>
<tr>
<td>2.11</td>
<td>Terminal Management</td>
</tr>
<tr>
<td>2.12</td>
<td>Door Operations</td>
</tr>
<tr>
<td>2.13</td>
<td>Passenger Count</td>
</tr>
<tr>
<td>2.14</td>
<td>Pantograph Control</td>
</tr>
<tr>
<td>2.15</td>
<td>Driver Route Knowledge Assistant</td>
</tr>
<tr>
<td>2.16</td>
<td>On-Train Ticketing, Retail &amp; Authentication</td>
</tr>
<tr>
<td>2.17</td>
<td>On-Train Reservations</td>
</tr>
<tr>
<td>2.18</td>
<td>On-Train Catering &amp; Services</td>
</tr>
<tr>
<td>2.19</td>
<td>Train Crew Information Services</td>
</tr>
<tr>
<td>2.20</td>
<td>Infrastructure Charges</td>
</tr>
</tbody>
</table>
Table 2  Operation related applications

G 2.5.7 A list of customer related applications is set out in Table 3. Providing accurate and timely train location and speed information would help train passengers plan their journey and reduce stress when there are disruptions.

Table 3  Customer related applications

G 2.5.8 A list of applications relating to on-train monitoring and diagnosis is set out in Table 4. These applications help maintenance staff within TOCs and/or maintenance companies, and infrastructure managers, to monitor and diagnose defects more efficiently.

Table 4  Applications relating to on-train monitoring and diagnosis

G 2.5.8  A list of applications relating to on-train monitoring and diagnosis is set out in Table 4. These applications help maintenance staff within TOCs and/or maintenance companies, and infrastructure managers, to monitor and diagnose defects more efficiently.
A list of infrastructure related applications are set out in Table 5. These applications focus on referencing, measuring and monitoring rail infrastructure.

<table>
<thead>
<tr>
<th>ID</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>Digital Route Map Creation</td>
</tr>
<tr>
<td>5.2</td>
<td>Structural Monitoring</td>
</tr>
<tr>
<td>5.3</td>
<td>Gauging Surveys</td>
</tr>
<tr>
<td>5.4</td>
<td>Automated Infrastructure Maintenance</td>
</tr>
</tbody>
</table>

Table 5  Infrastructure related applications

The following summarises the documents associated with this guidance note. Reference documents are also provided at the end of this guidance note.

a) RSSB research report T510. This research focusses on collecting and analysing data to assess the dependability of GNSS technology.

b) RSSB research report T671. Communication and positioning system in the GB rail industry. This research recommends the standardisation and methodology needed for the implementation of satellite positioning and digital communications technology within the railway environment.

c) RSSB research report T740. The analysis of historical GPS data from the railway network. This sets out the quality of the reception of GPS signals over the GB railway network as experienced on the Network Rail data recording trains.

d) RSSB research report T892. Data and analysis for a cost-effective GPS-based locator with simple augmentations. This research continues the investigation of the performance of the GNSS based locator following the previous RSSB research project T510. It has identified candidate architectures for increasing the availability of positioning data using a Class B locator (as defined in G 3.5 of this guidance note). The research delivered nine reports which are referenced as T892_D1 to T892_D9.

e) RSSB research report T990. Development of a strategy for on-train positioning. This research has developed a high-level industry strategy for on-train positioning, based on a common train location service that brings coherence to the provision of trainborne and trackside positioning capability.

f) The Galileo project GRAIL deliverables. This project investigates the use of GNSS to support applications related to ETCS. It includes a broader review of other applications in less detail.

g) Guidance on applicable digital communication and positioning technologies is given in GE/GN8577.

h) Guidance on the implementation of shared data connections between the train and the trackside is given in GE/GN8579.
**Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications**

## Part 3  On-Train Locator

### G 3.1  Definition of a locator

**G 3.1.1** A locator is an on-train system that provides train location, speed and timing information to support a range of on-train and back-office applications.

### G 3.2  Locator architecture

**G 3.2.1** The basic equipment required for an on-train GNSS based location system with the locator unit in its simplest form consisting only of a GNSS receiver is shown in Figure 2. The locator provides a standardised positioning output to the applications, and receives standard inputs from the antenna(s) either directly or through a splitter which would allow external devices to make use of the same GNSS radio frequency (RF) signal.

![Locator Architecture Diagram](image)

**Figure 2** Basic equipment for an on-train GNSS based location system

**G 3.2.2** The performance of a basic locator with a GNSS receiver can be improved through a method called augmentation. There are various satellite-based and ground-based augmentations available. For example, differential GNSS (DGNSS) is an augmentation which provides corrections to the GNSS signals to reduce errors and spatial-temporal effects that are difficult to model accurately. Details of DGNSS and other augmentation technologies are set out in T892_D8.

**G 3.2.3** The locator architecture where an augmented signal is provided to a GNSS receiver is shown in Figure 3.
Figure 3  Locator architecture with DGNSS augmentation

G 3.2.4 The limitation of the augmentation technique is that it can only improve the performance of a locator when a GNSS solution is available. In order to provide a positioning solution during periods when insufficient GNSS satellite signals are present, other complementary sensors and systems can be used to provide the infill. The method of integrating GNSS with other complementary sensors and systems is termed ‘hybridisation’. The sources of hybridisation data could include Inertial Measurement Units (IMUs), location database or map, speed sensors and terrestrial positioning signals.

G 3.2.5 A generic locator architecture indicating some potential hybridisation and augmentation sources that could be considered is shown in Figure 4. In the case where hybridisation is used, data from the GNSS receiver is integrated with one or more independent sources within a data fusion algorithm before the resultant position is output to the application. The ‘track beacons’ shown in Figure 4 refer to a number of trackside location technologies, including Eurobalises, or a radio frequency identification (RFID) source.

G 3.2.6 More descriptions on the augmentation and hybridisation sources shown in Figure 4 are set out in G 3.6.

G 3.2.7 Whether to apply hybridisation or augmentation sources to improve the performance of a locator is dependent on the application requirements and operating conditions. Further considerations of how to choose hybridisation or augmentation sources for a locator are set out in G 5.2.
G 3.3 **Locator quality of service**

G 3.3.1 The term ‘quality of service’ is used to describe the characteristics of the output of a locator in the area of the rail network where the locator is required to operate.

G 3.3.2 The three principal parameters of quality of service are:

a) Service coverage.

b) Accuracy.

c) Integrity.

G 3.3.3 Each of these parameters is statistical in nature, and there is no absolute guarantee of a particular level of performance, but rather a level of confidence that the equipment operates at or above the required performance. The parameters are interrelated (for example, specifying a high accuracy has a negative impact on integrity, and a low accuracy can make integrity more readily achievable).

G 3.3.4 The meanings of these terms in other transport sectors can be different. In official references, for example, the Federal Radio Navigation Plan (FRNP), the definition of the performance of the GNSS signals-in-space conforms to aviation usage. The definitions in this guidance note, and the use of the terms, conform to railway usage.

G 3.3.5 Although the GNSS signals have a specified continuity property, this is masked by the variable coverage experienced in the railway environment. The first decision for a railway application is the service coverage performance required from the locator.

G 3.3.6 Different applications require different qualities of service. For example, the simplest applications (such as an on-board automatic passenger information system) only need a basic level of service, getting occasional input from the locator unit as a ‘trigger’ to indicate that the train is within a defined geographical range of a given point. Other applications may require a continuous stream of highly accurate position information to be available.
**G 3.4 Quality of service parameters**

**G 3.4.1 Service coverage**

G 3.4.1.1 Service coverage provided by the locator refers to the proportion of the railway network on which a train’s position can be determined at the required level of accuracy and integrity. It is the characterisation of a lack of service coverage that is the main factor in determining whether an application can operate with GNSS alone, or whether hybridisation is required.

G 3.4.1.2 It is in the nature of the railway and GNSS processing that some temporary loss of service coverage should be accepted. The extent of the acceptability is defined by the application.

G 3.4.1.3 Depending upon the needs of the application, service coverage can be specified as:

a) The specific geographical area(s) where coverage is required.

b) The maximum distance that may be travelled without coverage.

c) The maximum time that may pass without coverage.

**G 3.4.2 Accuracy**

G 3.4.2.1 The specification for a locator may need to include accuracy for position, speed, time and direction / heading.

G 3.4.2.2 The accuracy of GNSS and the supporting technologies vary continually in time. An indication of the instantaneous accuracy can be given by the Dilution of Precision (DOP). The actual error present at any moment cannot be determined absolutely, for example, because of the presence of multipath effects, and varying durations of obscuration from the signals-in-space. Thus, although accuracy is the most commonly referenced performance parameter, it is meaningless without an associated measure of acceptable statistical variation, as shown in Figure 5.

**Figure 5** Statistical nature of accuracy

G 3.4.2.3 It is important to specify the minimum accuracy. Experience shows that for most of the time, much better accuracy can be expected. However, for a small amount of time it is inevitable that the specified minimum accuracy cannot be obtained. The application should be assessed to determine the consequences of inadequate accuracy and whether compensatory measures are required.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

G 3.4.2.4 In many applications the occasional operating inconvenience arising from inaccuracy will be acceptable; in others, the detection of marginal or inadequate accuracy could be required so that other measures can be put in place. Where, despite these measures, undetected inaccuracy could lead to safety concerns, an integrity limit can be specified to reduce to an acceptable level the risk that would arise from undetected inaccuracy or undetected lack of coverage.

G 3.4.3 Integrity

G 3.4.3.1 Integrity describes the trustworthiness of the output of a locator. It is a measure that is applied when the application is safety related or safety critical. There are three components to integrity:

a) Integrity risk (usually expressed as a probability of an undetected failure), that is, that a fault is present somewhere in the system and is not detected and, as a consequence, the data at the output of the locator is not trustworthy.

b) Integrity alert limit (also known as the threshold value) is the maximum allowable error in the measured position (or speed or time) before an alarm is triggered. The threshold value is normally greater than the nominal accuracy of the locator unit, to avoid excessive false alarms.

c) Time to alarm is the time elapsed between the occurrence of the failure in the system and its presentation to the user.

G 3.4.3.2 In Europe, GPS signals are monitored by the European Geostationary Navigation Overlay Service (EGNOS). The integrity information is not readily available to trains at present. However, it is readily available to control centres, which can take appropriate action if an integrity failure is detected.

G 3.4.3.3 In the locator, integrity can be provided by Receiver Autonomous Integrity Monitoring (RAIM). Doppler and carrier phase measurements can also be used.

G 3.4.3.4 The monitoring of GNSS signals to confirm integrity is only acceptable for safety-related tasks if the monitoring itself meets a defined level of integrity.

G 3.4.4 Other quality of service parameters

G 3.4.4.1 In addition to the main parameters set out above, there are other quality of service parameters that can be considered for applications on a case-by-case basis:

a) Availability / reliability: these terms are used in this document to describe the intrinsic performance of the on-board hardware.

b) Time To First Fix (TTFF): the time taken between switching the locator on, or resuming visibility of the satellites following a prolonged period of obscuration or being out of service, and obtaining the first reliable position and speed reports from the locator.

c) Time To Fix (TTF): the time taken between resuming visibility following a shorter period of obscuration (typically less than two hours) and obtaining the first reliable position and speed reports from the locator.

d) Fix rate: the frequency at which the locator unit is able to provide position solutions meeting accuracy and integrity requirements.

G 3.4.4.2 Further parameters defining performance requirements for applications are set out in G 5.1.
G 3.4.5 The interrelationship between service coverage, accuracy and integrity

G 3.4.5.1 A lack of service coverage has an immediate effect upon accuracy and integrity, so it may be necessary for the locator to estimate when the accuracy has fallen below a specified threshold. There are two strategies:

   a) Suspend the applications and functions concerned.

   b) Modify the confidence intervals for position and speed data, so as to continue a degraded level of operation, taking into account a reduced level of confidence in data provided by the locator.

G 3.4.5.2 Accuracy specifications and integrity specifications have an inverse relationship. Excluding the hardware integrity performance: high accuracy and low integrity, and low accuracy and high integrity, have an equivalence in terms of locator performance.

G 3.4.6 Vulnerability of GNSS solutions

G 3.4.6.1 The GNSS signals are very low power and can be vulnerable to unintentional electromagnetic interference, and deliberate spoofing / jamming. If not detected, these threats could cause degradation in the accuracy and availability of GNSS solutions.

G 3.5 Service classes

G 3.5.1 Rationale for service class definition

G 3.5.1.1 This document sets out three classes of locator requirements, each defined by a level of performance (service coverage, accuracy and integrity). The rationale for defining a small number of classes is:

   a) To encourage users to identify locator requirements according to the class appropriate for their applications.

   b) To encourage the supply market to focus on providing locator products appropriate for the railway environment that align with these classes.

G 3.5.1.2 A proliferation of bespoke products would be expected if a specific locator were to be designed for each application. This would result in higher costs.

G 3.5.1.3 The economics of these technologies are such that, if an application has performance requirements which exceed those of a particular class, rather than modify the product of that class, it might be preferable to purchase the Commercial-Off-The-Shelf (COTS) product of a higher class.

G 3.5.2 Service class definitions

G 3.5.2.1 Three classes of locator (A, B and C) are defined for general use within the railway. Table 6 sets out the relationship between the three classes in terms of the quality of service parameters.

<table>
<thead>
<tr>
<th>Class</th>
<th>Service coverage</th>
<th>Accuracy</th>
<th>Integrity</th>
</tr>
</thead>
</table>
| C     | Limited to areas with an assured view of the satellites  
>70% service coverage (average across whole of GB network) | Better than 13 m at 95% confidence  
1 m to 2 m at 95% confidence with differential augmentation (in open skies) | Desirable but not required  
May be provided by some receivers (for example, with built-in RAIM or differential augmentation) |
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

<table>
<thead>
<tr>
<th>Class</th>
<th>Service coverage</th>
<th>Accuracy</th>
<th>Integrity</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Service coverage is increased by use of inertial hybridisation or other dead reckoning</td>
<td>Better than 13 m accuracy at 95% confidence&lt;br&gt;1 m to 2 m at 95% confidence with differential augmentation (in open skies)</td>
<td>Desirable but not required&lt;br&gt;May be provided by some receivers (for example, with built-in RAIM or differential augmentation)</td>
</tr>
<tr>
<td>A</td>
<td>Service coverage can be increased by use of inertial hybridisation or other dead reckoning</td>
<td>Better than 13 m accuracy at 95% confidence&lt;br&gt;1 m to 2 m at 95% confidence with augmentation or hybridization (in open skies)</td>
<td>Integrity level up to SIL2</td>
</tr>
</tbody>
</table>

Table 6  Summary of classes of locator requirements

G 3.6  Design options

G 3.6.1  Class C

G 3.6.1.1 A Class C locator will generally consist only of a GNSS receiver. Its distinguishing feature is that it suffers from obscuration and consequent loss of service coverage. When based upon COTS products the accuracy performance is likely to vary significantly between products, and integrity is usually not specified.

G 3.6.1.2 The performance of an application based solely upon GNSS could be affected by the normal railway environment, as shown in Figure 6, where:

a) Decreased coverage could be caused by the GNSS signals being obscured in deep cuttings, buildings, bridges, station canopies and foliage.

b) Substantial loss in accuracy occurs due to multipath effects.

c) Complete loss of a signal happens in tunnels.

G 3.6.1.3 The robustness of the GNSS solution at a particular location varies according to the number of satellites in view (this will increase over time as more satellites are launched). The accuracy performance also varies with the geometrical arrangement of the satellites with respect to the user, for example high accuracy will be achieved if the satellites are evenly distributed around the user (known as low DOP), whereas accuracy can be much lower if the visible satellites are all in a line (known as high DOP), as is the case when the user is in a cutting.
G 3.6.1.4 A Class C locator may be designed to take advantage of augmentation data which can improve positioning performance, but, in all cases, this augmentation data can only improve upon a GNSS solution which is already available. The ability of a Class C locator to provide a position output is entirely dependent therefore on the availability of the GNSS solution.

G 3.6.1.5 The augmentations options include:

a) Differential GNSS – provides corrections to the GNSS signals which can be used in the receiver to reduce positioning errors. It can also provide a level of integrity by identifying satellite faults which have a regional effect and informing users of these.

b) Assisted GNSS (A-GNSS) – is used to enhance GNSS signal acquisition and tracking by providing essential navigation data to the GNSS receiver over an alternative communication channel, that is, not relying on recovering this information from the satellite signal itself. In open sky conditions, it typically takes a receiver around 20 to 30 seconds from start-up to obtain the required ephemeris data (satellite orbit and clock information) from each satellite and to then determine a first position. In obstructed environments though, it can be difficult to maintain even 20 or 30 seconds of uninterrupted tracking to each satellite with a sufficiently good signal strength, which can lead to periods of many minutes with no position fix. A-GNSS improves the TTFF, by providing the essential ephemeris data in a few seconds. Once satellite signals are tracked and are providing a range of measurements, a position solution can then be determined.

c) Multi-GNSS – the combined use of GPS and other constellations can improve the availability of position solutions, especially where visibility of the sky is limited.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

G 3.6.1.6 At the date of publication of this document, there is yet no differential service suitable for the railway in real-time for most applications. This is because there are problems receiving corrections in the railway environment due to signal interference for a ground-based differential solution, and due to low elevation of geostationary satellites at mid and high latitudes for a space-based differential solution.

G 3.6.1.7 For applications which require high availability positioning from start-up, some form of assistance will be of benefit. The selection of which form of assistance is most appropriate will be driven by the available communications’ means on the train and their interfaces to the location elements. In the majority of cases it is expected that connectivity should not be a problem, so a conventional assistance solution could be used.

G 3.6.2 Class B

G 3.6.2.1 A Class B locator is designed to increase the availability and continuity of a positioning solution over a Class C locator by providing a position output during periods when insufficient GNSS satellite signals are present. The improved availability and continuity of a Class B solution is typically achieved by hybridisation – integrating GNSS with one or more other complementary sensors and systems. Hybridisation works by calibrating the errors in the other sensors when GNSS is available, so that the sensors can provide the infill when GNSS is not available.

G 3.6.2.2 Typical hybridisation sources include:

   a) IMUs – an electronic device which detects acceleration and angular rates. Integrating once provides velocity components, and twice provides relative position. An IMU can provide accurate relative positioning over short periods, but errors can increase rapidly during periods of un-calibrated operation, that is, no GNSS available.

   b) Location database or Map – this could take a variety of forms, including a Digital Route Map or Link Node Map. Within the locator this data can be used to constrain errors in the combined positioning solution when GNSS is available, and through routing logic it can be used to increase the availability of a positioning solution during GNSS outages. Routing logic can, for example, use last known position, speed and heading, with assumption of the possible route to extrapolate future positions.

   c) Train speed data – Odometry data from the train wheels, including conversion from natural source to digital data (for example, end-axle frequency probe, Wheel Slip Protection / Prevention (WSP) and analogue signal) can provide a valuable input for a locator. Combining displacement information with direction, from an IMU or compass, for example, enables a very effective relative positioning solution. However, the disadvantage of this is that the errors are cumulative because, as with all Dead Reckoning (DR) methods, the new positions are calculated from previous positions.

   d) Terrestrial positioning – using signals transmitted from terrestrial rather than satellite sources. Two alternative technologies have been identified as being of potential interest for rail applications:

      i) Enhanced Long-Range Navigation (eLORAN) offers an independent positioning capability with good propagation properties and reasonable coverage of the UK. It requires a separate on-board antenna and receiver. Calibrated eLORAN may provide a solution to positioning in covered stations and during long periods of no GNSS signals.

      ii) A number of positioning techniques are used routinely in mobile phones. The most commonly used, and simplest, cellular positioning technique is Cell ID. The mobile phone position is simply ‘assigned’ the known position of the Base Transceiver Station (BTS) with which it is in contact. The accuracy of the user position will be a function of the distribution of the BTS network. There are, however, a number of techniques which can be used to obtain more accurate positions from cellular positioning, as set out in Annex B of T892_D2.
**Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications**

G 3.6.2.3 The hybridisation of the GNSS with either an IMU or other DR sensors provides an increased availability of positioning solutions, as the complementary sensors can continue positioning when satellite signals are blocked. Additionally, where there are areas with a high multipath environment, the IMU (or other DR sensors) can serve to improve the solution as it smooths the GNSS derived position through the area of poor positioning quality. To achieve this potential benefit, select equipment that is suitable for the rail operating environment and configure it correctly.

G 3.6.2.4 Further details on hybridisation can be found in T892_D2 and augmentation in T892_D2 and T892_D8.

G 3.6.3 Class A

G 3.6.3.1 A Class A locator is distinguished by its ability to provide a definable level of integrity (up to SIL2). The response to a fault in the signal-in-space is to detect it and isolate its consequence with a defined certainty.

G 3.6.3.2 Integrity can be provided using techniques which are entirely internal to a GNSS receiver and require only the standard satellite ranging signals as input, referred to as RAIM. Integrity can also be provided for a GNSS solution using augmentations, for example EGNOS. However, as external augmentations cannot monitor all potential error sources which may impact positioning, they will typically be used in combination with RAIM.

G 3.6.3.3 The use of the Doppler information and carrier phase measurements can also improve integrity of the position solution. There is also the option of using a dual frequency receiver. These techniques are useful in the railway environment where multipath is considered a significant source of hazard. Due to the topography of the GB railway environment the locator needs to deal with regular obscuration. A hybrid system has the potential to provide high integrity, because entirely independent sources of information can be used to detect anomalies.

G 3.6.3.4 The hybridisation sources set out in G 3.6.2 and other complementary positioning sources that could be available on board the train can be used to support the integrity of the locator output. One of the solutions is the tachometer and IMU combination which can provide integrity for a limited period of time. This can be extended by the use of map-matching to track coordinates. Once this time limit is reached, operating procedures can be used to manage the continuing degradation.

G 3.6.3.5 Jamming and spoofing of GNSS signals represent threats to the integrity of the locator. Measures for integrity have the capability to detect them in the same way as other threats are detected. Adequate measures enable these to be treated as an inconvenience, rather than a threat to SIL1 and SIL2 applications. The use of RAIM (applicable to all sensors), map-matching with IMU and other sensors is capable of providing adequate protection against erroneous signals, from whatever cause, as part of the data fusion process. There is also the use of anti-jamming technology; for example, controlled reception pattern antenna (CRPA), previously used in the military domain, which can be adopted for safety related railway applications.

G 3.6.3.6 In achieving integrity, there is a compromise to be made between the functionality adopted to obtain the necessary diversity and fault detection, and the need to aim for simplicity to facilitate the proof of safety. The limitation to the achievable Safety Integrity Level (SIL) is essentially due to single channel hardware limited to SIL2, or at best low SIL3. SIL4 locator software is feasible, but known not to be commercially available outside of bespoke applications.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

G 3.6.3.7  A Class A+ is defined to support applications with an integrity performance up to SIL4. The necessary functionality is available, and in time may provide better service coverage, accuracy and integrity processing at less cost. The problem is to contain the cost of the safety platform on which these are implemented to enable such locators to be economic. To maintain an open market it is desirable to have techniques that make bespoke safety platforms from a given supplier unnecessary. The viability of these techniques as yet remains unproven.

G 3.6.3.8  It is expected that GALILEO, the European GNSS, when fully operational, may be able to influence the practical implementation of safety-related railway applications.
Part 4  Locator External Interfaces

G 4.1  Introduction

G 4.1.1 The purpose of this part is to provide guidance on interfaces for the on-train locator, in order to facilitate cost-effective integration and technology refresh of GNSS locator products. It provides information to support implementers of locator equipment and of railway applications which use locator data.

G 4.1.2 The guidance on interface specification deals with external interfaces only. It aims to be as generic as possible, allowing a multitude of applications to be supported and a variety of locator units to be used within a common framework.

G 4.1.3 In almost all applications it is expected that a train position determined by a locator is related to railway locations. The process of translating a geospatial location to a railway-relative one is considered external to the locator and will be part of an on-train or back-office application.

G 4.1.4 In line with existing guidance it is recommended that the locator position data output adopts the National Marine Electronics Association (NMEA) standard. NMEA is a widely used standard for reporting outputs from GNSS receivers and other navigation equipment, and is supported by all major manufacturers.

G 4.1.5 More details on the NMEA standard and rationales behind the guidance on interface specification can be found in T892_D2.

G 4.2  External interface overview

G 4.2.1 An overview of the locator external interfaces is shown in Figure 7. The standard interfaces include:

a) Interface A – Locator Position Data Output. This interface provides location information to the applications.

b) Interface B – Signal to and from antenna(s). This interface is used to receive the GNSS signals. Typically, the antenna would be situated on the roof of the train. Active antennas will require a power supply from the locator.

c) Interface C – Power supply. This interface provides power supply to the locator from the train's batteries.

d) Interface D – Control, command and train speed input. This interface manages the control and command interfaces and provides train speed input to the locator.

![Locator interfaces overview diagram](image-url)
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

G 4.2.2 These interfaces are set out further in G 4.3 to G 4.6. The assumptions that influence the selection of the four interfaces are set out in section 2.4 of the RSSB research report T892_D2 on the SPARK website.

G 4.2.3 A summary of the main functions supported in each of these four interfaces is set out in Table 7.

<table>
<thead>
<tr>
<th>Interface</th>
<th>Locator input</th>
<th>Locator output</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Locator positioning data</td>
<td>None</td>
<td>• Locator position data to external applications</td>
</tr>
<tr>
<td>B Antennas</td>
<td>• GNSS RF signal reception</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Differential correction reception over GNSS frequencies, cellular network or terrestrial RF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Terrestrial navigation signals (eLORAN and cellular)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• A-GNSS over cellular network or Wi-Fi</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Map updates over cellular or radio network or Wi-Fi</td>
<td></td>
</tr>
<tr>
<td>C Power</td>
<td>Power supply to locator</td>
<td>None</td>
</tr>
<tr>
<td>D Control and command</td>
<td>• Control signals</td>
<td>• Time synchronization pulse</td>
</tr>
<tr>
<td></td>
<td>• Command / configuration signals</td>
<td>• Command / configuration acknowledgements and status messages</td>
</tr>
<tr>
<td></td>
<td>• Train speed data</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Map updates via on-train data transfer</td>
<td></td>
</tr>
</tbody>
</table>

Table 7 Locator interfaces summary

G 4.3 Interface A: locator position data output

G 4.3.1 Message format

G 4.3.1.1 Use of NMEA 0183 Standard for Interfacing Marine Electronic Devices, Version 2.3 or later as the locator output message format

G 4.3.1.1.1 Although version 2.3 has some limitations with respect to later versions, the message formats are consistent, that is, a field may be able to take a greater range of values in later versions but the field itself is still present in version 2.3. Mandating later versions would limit the choice of usable receivers but would not gain any significant additional message content.

G 4.3.1.1.2 NMEA 0183 is selected, rather than NMEA 2000, as it is far more widely supported on existing equipment. If data is distributed over a controller area network (CAN) bus, a device to convert from NMEA 0183 to NMEA 2000 can be introduced externally.

G 4.3.1.2 Use of standard NMEA parametric sentences for all sentences

G 4.3.1.2.1 The NMEA standards identify a set of sentences, each containing different equipment data. A sentence is self-contained and independent from other sentences. The NMEA sentences of most interest for this document are those which contain position data. An overview of the NEMA standard and sentence format can be found in section 3.2 of T892_D2.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

G 4.3.1.2.2 The required data output can be supplied through a combination of existing standard sentences. This approach will introduce some redundancy as some fields are repeated in different sentences, and some fields, particularly those defined specifically for maritime use, will not contain useful information for railway applications. However, recommending only the use of standard sentences keeps the choice of GNSS equipment wide.

G 4.3.1.2.3 Defining proprietary formats specifically for rail applications could make the locator output more concise, but the use of bespoke messages is likely to increase cost. The demand for GNSS receivers in rail does not appear large enough to give receiver manufacturers sufficient incentive to support any new messages on standard products.

G 4.3.1.2.4 Within a locator there is scope for intermediate processing which could take standard outputs from a GNSS receiver or other device and reformat them to a bespoke message before distribution over the locator output interface. But even relatively simple reformatting of this kind is likely to increase cost for minimal benefit.

G 4.3.1.2.5 A far more significant cost increase would come if the output interface specifies data that is not provided by standard equipment in any format. This could not then be catered for through intermediate data reformatting but would require some re-engineering of the positioning equipment itself. Based on existing application requirements, there appears to be no case to recommend bespoke options of this kind.

G 4.3.2 Message set

G 4.3.2.1 Use of RMC, GGA and GLL sentences for all classes of locator

G 4.3.2.1.1 The following messages provide the basic positioning data needed to support current and future rail applications:

a) RMC – Recommended Minimum Specific GNSS Data.
b) GGA – Global Positioning System Fix Data.
c) GLL – Geographic Position – Latitude / Longitude.

G 4.3.2.1.2 All of these messages are widely supported across all grades of receiver and by all leading manufacturers (for example, Qualcomm, ST MicroElectronics, CSR, Texas Instruments, Trimble, Novatel, Javad, Leica and U-Blox). The messages are all relatively small, giving a combined size of less than 2000 bits. More detailed descriptions of these messages is set out in T892_D2.

G 4.3.2.2 GSA and GSV sentences are desirable for all classes of locator

G 4.3.2.2.1 GSV and GSA provide more information of the GNSS position solution, as follows:

a) GSA – GNSS DOP and active satellites.
b) GSV – GNSS satellites in view.

G 4.3.2.2.2 GSA and GSV sentences can be used for recipient applications to describe the quality of their position solution. GSA and GSV are of benefit for experimental purposes to help characterise GNSS coverage across GB railways, and for diagnostic purposes, by allowing the quality of positioning to be related to satellite conditions. Both messages are widely supported across all grades of receiver and by all leading manufacturers. The choice of receiver is therefore not unduly limited.
G 4.3.2.2.3 GSA and GSV sentences are considered desirable because no rail applications today clearly require this type of data. With a single satellite constellation, including the two messages would add up to around 3300 bits to the output size (most of this is because a single GSV message can only include data for up to four satellites, so multiple messages are needed to provide information on all satellites in view). This data size needs to be scaled for the number of constellations used in the solution.

G 4.3.2.3 The GNS sentence is desirable for any locator using a multi-constellation (for example, GPS + GLONASS) receiver

G 4.3.2.3.1 This sentence is very similar in content to GGA but informs a recipient about the contribution of different satellite constellations:

- GNS – Global Positioning System Fix Data.

G 4.3.2.3.2 If GNS sentences are supported, they can supply equivalent information to GGA. In the future, it is not clear if all multi-constellation receivers will move to this sentence; the option also exists to maintain existing messages, for example GGA, and have separate GPS and GLONASS versions identified through the talker prefix.

G 4.3.2.3.3 It is not advisable to switch from GGA to GNS depending on specific receivers, as the recipient application is unlikely to be able to process the data interchangeably even if the main content is identical, simply because the sentence names will not match. Replicating data is also undesirable, but it is preferable to sending data which cannot be processed.

G 4.3.2.4 GST, GBS and GRS sentences are desirable for any locator which may be expected to contribute integrity data (Class A)

G 4.3.2.4.1 At present it is not clear how a locator will contribute to meeting the integrity requirements of specific applications, but if it is foreseen that a locator may need to provide integrity information for future applications, it is desirable to select a receiver which already supports these NMEA sentences, as follows:

- a) GST – GNSS Pseudorange Error Statistics.
- b) GBS – GNSS Satellite Fault Detection.
- c) GRS – GNSS Range Residuals.

G 4.3.2.4.2 These sentences are not widely supported in standard GNSS equipment as they rely on fairly complex and specialist internal processing to determine the information. Generally, these sentences are more typically supported on more expensive professional grade receivers (for example, Novatel OEMV series, Trimble OEM Precision and 'R' series, C-NAV and NavComm SF); but they are also supported by much lower cost U-Blox 5 and 6 consumer grade chipsets which are used in mass market products, such as personal navigation devices (PNDs) and car SatNavs.

G 4.3.3 Resolution of position data

G 4.3.3.1 Provision of a resolution of at least 4 decimal places of a minute for latitude and longitude in one or more of the RMC, GGA and GLL sentences

G 4.3.3.1.1 This leads to a minimum resolution of just less than 0.2 m, which is considered adequate as the vast majority of rail applications have a positional accuracy requirement of no more than 1 m. Allowing this resolution to be provided in at least one, but not necessarily all, of the three mandatory NMEA sentences, increases the probability that this can be accommodated using existing equipment without modification. If this resolution requirement cannot
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

be met it will not be possible to provide sufficient accuracy for many current and future applications.

G 4.3.4 Reference frames
G 4.3.4.1 Expressing latitudes and longitudes in the WGS-84 reference frame

G 4.3.4.1.1 This is already the convention applied in the NMEA standard and is the standard reference frame for GNSS positioning. The convention provides consistency amongst locators and between locator outputs and other location data. It does not impose any additional constraints or requirements on standard equipment.

G 4.3.4.2 Include altitude and Geoidal separation for height information reported in the GGA or GNS sentences, to allow ellipsoidal height to be determined

G 4.3.4.2.1 Populating both of these fields supports consistent height data that can be used across all applications. This is a standard convention and does not impose any additional constraints or requirements on standard equipment. In cases where a receiver does not use an inbuilt Geoid model, and hence does not attempt to convert from GNSS ellipsoidal height to a height above local or global sea level, the altitude field will indicate ellipsoidal height directly, in which case the associated separation field will indicate zero.

G 4.3.4.2.2 Use consistent reference frames when computed positions are related to a location database or trackside infrastructure, as using incorrect height datums, can lead to errors of tens of metres.

G 4.3.5 Message rate
G 4.3.5.1 Provision of position data at a rate of at least 1 Hz

G 4.3.5.1.1 The vast majority of rail applications identified to-date require position information at a rate of 1 Hz or lower. If the locator can provide data with at least this rate, then it meets the requirement for the majority of applications using only standard GNSS equipment.

G 4.3.5.1.2 For most locators it is expected that this rate will be configurable, so the rate can be set according to the most demanding recipient application being supported. If it is not configurable and this 1 Hz default is much higher than applications actually require, it is expected that the application would filter, or select, the data to process as an initial operation.

G 4.4 Interface B: antennas
G 4.4.1 Antenna configurations

G 4.4.1.1 The locator is based on GNSS technology and therefore requires an antenna interface which is used to receive the RF GNSS signals. Typically, the antenna is situated on the roof of the train. In addition to the principal GNSS antenna, further antennas, or antenna types can be considered to support some of the augmentation and hybridisation options. These may include:

a) DGNSS antenna – to receive differential messages over terrestrial communication channels, typically a 300 kHz radio frequency.

b) Communications antennas – to receive data over a cellular, radio or wireless internet network. Data may include A-GNSS messages and map updates, for example, and some signals may support ranging.

c) eLORAN – for any additional terrestrial radio-navigation signal a further antenna will be needed.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

G 4.4.1.2 Initially it is assumed that the locator will use a dedicated GNSS antenna on the train roof (as shown in Figure 8). If required, a differential antenna could be included in the same housing. The RF signal from the GNSS antenna would go to a splitter which would allow external devices to make use of the same GNSS RF signal. If the locator concept of a single positioning device per train, providing location data for all on-board and centralised applications is realised, then a splitter would not be required as there would not be other on-train GNSS receivers needing to share the signal. However, including a splitter so that a single antenna unit can support multiple receivers external to the locator increases flexibility for future on-train equipment.

Figure 8 Dedicated navigation antenna with external communications antenna(s)

G 4.4.1.3 If eLORAN is used, a dedicated antenna will be required with a direct input to the locator.

G 4.4.1.4 In this configuration, any communications inputs are received from external pre-existing antennas which are in place to support existing train communications functions. These antennas may support multiple terrestrial or satellite communications channels, and in each case the locator would need to have a specific input port and modem to decode and use the data.

G 4.4.1.5 It is expected, in general, that any modem would be internal to the locator and that there would not be external on-train systems which receive data initially, decode it, and then pass it on to the locator. The exception to this could be location database updates which might be received intermittently, from a Wi-Fi hotspot for example, and stored on-train in an external system before being relayed to the locator; in terms of interfaces this latter case is set out in G.4.6.

G 4.4.1.6 An alternative configuration in which a single rooftop antenna housing includes all navigation and communications antennas required by a locator is shown in Figure 9. In this configuration communication input may go directly from the antenna to a locator port, or may first go through an external device (Diplexer) to separate channels, for example Wi-Fi and General Packet Radio Service (GPRS), before being sent to separate locator ports. In such a scenario it is expected that any supported communications streams can be made available to other on-train devices.

G 4.4.1.7 Dual redundant antennas are available to provide more robustness and resilience for safety related applications.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

Figure 9  Common comms / nav antenna

G 4.4.2  GNSS antenna selection

G 4.4.2.1  The selection of GNSS antenna to be used with a locator is driven by application requirements and the design choices which are then made to satisfy these requirements. Some basic recommendations can be made on this interface independent of these design considerations, others are perhaps more appropriate for future performance trade-offs:

a)  It is recommended to support multiple GNSS devices from a single roof antenna via a splitter. This provides flexibility in the case where the locator is not the only device using the received signal, avoiding the need for multiple GNSS antennas on a train roof.

b)  Use an active antenna whenever the antenna receiver distance is greater than 0.1 m, which will be the general case.

c)  Include a power supply to the GNSS antenna to support active antennas.

d)  Include a surge protector along the connecting cable from the locator to the roof mounted antenna, to protect against unwanted surges from any sources, for example the train power supply, conductive and inductive lightning strikes.

e)  Include DC blockers in the case where an antenna is connected, via a splitter, to multiple devices able to supply power.

G 4.4.2.2  Table 4-1 of T892_D2 summarises the central frequencies on which Open GNSS signals are broadcast today, and the frequencies allocated for future open services. All these signals fall within the L-band (1-2 GHz) of the radio spectrum.

G 4.4.2.3  At present no clear recommendation can be made on whether to use a single or dual frequency antenna. This will be driven by emerging application requirements. For future proofing, though, installing a more expensive dual frequency antenna initially will support a single frequency solution; it will also support a future dual frequency solution if a case emerges for it, without the need of a new procurement and installation.

G 4.4.2.4  Currently, dual frequency solution will use GPS L1 (1575.42 MHz) and L2 (1227.6 MHz) frequencies, but over the next 10 to 15 years a GPS L1/L5 solution is likely to become the standard dual frequency option. An L1/L2/L5 antenna would be preferable for future-proofing purpose.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

G 4.4.2.5 In principle, the use of multiple constellations should have a noticeable benefit to the availability of a GNSS solution, particularly in partially obstructed environments. With the recent replenishment and upgrade of the GLONASS constellation, GPS + GLONASS equipment is becoming increasingly common. Until recently it tended to be only professional-grade receivers which made use of the additional constellation, but in 2010 and 2011 a number of consumer grade chipsets using GPS and GLONASS have entered the market. There are now smart-phones for example with a dual-constellation GNSS solution. To support future GPS + GLONASS solutions in rail it would make sense to install antennas now which support both systems, even if a GPS-only solution is used initially. However, the performance benefits of adding GLONASS are still to be evaluated in GB rail.

G 4.4.2.6 Further details regarding characteristics of antennas, including dimensions, gain, power supply, frequency band and other typical examples can be found in section 8 of T892_D8.

G 4.4.3 Supporting augmentation and hybridisation

G 4.4.3.1 The need for augmentations and hybridisation for a locator depends on the requirements of the applications it is supporting and the design which is selected to meet those requirements.

G 4.4.3.2 A summary of the augmentation and hybridisation data streams which may need to be supported by the antenna interface is set out in Table 8. The message types listed in the table are set out in internationally accepted data transmission standards defined by the Radio Technical Commission for Maritime Services (RTCM), Radio Technical Commission for Aeronautics (RTCA), Open Mobile Alliance (OMA) and other bodies.

<table>
<thead>
<tr>
<th>Source</th>
<th>Antenna</th>
<th>Message type</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>DGNSS (Ground - Governmental)</td>
<td>DGNSS (eLORAN)</td>
<td>RTCM 104</td>
<td>300 kHz</td>
</tr>
<tr>
<td></td>
<td>DGNSS (Ground/Space - Commercial)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DGNSS</td>
<td>RTCM 104 and Proprietary</td>
<td>Use of Geostationary satellites and terrestrial transmissions</td>
</tr>
<tr>
<td>EGNOS (Space)</td>
<td>GNSS</td>
<td>RTCA 229 C/D</td>
<td>Uses standard L1 antenna</td>
</tr>
<tr>
<td>EGNOS (Ground)</td>
<td>Comms</td>
<td>RTCA 229 C/D or cached bespoke messages</td>
<td>Only prototype solutions and services available today</td>
</tr>
<tr>
<td>A-GNSS</td>
<td>Comms</td>
<td>OMA Secure User Plane Location (SUPL) standard used for cellular networks</td>
<td>RTCM message 17 also provides ephemeris</td>
</tr>
<tr>
<td>Cellular positioning</td>
<td>Comms</td>
<td>Network operator solutions based on the LTE (Long-Term Evolution) Positioning Protocol (LPP)</td>
<td></td>
</tr>
<tr>
<td>eLORAN</td>
<td>eLORAN H-field</td>
<td>RTCM 127 (Draft)</td>
<td>90 to 110kHz Limited number of devices available</td>
</tr>
<tr>
<td>Location database updates</td>
<td>Comms</td>
<td>Various</td>
<td>Updates to a pre-loaded database over comms antenna</td>
</tr>
</tbody>
</table>

Table 8 Summary of augmentation and hybridisation options over interface B
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

G 4.4.3.3 If DGNSS solutions are used, a dedicated antenna will be required and the standard RTCM 104 format is adopted.

G 4.4.3.4 The ability to use EGNOS messages on a GNSS receiver is unlikely to be the deciding factor in choosing it for a locator. However, as this ability is quite likely to be present in most candidate solutions, it requires no additional antenna and, as it is a freely available service, it would be worth using as it can potentially provide some performance benefit in both accuracy and integrity.

G 4.4.3.5 Both EGNOS Data Access System (EDAS) and Signal in Space over the Internet (SISNet) could potentially be used to relay EGNOS messages to a locator over a terrestrial communications network, to overcome problems of poor satellite visibility. However, replicating the standard correction service delivered by geostationary satellites requires a continuous data link to be maintained.

G 4.4.3.6 Assistance services can be used for locators supporting high availability applications in obstructed environments. Open Mobile Alliance Secure User Plane Location (OMA SUPL) protocol is a well-defined standard which can be used to relay the assistance data over cellular networks.

G 4.4.3.7 The message format for eLORAN is being developed by the RTCM Sub Committee 127. If eLORAN is used, a dedicated antenna that supports the RTCM 127 format will be needed.

G 4.4.3.8 If a locator includes a location database, provision should be made for the update of the database. Base the selected means to do this on the format of the database and the size and frequency of expected updates.

G 4.4.4 Antenna placement

G 4.4.4.1 See the guidance set out in sections G 5.5.1, G 5.5.2 and G 5.5.3 for details.

G 4.5 Interface C: power

G 4.5.1 The locator is expected to be powered from the train's DC auxiliary supply, which is backed up by the auxiliary battery.

G 4.5.2 It is important, particularly when retrospectively fitting equipment, that the power demand of the locator is minimised. If it is not, then costly provision of either additional battery charging and / or battery capacity may be required.

G 4.5.3 Different types of rolling stock in use in GB have varying nominal control voltages, ranging from the diesel multiple units (typically using a 24 V battery) up to electric multiple units (typically using a 110 V battery).

G 4.5.4 Additionally, the control voltage can vary, as specified in section 5 of BS EN 50155, and it is essential that the locator can operate over this complete range.

G 4.5.5 Due to the high variability of the input power, it is normal to include a converter that converts the train control supply into a more suitable voltage for the locator.

G 4.5.6 The locator (or its power supply) is protected by its own miniature circuit breaker (MCB) at an appropriate trip level.

G 4.5.7 Spikes and surges occur at a very high level on the train's control supply due to the switching of large unsuppressed inductive loads. Existing standards for suppressing spikes / surges include BS EN 50155 and BRB/RIA Specification No 12.

G 4.5.8 It is normal to provide a power supply that can deal with the large voltage range, and spikes and surges, in the course of supplying the equipment.
G 4.5.9 On many trains an automatic load shed system is employed, for example, a time after the engine has stopped running or loss of battery charging supply, cutting power to any connected devices. It is important that the locator is viewed as essential equipment that is not load shed on loss of battery charging.

G 4.5.10 The battery is often disconnected from its load via a low voltage protection device if the battery voltage falls below 0.7 of the nominal battery voltages (BS EN 60077 Part 1) to prevent equipment connected to battery behaving in an uncontrolled and erratic manner as the battery voltage falls. Additionally, precautions should be taken to avoid irreparable damage caused to a battery by deep discharge from low-power consumption equipment such as the satellite positioning equipment.

G 4.5.11 Requirements on safety equipotential bonding of the device are set out in GM/RT2304, GM/RT2111 and BS EN 50153.

G 4.5.12 BS EN 50121-3-1 sets out the test to be undertaken to achieve appropriate electromagnetic compatibility (EMC) certification.

G 4.6 Interface D: control and command interface

G 4.6.1 Control input interface
G 4.6.1.1 The control interface consists of a signal that is used to power-up / power-down the locator. This interface can be linked to a range of potential cab signals, including:

a) Cab occupied, or not occupied.

b) Motion.

G 4.6.1.2 The control input interface can be used to provide an indication of when the locator start and stop providing position outputs.

G 4.6.1.3 A simple assumption that the locator will operate all the time that it has power may be too crude, as there can be significant periods when no positioning solution is required but power is still supplied.

G 4.6.2 Command / configuration interface
G 4.6.2.1 The functionality of the locator can potentially be modified through the provision of a command / configuration interface. This interface would allow the system developer to configure the locator processing software to an optimal setting for the intended application(s). Typical examples of the types of command sent to a GNSS receiver include:

a) Communication settings (for example, configuring I/O port IDs and baud rate, identify sources of correction data).

b) Mode settings (for example, enable / disable DGNSS or Satellite, or Space, based Augmentation Service (SBAS), set static or dynamic).

c) Position solution settings (for example, disable / enable use of carrier smoothing, set measurement weighting options, disable / enable RAIM).

d) Logging control (defining data to be recorded, including data type, recording rate, message type etc.).

G 4.6.2.2 A further application of the interface is to deliver firmware updates to the locator processor. For instance, it should be possible to activate / install new software or to apply a firmware patch to cure a detected bug or fault.
G 4.6.2.3 Professional GNSS receivers, for example the Novatel OEMV family of products, as set out in OM-20000094, tend to be highly configurable. This allows an expert user to control even the very low level details of the positioning solution and to output a huge variety of data which can then be used in offline processing software.

G 4.6.2.4 It should be possible to query, or poll, the current configuration of the locator and to receive status information in response. Similarly, when a configuration or command update is sent to the locator, an acknowledgement is sent in response indicating whether the command has been successfully executed.

G 4.6.2.5 The interface, as a minimum, can be used for updating receiver firmware. The cost of maintaining and using this interface will be far less than the cost of new equipment procurements and installation.

G 4.6.3 Train speed input

G 4.6.3.1 Train speed input may provide a useful additional source of data for the positioning solution, when available. It is important that this is a passive ("listening") interface, so that the locator does not interfere in any way with safety-related on-train equipment such as the speedometer, and locator faults do not affect the running of the train.

G 4.6.3.2 Wheel slip systems can be used for a good reference speed, and wiring is relatively cheap for multiple units. There are no standard output specifications, although manufacturers can provide the relevant information on specific train installations. BS EN 15380-4:2013 is intended to categorise all the train functions.

G 4.6.3.3 It is important that the locator does not seek to impose a standard interface specification on any train speed inputs which it may use, and supports the speed input data source where an interface is available, feasible and safe. The equipment’s primary purpose is not to supply data to a locator, so its interfaces are defined by its primary functions and not that of a secondary application (the locator).

G 4.6.4 GNSS time synchronisation

G 4.6.4.1 GNSS receivers which can provide a pulse per second (PPS) output can be used for time synchronisation. This is widely supported on all grades of receivers, from very low cost chipsets to professional survey equipment, so should not unduly limit the choice of receiver or have a procurement cost impact.

G 4.6.4.2 The timing accuracy requirements of applications will determine the grade of GNSS receiver required, but this interface is independent of this.

G 4.6.5 Location database update

G 4.6.5.1 Updates to location databases can be achieved over interface B or interface D. As many databases in guidance systems today use proprietary formats, there is no consistently used standard protocol and format for transferring location data updates.

G 4.6.5.2 The format for providing any updates for a locator will be driven by the format of the selected location database. It is not clear today whether this will be an open format or whether a propriety format will be used. The data volumes involved can also affect the updating method. If the updates require large data sizes, it may be preferable to update with a Secure Digital (SD) card, for example, or to connect to the locator over a local Ethernet, serial, USB or Wi-Fi connection. If the entire database is of a manageable size, it may be preferable to simply replace the database with a complete new version, including any updates, rather than making only isolated changes.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

Part 5  Implementation and Installation

G 5.1  Defining requirements

G 5.1.1.1 For applications that require locator technology, the following attributes can be considered. More details are set out in T892_D1:

a) **Application implementation** – If the application is based on-board or off the train.

b) **Time** – Does the application require a time and what type of timing signal:
   i) Time stamp – to provide a record of a precise time?
   ii) Time feed – to supply continuous feed of a timing signal?
   iii) Time synchronisation signal – to provide a synchronisation pulse that enables a series of systems to use the same time?

c) **Position** – does the application require knowledge of the position of the train and (if known) what type of position information is required:
   i) Absolute position?
   ii) Relative distance (between two points)?
   iii) Distance (from a fixed point)?

d) **Speed** – does the application require knowledge of train speed?

e) **Direction** – does the application require knowledge of the direction, that is, heading of the train?

f) **Fix dimensions** – what dimensions are of interest to the application:
   i) Along track – is location required in the along track direction?
   ii) Across track – is location required in the across track direction (including track discrimination)?
   iii) Height?
   iv) Map coordinates – geographical coordinates of train position?

g) **Fix interval** – what is the output interval for the location subsystem? The value can be derived based on existing applications, best practice and where the application is deployed, that is, on-train, off-train, or both. For on-train applications, the fix interval is normally 1 s (based on current use). For off-train applications the fix interval is generally assumed to be 6-10 s, which is thought to be adequate to provide a real-time update of train location to a control centre. There are specific applications (for example, ERTMS) where 50 Hz could be required to conform to the intended use of locator technology within ERTMS systems, that is, for balise capture purposes. The distance travelled during the fix interval has implications for the along track position accuracy.
In addition to the attributes set out above, performance requirements for the intended applications should also be considered. The following parameters include, but also extend the parameters set out in G 3.4.

a) **Coverage** – required service coverage area for the intended application.

b) **Time accuracy** – required timing accuracy, 95% (seconds). This parameter is derived from the position accuracy and the distance travelled by the train within 1 s.

c) **Position accuracy** – required positioning accuracy, 95% (metres). For applications that are interested in along track dimension, the position accuracy is a function of the distance accuracy and the distance travelled within a fix interval.

d) **Speed accuracy** – required speed accuracy, 95% (m/s). The parameter is expressed as 2-5% of nominal speed of the train during the application. The speed varies according to fast line, slow line, known locations (for example, stations) or during degraded operations.

e) **Direction / heading accuracy** – required heading accuracy, 95% (expressed as degrees). High accuracy is required for those applications where direction is critical. Such applications specify 2-5 degrees accuracy. Direction accuracy of 22.5 degrees refers to compass points, in order to provide coarse directional information to the on-train or off-train system.

f) **Integrity alert limit** – describes the maximum 99.9%+ accuracy requirement, which if exceeded will generate an alarm not to use the locator (expressed as metres).

g) **Time to alarm** – the maximum time allowable to detect and communicate that there is an error in the system. This parameter is conditioned by the distance the train can travel within the time it takes to detect and communicate the error to the system.

h) **Mission time** – the expected duration of the application. This parameter is used to determine whether an application is running continuously during the journey or only required at key points / sections (expressed in seconds). If it is running continuously, then the application may be able to tolerate some outages (loss of GNSS). If the application is only required at specific locations, where there are little or no GNSS signals, then it will require specific augmentation technology to assist.

i) **Continuity** – given the application has started, the probability that it will be able to finish without loss of service. This parameter is based on the mean-time-to-failure (outage) and the mission time.

j) **Availability** – the probability that the application is available to be used when required. This parameter is based on a combination of the mean-time-to-failure (outage) and the mean-time-to-restore (re-acquire GNSS).

k) **Tolerable start-up time** – a parameter used to express the allowable time taken to initiate the application, as measured from the instant when the system is activated.

l) **Number of tolerable failures (per day)** – a parameter that helps to identify the permissible mean-time-between-failures (outages) for a particular application. The parameter has been based on assessing a safe number of outages that will enable the application to continue (based on experience of GNSS outages from the T510 project).

m) **Interfaces** – what type of interfaces exist for the locator and the application?

   i) Data stream – continuous provision of time / position / speed data.

   ii) Reference – a single snapshot time / position fix used to tag data associated with an event.

   iii) Geo-fence – defining the boundary of a zone of interest.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

G 5.1.1.3 Consider communications and antenna requirements when determining the overall system performance requirements for specific application(s).

G 5.1.1.4 Consideration should be given to foreseeable future applications so that potential future needs are captured.

G 5.2 Choice of locator

G 5.2.1 The choice of GNSS locator depends on its ability to satisfy the requirements of the intended application(s) in terms of the three primary quality of service parameters set out in G 3.4, namely, service coverage, accuracy and integrity. It is the responsibility of the user of the intended application to map these application-specific quality of service requirements onto the classes of service set out in G 3.5. It is important to pay particular attention to those operational environments in which the performance of GNSS alone may not be sufficient to meet application requirements.

G 5.2.2 The primary characteristic of the operational environment of the railway is the signal obscuration, due to tunnels, canyon effects, stations and foliage. Therefore, the first decision is to consider whether GNSS alone will meet the coverage requirement. If not, hybridisation would be required to improve the service coverage.

G 5.2.3 Having determined whether or not hybridisation is needed, the next assessment to be made concerns the accuracy requirement. Beyond a certain threshold of accuracy, even if hybridisation is not required for reasons of service coverage, a form of augmentation or hybridisation may be required to meet the accuracy requirement.

G 5.2.4 Where integrity is required for safety-related applications, an integrated solution with a form of hybridisation is usually required. Depending on the architecture of the specific application, it may require systems, including the locator, to only supply positions with an assured level of confidence. Alternatively, it may require contributing systems to provide continuous position inputs but with associated quality metrics that will allow the application to determine if the positions are fit-for-purpose.

G 5.2.5 When different solutions are available, it is necessary to apply selection criteria to determine the most appropriate solution. In addition to quality of service, other criteria are cost and upgradeability. The trade-off is made by considering longer-term strategy, as well as short-term drivers. For example, if future requirements call for a higher performance locator, then an easily upgradeable solution – or even a higher performance option – is generally preferable over a lower cost option.

G 5.2.6 When considering upgradeability, the solution selected is such that the different augmentation services considered can be added successively, for example a satellite navigation antenna installed for GPS is likely to be able to receive Galileo and EGNOS signals as well, and would only require a receiver upgrade. By contrast, for an upgrade which involves adding or replacing hybridisation inputs, replacement of the locator (in whole or in part) may be the only option.

G 5.2.7 Consider the whole life-cycle cost of procurement, installation, operation and maintenance of the locator. The life-cycle costs include the data management arrangements.

G 5.2.8 The operational environment of a locator needs to be considered for it to work in the relevant temperature and humidity range. Size and weight is likely to be less critical for a train installation, but could dictate the possible positions to install the locator, for example, in a roof cavity or on the floor.

G 5.2.9 Another key feature to consider is the ability of a locator to output additional information to facilitate continuous performance monitoring. It is also important to consider configurability of the locator so that options are available to adjust setting of locator solutions for potential performance improvement.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

G 5.2.10 Wherever practicable, the performance of different locator solutions is simulated prior to any procurement. These simulations are available either via the purchase of COTS products or commercial consultancy services. This can provide a cost-effective alternative to, or complement, wide-area performance trials.

G 5.3 Procurement of GNSS equipment
G 5.3.1 GPS buyer’s guide

G 5.3.1.1 RSSB’s research report T892_D8 provides useful information in supporting the procurement of GNSS equipment (receiver only) for rail applications. The report includes a quick guide aiming to answer the anticipated frequently asked questions, some of which are set out in Table 9. More detailed answers are also provided in T892_D8. The quick guide includes descriptions on the types of receivers available, and outlines how receiver performance is likely to be presented on a product sheet.

G 5.3.1.2 More detailed introductions on the following are also provided in the research report:
   a) Types of features and techniques of a receiver that contribute to its performance.
   b) Main elements of a receiver.
   c) Various form factors which a receiver may take.
   d) Aspects considered regarding the antenna.

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Is a more expensive receiver better than a cheaper one for rail applications?</td>
<td>Generally not, except for survey applications.</td>
</tr>
<tr>
<td>2</td>
<td>If I am buying equipment in which the receiver is already integrated, how can I tell if it is suitable for my application?</td>
<td>An equipment supplier should be able to provide details of the GNSS receiver chipset used, usually in the form of a ‘product sheet’.</td>
</tr>
<tr>
<td>3</td>
<td>Is there much difference between receiver products of the same general type produced by different manufacturers?</td>
<td>Yes, there can be. The positioning performance achieved in obstructed environments by consumer grade receivers can vary significantly in like-for-like trials. Professional grade receivers tend to be more easily comparable as they compete on similar accuracy and operational efficiency / flexibility criteria. Levels of performance and configurability still vary, but less so.</td>
</tr>
<tr>
<td>4</td>
<td>What are the key questions to ask a supplier?</td>
<td>Key questions include: a) What outputs can I obtain from this receiver? b) What is its accuracy and under what conditions are these performances delivered? c) What is the signal acquisition and tracking sensitivity of the receiver and under what conditions are these performances delivered? d) What options do I have for configuring this receiver? e) What options do I have for upgrading the receiver to future features?</td>
</tr>
<tr>
<td>No.</td>
<td>Question</td>
<td>Answer</td>
</tr>
<tr>
<td>-----</td>
<td>--------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>6</td>
<td>What are the main error sources in a GNSS solution, and can I buy a receiver which eliminates, mitigates or at least detects them?</td>
<td>In obstructed areas the dominant error source will be ‘multipath’ which is caused when satellite signals are reflected before reaching the user receiver. It can lead to position errors of tens or even hundreds of metres. No receiver can fully protect against the effects of multipath.</td>
</tr>
<tr>
<td>6</td>
<td>Many manufacturers are now promoting receivers using GPS and GLONASS, and also using EGNOS. What are these, and should I be buying equipment which uses them?</td>
<td>GLONASS is the Russian equivalent of GPS. GLONASS is widely supported on professional grade receivers and is now becoming increasingly common for consumer receivers. EGNOS is a space based augmentation solution that uses the L1 frequency which is commonly supported as a standard receiver feature; it seems worthwhile to include this capability even if the performance benefits may be only moderate.</td>
</tr>
<tr>
<td>7</td>
<td>Most of the mass-market receivers appear to use A-GPS. What is the ‘A’ and do I need it?</td>
<td>The ‘A’ stands for ‘Assisted’, leading to the terminology A-GPS, A-GNSS, and ‘assistance’. For applications which require high availability positioning from start-up, that is, low TTFF as set out in G 3.4.4.1), some form of assistance will be a benefit.</td>
</tr>
</tbody>
</table>
| 8   | How can I ensure I buy a receiver which allows a scalable and future-proof solution? | It is not possible to buy a receiver which can guarantee this, but there are a few points to look for:  
  a) Better anticipate your future requirements.  
  b) Configurability of the receiver.  
  c) Ask about future features which can be enabled through a firmware update.  
  d) Select an antenna which covers the frequencies which may be of interest in the future. |

**Table 9  Frequently asked questions**

**G 5.3.2  Class C locator**

**G 5.3.2.1** A Class C locator will generally consist only of a GNSS receiver, as set out in G 3.6.1. T892_D8 classifies receivers into two broad categories: professional and consumer grade, and recommends high sensitivity consumer grade for railway usage. Typical applications and some general characteristic of the categories of receivers are set out in Table 2-1 of T892_D8.

**G 5.3.2.2** T892_D9 Data Analysis Report analysed the data for three GNSS-only solutions: a professional grade dual-frequency GPS receiver, a GPS receiver added with GLONASS capability and a consumer grade high-sensitivity single frequency GPS. The results showed that GNSS on its own works well in open areas. Accuracies for the different solutions range from 3 m to 6 m (95%) and availabilities are typically 96% to 99% for the areas assessed.
G 5.3.2.3 T892_D9 showed that overall there was a very slight improvement in accuracy using a professional grade dual frequency GPS receiver compared to a low cost consumer grade high-sensitivity single frequency GPS. However, the improvement in accuracy was offset by the lower availability performance, because the professional grade receiver does not provide position solutions in many partially obstructed areas, whereas the high-sensitivity receiver does. The professional grade receiver is thus considerably less suited to railway application.

G 5.3.2.4 In view of the above, the high-sensitivity consumer grade receiver is considered suitable for rail applications requiring only a Class C locator.

G 5.3.2.5 RSSB research report T740 provides characterised GPS performance over the GB rail network using data collected from the measurement trains.

G 5.3.3 Class B locator

G 5.3.3.1 RSSB research project T892 collected and analysed data from a range of equipment using alternative hybridisation solutions across a range of operating environments.

G 5.3.3.2 T892_D9 has concluded that the most robust and reliable solution was provided by a low cost, high-sensitivity GPS receiver hybridised with simple dead reckoning which uses a single axis gyroscope to measure change in heading, and a speed / distance input from the train wheel speed sensor (WSS). This DR hybridisation solution would be a suitable and cost-effective equipment choice for a Class B locator.

G 5.3.3.3 This solution provided an accuracy of 4 m to 6 m (95% confidence) in open and moderately obstructed areas. During GPS outages, positioning errors increased slowly and quite predictably for extended periods. Over a GPS outage of 30 s horizontal errors increased by around 2 on average, and 8 m 95%. Applying this solution can increase the availability of positioning for rail applications which encounter obstructions to satellite signals, in a relatively simple, robust and low cost way (£300 to £400).

G 5.3.3.4 The implementation of the DR hybridisation solution, investigated in research project T892, lacked a direction-of-travel input from the train. This additional input is required to accommodate reversals of the train. The performance of the DR hybridisation algorithm with the implementation of a direction-of-travel input has since confirmed that the solution provides continuous positioning when a train runs in reverse.

G 5.3.3.5 T892_D9 also evaluated an off-the-shelf GPS + IMU solution (~£3,500). It did not produce adequate positioning during GPS outages, and the addition of the IMU data actually degraded the solution when GPS positioning was possible.

G 5.3.3.6 Another solution evaluated by T892_D9 is the combination of a professional grade dual-frequency receiver with a relatively high grade Inertial Measurement Unit IMU (~£20,000). This provided a solution which can maintain accurate positioning for short and medium periods of GPS outage (up to around 30 s); but for longer outages, and successive outages with little time to recalibrate in between, the solution became unreliable.

G 5.3.4 Class A locator

G 5.3.4.1 The need of a Class A locator for a specified integrity level leads to a bespoke solution, as typical COTS positioning solutions do not provide the transparency that is required to verify the solution to the confidence level required.

G 5.3.4.2 The differential augmentation is able to contribute to the assurance of integrity. Its use requires a careful choice of locator architecture, including the manner in which the data fusion is implemented. This complex subject is for the designer, not the user; but the user needs to have at his disposal the evidence sufficient to support a claim by a supplier that their design meets the user’s integrity requirements for the application.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

G 5.3.4.3 Similarly, the choice of the integration of the IMU within the data fusion needs careful consideration. It is important that the choice is supported by a cogent rationale, and the integrity of the IMUs data in the absence of GPS signals is supported by a design concept. (One possibility is to use a tachometer, which can simplify the IMU required.)

G 5.3.4.4 Given the relatively low integrity requirements of SIL1 and SIL2 applications for a Class A locator, adopt the simplest solution possible to avoid complexity. As techniques such as dual frequency receivers, Doppler and Carrier phase measurements become more common and available in COTS products, their cost reduces. Where multipath is required to be effectively controlled, the products with these techniques are recommended for a Class A locator, Long Range Kinematic (LRK), Real-Time Kinematic (RTK) although are unlikely to be essential but, if available in a competitively priced COTS unit, they should be considered. For SIL1 and SIL2 applications the precautions set out in BS EN 61508-1:2010 should be sufficient for the acceptability of the hardware and software.

G 5.3.4.5 Research report T892_D8 points out that there are a small number of professional receivers designed for high integrity, as they are used in safety-related applications. These devices are unlikely to be found directly by a general GNSS buyer looking to make a standalone purchase, as they are typically used within an integrated avionics system, shipborne navigation system or for military applications. These receivers are developed for an application in which a clear view of the sky, and consequently good satellite signal reception, is assumed.

G 5.3.4.6 For obstructed environments, a hybridised solution with a combination of IMU, Tachometer / Odometer and Map, as set out in G 3.6.4, could be used, with the support of RAIM and differential augmentations (for example, EGNOS).

G 5.4 System integration

G 5.4.1 System definition

G 5.4.1.1 System definition includes defining existing vehicle interfaces. If this information is not available it may be necessary to make on-vehicle measurements. It is important that the responsibility to define the interface is clearly stated within specification / contractual documentation.

G 5.4.2 Responsibility

G 5.4.2.1 Consider requirements of the integration with existing vehicle systems, such as speed measuring, when the implementation of a system is initiated. Clearly state the responsibility for the integration within specification / contractual documentation.

G 5.4.3 Risk assessment

G 5.4.3.1 The risk assessment of the system includes:

   a) An assessment of the consequences of the failure of system interfaces, such as the possible false energisation of vehicle wiring.

   b) An assessment of the use of the system, on an application-by-application basis, covering the various failures that might occur, and reflecting the statistical nature of the performance of the locator unit.

   c) An explicit consideration of the potential impacts, due to the vulnerability of the satellite navigation system to unintentional electromagnetic interference, as well as the security threat of jamming and / or spoofing.

G 5.4.4 System support and maintenance

G 5.4.4.1 Set out the user’s maintenance objectives for the system at the start of the project. Give attention to the management of supporting data.

G 5.4.4.2 Routine maintenance is not required unless advised by the manufacturer.
G 5.4.5  Role of design
G 5.4.5.1  It is essential that maintenance and testing contribute to meeting reliability targets for a system in service. This is best achieved by placing maintainability at the heart of the design process.

G 5.4.5.2  Include in the design of the locator unit built-in test equipment and auto-diagnosis that is compatible with the COTS and maintainability requirements. Where there is a conflict, a life-cycle cost model is analysed to determine which should take precedence.

G 5.4.5.3  When a fault is detected, the built-in facilities can identify the unit concerned and assign a fault code. Make this information available to the staff responsible as part of the train’s standard maintenance facilities.

G 5.4.5.4  The design of the locator is such that databases are maintained within their period of validity, and corruption detected with a high degree of confidence. Updating databases is subject to verification so that amendments are shown to be correct. Procedures are commensurate with the level of safety required and not more demanding, as this would lead to a waste of resources.

G 5.4.6  Built-in self-test
G 5.4.6.1  Examples of automatic self-testing operating at switch-on, and running continuously in the background are:

a)  Testing of system memory at start-up.

b)  Verification that software versions are valid.

c)  Verification that database versions are valid.

d)  Verification that hardware interfaces are working. Useful indications include confirmation of the train consist data, so that the interfaces and equipment present can be identified, and confirmation of the serviceability of the train communications.

G 5.4.6.2  In the event of failures, notifications can be provided:

a)  To the train maintenance system.

b)  To the train crew, if any action is required to enable the train to continue in service.

G 5.4.6.3  Subsequent action, for example reporting failures to a central server, depends upon the train’s maintenance system.

G 5.5  Equipment installation

The following is based on principles used on successful installations. It may not be possible to comply with them completely, and the alternatives are considered on a case-by-case basis.

G 5.5.1  Antenna position
G 5.5.1.1  It is preferable to share one antenna between all positioning applications, as far as is practicable. This avoids the proliferation of multiple equipment serving the same function and, potentially, compromising one another’s performance, which complicates the systems integration process. There are also limitations imposed on the number of antennas by the vehicle body construction.

G 5.5.1.2  Locating the antenna on the vehicle longitudinal centre line and as close to horizontal as practicable, maximises the line of sight of the satellites.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

G 5.5.1.3 To combat multipath effects, antenna positioning is of prime importance. Place the antenna above the highest reflector, to prevent reflected waves from arriving from and above the horizon. Certain antennas require a ground plane to increase gain at low elevation angles. However, the ground plane itself may diffract signals incident on the antenna at low elevation angles (see also G 5.5.2).

G 5.5.1.4 Place the antenna as far as practicable from all potential sources of electromagnetic interference (EMI), including other antennas, to maintain electromagnetic compatibility with the existing vehicle equipment. The minimum distance of 1 m from GSM/GSM-R antennas for a receive-only GNSS antenna is given in GK/GN0602.

G 5.5.1.5 The separation distance applies regardless of which service the antenna is receiving – GPS, Galileo, EGNOS, other SBAS.

G 5.5.1.6 Due to the broad spectrum of noise that is generated during arcing, a minimum distance of 5 m is reasonable from pantographs and associated switchgear.

G 5.5.1.7 When the antenna position is being determined, consider the position of the receiver so that the cable length between the two is kept as short as practicable; this is to avoid unnecessary signal attenuation, although an appropriate splitter selection could mitigate the loss.

G 5.5.1.8 If the locator also includes an IMU it will be required to place the antenna at a 'lever arm' separation from the locator. This lever arm (the offset distance from a GPS antenna to the IMU centre) should be measured and input into the locator processing algorithms to guarantee the best quality of positioning.

G 5.5.1.9 Guidance on the placements of antennas, including requirements for the separation of different antenna types is given in GK/GN0602 and GE/GN8579.

G 5.5.1.10 When placing the GNSS antenna, consider the future fitting of other antennas, for example GSM-R (both voice and data). Newer vehicles generally have large cab equipment cupboards to facilitate the fitting of ERTMS equipment and therefore fitting the GNSS antenna at the cab end of such a vehicle is practicable. Older vehicles have limited cab equipment space, and equipment cupboards at the inner end tend to have more space available which would facilitate retro-fitting of antenna at that end.

G 5.5.1.11 When multiple units are joined together as one train, the role of the intermediate antennas and systems should be assessed to determine whether they are required to be in service.

G 5.5.2 Antenna installation and maintenance

G 5.5.2.1 Low-profile GNSS antennas are available that have a similar height to existing cab radio antennas. If the antennas are mounted at the same height in a similar longitudinal line as the existing cab radio antennas, demonstrating that gauge is not infringed should be straightforward provided the existing cab radio antenna is in gauge. Guidance on gauging is given in GE/GN8573.

G 5.5.2.2 Any ground plane requirements specified by the antenna supplier should be observed. If the antenna is mounted on a non-metallic roof it may be necessary to incorporate a ground plane within the mounting arrangement or apply a metallic film on the roof underside. Alternatively, an antenna that does not require a ground plane may be more practical.

G 5.5.2.3 Bonding any exposed conductive part firmly to the vehicle frame prevents the antenna and cabling from rising to an excessive potential, should the overhead line equipment come into contact with the antenna. This could be achieved by locally removing the existing insulating roof paint and replacing it with a conductive one, such as zinc primer, providing the roof is adequately bonded via the vehicle frame and running gear to the running rails. Requirements for bonding capacity are set out in section 2.1.2 of GM/RT2111.
G 5.5.2.4 For the cable connecting the antenna and receiver, protect the cable from being inadvertently used as the safety equipotential bond for the antenna ground plane and mounting plate. None of the cable conductors, sheath, or screen provide sufficient safety bonding for the antenna ground plane or mounting plate.

G 5.5.2.5 The cable between the antenna and the receiver is also a particular threat to EMC; measures to reduce the risk include:

a) The cable is routed separately to all other cables and not tied to them.

b) The cable is separated from other cables by a minimum of 150 mm.

c) If it is necessary to cross over other wiring, the cables are aligned perpendicularly.

d) The cable is as short as practicable.

G 5.5.2.6 Seal connections and maintain the level of sealing whatever the design of the installation. It is recommended that the antenna is sealed to a minimum of IP66, as set out in BS EN 60529:1992+A2:2013, although higher ratings may be required if high-pressure jets are expected to be used for train cleaning.

G 5.5.2.7 Consideration should also be given to the environmental and protection conditions, as set out in BS EN 50155:2007. The environmental conditions and worst-case parameter to consider for train roof space is set out in Table 10 in G 5.5.5.

G 5.5.2.8 Ideally, the design of the installation only requires roof access, in order to maintain or replace the antenna. If this is not practicable, then the ease of access to the underside of the roof should be considered.

G 5.5.3 Receiver fitment standards

G 5.5.3.1 Relevant standards for electronics equipment used on rolling stock include BS EN 50155:2007 and BRB/RIA Specification No 13. Included within BS EN 50155:2007 are the environmental conditions that the equipment can be exposed to. These are usually more onerous than those that are applied to standard commercial PC equipment and therefore should be carefully considered, together with the actual equipment installation, to minimise equipment failure.

G 5.5.3.2 For retrofit applications, older vehicles usually have a control system based on relays that have unsuppressed coils. This means that supplies and battery volt connections can contain high-voltage direct transients and non-battery voltage connection indirect transients. Experience has shown that, if electronic equipment is being retrospectively fitted to vehicles produced earlier than approximately 1995, then meeting the requirements of BRB/RIA Specification No 12 should be considered, together with the standards identified by the train builder. Testing of older vehicles not built to BRB/RIA Specification No 12 should be considered.

G 5.5.3.3 The general principles for on-train receiver (and general equipment) design include:

a) The use of enclosures suitable for rolling stock.

b) The use of reverse polarity protection.

c) Maintenance and depot handling requirements, including electrical protection on test equipment.

d) Polarisation of connectors and use of different connector sizes.

e) Avoidance of gold plating on frequent use connectors.

f) Provision of spare cables within any looms.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

G 5.5.4 Power supply

G 5.5.4.1 The auxiliary supply on an Electric Multiple Unit (EMU) or electric locomotive is derived from the traction supply and is subject to interruptions when the train goes through neutral sections (25 kV AC overhead) or 3rd rail gaps (750 V DC). To prevent the frequent loss of operation when this happens, the system can be supplied from a vehicle battery-backed DC supply or its own Uninterruptible Power Supply (UPS). More details on power supply are set out in G 4.5.

G 5.5.5 Position of the locator

G 5.5.5.1 To limit the length of cable to the antenna, a suitable position for the locator might be the roof space or body-end equipment cupboards (passenger vehicles). Provide ease of access for installation and maintenance so that the equipment can be exchanged within a target time of 30 minutes.

G 5.5.5.2 When retrofitting equipment to existing vehicles, the usual locations available, particularly on multiple units, are as set out in Table 10, together with the specific environmental threats to consider. Locator equipment should not require forced ventilation, to prevent blowing unwanted dust into safety-critical equipment.

<table>
<thead>
<tr>
<th>Location</th>
<th>Environmental consideration</th>
<th>Worst-case parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment cupboards</td>
<td>Heat sources</td>
<td>Max 55°C</td>
</tr>
<tr>
<td></td>
<td>Ventilation requirements</td>
<td>Zero air flow</td>
</tr>
<tr>
<td></td>
<td>EMI sources</td>
<td></td>
</tr>
<tr>
<td>Roof space</td>
<td>Heat sources</td>
<td>The ‘T3’ category (70°C) as set out in BS EN 50155:2007</td>
</tr>
<tr>
<td></td>
<td>Solar gain, temperatures in</td>
<td>Seal the antenna to IP66 or higher, as set out in</td>
</tr>
<tr>
<td></td>
<td>excess of 50°C have been</td>
<td>BS EN 60529:1992+A2:2013</td>
</tr>
<tr>
<td></td>
<td>recorded in these locations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ventilation requirements</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leaking roofs</td>
<td></td>
</tr>
<tr>
<td>Luggage rack / stack</td>
<td>Passenger interference</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ventilation requirements</td>
<td>Zero air flow</td>
</tr>
<tr>
<td>Underseat</td>
<td>Passenger interference, a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>substantial enclosure, usually steel, is required for this location</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ventilation requirements</td>
<td>Zero air flow</td>
</tr>
<tr>
<td></td>
<td>Liquid ingress from cleaning / passengers</td>
<td>Seal the equipment to BS EN 60529:1992+A2:2013 IP65.</td>
</tr>
</tbody>
</table>

Table 10 Equipment location options

G 5.6 EMC considerations

G 5.6.1 The equipment should not be located close to known sources of EMI, such as the following:

a) Rotating machines and associated chokes and cables.

b) Line filter chokes and their connection cables.

c) Traction converters, transformers, alternators and their respective connection cables.

d) Traction supply cables on electric locomotives and EMUs.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

e) Pantographs and circuit breakers and their associated cables.

f) Large contactors and electro-pneumatic (EP) valves and other traction equipment switchgear.

g) Roof mounted rheostatic braking resistors and their supply cables.

G 5.6.2 BS EN 50155:2007 specifies the minimum limits for both emissions and susceptibility that are required to maintain electromagnetic compatibility with the existing vehicle equipment. If the equipment is to be located in the vicinity of possible sources of EMI, such as those given in G 5.6.1, then apply more onerous limits regarding susceptibility.
Appendix A  Example Applications

This appendix provides selected applications to illustrate the use of a GNSS based locator to achieve a given performance. The descriptions and requirements proposed in this appendix are based on T892_D1.1, T892_D1.2, unless otherwise referenced. The examples are for illustration purpose only – users of similar applications are responsible for deriving their own requirements.

G A.1  Energy metering

G A.1.1 GM/RT2132 sets out the energy metering requirements when electric traction units are fitted with an energy measuring system that provides data to be used by the infrastructure manager for billing purposes. The location function for the metering system is set out in section 2.4 of GM/RT2132.

G A.1.2 The following table sets out the performance requirements. Potentially a Class C locator can be used to achieve the performance requirements.

<table>
<thead>
<tr>
<th>Coverage and availability</th>
<th>Accuracy (95%)</th>
<th>Integrity</th>
<th>Fix interval</th>
<th>Design choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB network</td>
<td>Position (250 m)</td>
<td>Desirable</td>
<td>30 s</td>
<td>Class C locator</td>
</tr>
<tr>
<td>70%</td>
<td>Speed (5 km/h)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Time stamp (1 s)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

G A.2  Customer Information System (CIS)

G A.2.1 A Customer Information Systems (CIS) is located in stations, where indicator boards and / or public address system give information about the destinations, calling points and predicted departure times (or cancellation status) of the next trains.

G A.2.2 Pre-trip information for customers who have not yet arrived at a station is widely available electronically, through mobile phones, tablets, desktop computers and the National Rail Enquiries telephone service. Local radio and TV highlight more significant disruptions, particularly at peak times.

G A.2.3 Information for pre-trip use and for station CIS is produced by a centralised system called Darwin. Darwin obtains train running data from train describers and TRUST. On the busiest routes these sources generally produce acceptable results, but in many areas movement reports are infrequent and / or are not timely and results are poor. Improved reporting of train location and speed will increase information in these areas, leading to better information for customers to support their travel planning.

G A.2.4 The provision of on-train information is variable and particularly suffers during times of service disruption. Some trains rely entirely on staff making public address announcements, while others also have displays. Rail Vehicle Accessibility Regulations will require more widespread fitment of displays in the next few years, and provision is being made for these systems to take information from Darwin. Improved information quality at stations, on trains and through apps will lead to greater confidence amongst passengers and help them to better plan onward travel if their journey is disrupted.

G A.2.5 GPS data is being used to provide greater accuracy, granularity and timeliness for a better customer information system. The following table sets out the performance requirements. Potentially, a Class B locator can be used to achieve the performance requirements.

G A.2.6 The fix interval value has referenced the draft specification for customer information from ATOC.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

<table>
<thead>
<tr>
<th>Coverage and availability</th>
<th>Accuracy (95%)</th>
<th>Integrity</th>
<th>Fix interval</th>
<th>Design choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB network</td>
<td>Position (33 m)</td>
<td>Desirable</td>
<td>Between 10 – 30 s</td>
<td>Class B locator</td>
</tr>
<tr>
<td>95%</td>
<td>Speed (5 km/h)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Time stamp (0.1 s)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

G A.3 On-Train Monitoring Recorder (OTMR)

G A.3.1 The OTMR provides a complete record of the parameters set out in GM/RT2472, with the addition of any others specified by the train operator.

G A.3.2 Data recording takes place in a crash survivable memory module, with journeys in excess of 24 hours duration easily accommodated. The data is protected from damage during a vehicle accident, providing a secure record for incident investigations. The recorded information can be transferred to a PCMCIA memory card for routine data extraction and analysis.

G A.3.3 Many OTMR units are able to receive external inputs from time and positioning sensors. Logging of time and positional data can be performed regularly, both after a specific time interval has elapsed or after a set distance has been travelled, whichever occurs first. A number of digital inputs can also be used to trigger logging of positional data. For example, the 'door-open' status could be used to log the exact location of the vehicle when the doors were opened.

G A.3.4 The stored data can be analysed to provide a database of time and position references against signal numbers, platform etc.

G A.3.5 The quantitative values for PVT and fix interval set out in the following table are derived from BS EN 62625-1:2013. The standard sets out the specification of an on-board driving data recording system for the purpose of recording data about the operation of the train.

<table>
<thead>
<tr>
<th>Coverage and availability</th>
<th>Accuracy (95%)</th>
<th>Integrity</th>
<th>Fix interval</th>
<th>Design choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB network</td>
<td>Position (1 m)</td>
<td>Desirable</td>
<td>Maximum sample rate 250 ms</td>
<td>Class B</td>
</tr>
<tr>
<td>95%</td>
<td>Speed (1 km/h)</td>
<td></td>
<td>250 ms</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Time stamp (1 s)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

G A.4 Train based infrastructure monitoring

G A.4.1 This application covers the potential use of in-service trains, that is, not special measurement trains or research vehicles, in the monitoring of infrastructure asset condition.

G A.4.2 Condition-based monitoring, using information obtained by in-service vehicles, may enable the detection of a defect at an early stage, thus ensuring maintenance interventions are more proactive rather than reactive.

G A.4.3 Train-based infrastructure monitoring will monitor and report the status of an asset as the train passes it – the parameters monitored depending on the sensors fitted to the train.

G A.4.4 For example, maintenance can be focused on locations most requiring attention by utilising data acquired by real-time monitoring of actual vibration levels or accelerations or by using outputs from Wheel Slip Protection (WSP) and sanding systems to identify poor adhesion sites and allow appropriate measures to be put in place to reduce delays.

G A.4.5 To realise the maximum benefit of such applications it is important to be able to reliably and accurately locate any measurements that are being made. In order to do this the following information would need to be captured in parallel with the asset data: location (latitude and longitude), date and time, and vehicle speed.
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

G A.4.6 Such systems require high coverage, availability and accuracy.

<table>
<thead>
<tr>
<th>Coverage and availability</th>
<th>Accuracy (95%)</th>
<th>Integrity</th>
<th>Fix interval</th>
<th>Design choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB network 99%</td>
<td>Position (2 m to 10 m depending on the asset and monitoring type) Time stamp (0.1 s)</td>
<td>Desirable</td>
<td>1 s</td>
<td>Class B locator with augmentation to provide higher accuracy when required</td>
</tr>
</tbody>
</table>

G A.5 Traffic management and regulation

G A.5.1 Traffic management is the process of managing the train operations in such a way as to fulfil the performance objectives of the network. This includes the optimal routing of trains and the integration of trains operating at speed and on time with other trains operating in degraded modes running with delay. The application also includes the measures required to recover the railway from disruption. Traffic managers control the movement of trains by making judgements of the position and speed of the trains, and anticipation of their future performance. Comparison of predicted and actual performance can be used to pre-empt future difficulties. Adequate management of traffic (accurate positioning and real time communications) can improve utilisation of line capacity. Traffic management systems are also useful in determining and allocating responsibilities when a failure of a train on the network occurs, thus affecting the rest of the services.

G A.5.2 The application would benefit from higher resolution of train time, position and speed than can be provided by the trackside detection devices. This is a sub-network scale application, and hence an important feature as all trains operating within the sub-network can provide consistent and reliable time, position and speed information to the traffic management system so that the system can manage the traffic optimally, based on trusted input.

G A.5.3 The following table shows the performance requirements.

<table>
<thead>
<tr>
<th>Coverage and availability</th>
<th>Accuracy (95%)</th>
<th>Integrity</th>
<th>Fix interval</th>
<th>Design choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-network 99%</td>
<td>Position (17 m) Speed (5 km/h) Time stamp (0.1 s) Heading (22.5 degree)</td>
<td>Desirable</td>
<td>6 s</td>
<td>Class B locator</td>
</tr>
</tbody>
</table>
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

Definitions

**Accuracy**
Accuracy can be defined as the degree of conformance between the measured position at a given time and its true position at that time. For more explanation see G 3.4.2.

**Augmentation**
Augmentation refers to techniques which enhance the performance of the basic GNSS system in some way. Typically this will involve the monitoring of satellites over a ground-based reference network in order to provide a user with correction messages which can be used to improve position accuracy.

**Dead reckoning**
Dead reckoning improves availability, that is, reduces service gaps, due to poor satellite visibility. It can use tachometry, speed sensors (such as Doppler) and directional information (say, a compass), together with a form of map.

**EGNOS**
The European Geostationary Navigation Overlay Service, EGNOS, is the European Satellite Based Augmentation Service (SBAS) which complements the US Global Positioning System (GPS) by providing corrections and integrity information over Europe.

**Ephemeris**
Ephemeris refers to the information which describes the satellite position and clock information. A GNSS position solution in effect treats the satellites as known points in space and determines the receiver position by measuring distances to these known points. Each GNSS satellite broadcasts its own ephemeris, sometimes referred to as navigation data.

**Galileo**
The global navigation satellite system developed under the Galileo Programme will provide Europe a fully autonomous satellite-based positioning, navigation and timing capability, for global high performance services.

**GBS**
GBS is one of the position data sentences defined by NMEA. It is used to support RAIM by providing information on faults per satellite.

**GGA**
GGA is one of the position data sentences defined by NMEA. It contains latitude, longitude, height and quality indicators.

**GLL**
GLL is one of the position data sentences defined by NMEA. It includes latitude, longitude and a Mode Indicator which indicates the type of solution used when computing a position.

**GLONASS**
The GLObal NAvigation Satellite System, operated by Russia consists of a constellation of 24 satellites. Its signals are similar to, but have differences from, the GPS signals.

**GNSS (Global Navigation Satellite System)**
A generic term to describe the technology of navigation by satellite applicable to all such systems, for example, GLONASS, GPS, and Galileo.
GPS
The Global Positioning System, originally deployed by the USA for military use but now available for civil use. It consists of 24 satellites that orbit the earth and provides location and time information, anywhere on or near the earth where there is an unobstructed line of sight to four or more GPS satellites.

GRS (GNSS Range Residuals)
GRS is one of the position data sentences defined by NMEA. It supports RAIM by providing range residuals (the difference between calculated range and measured range) for satellites used in the positioning solution.

GSA
GSA is one of the position data sentences defined by NMEA. It includes GNSS DOP information and IDs of all satellites used in computing the position solution.

GST
GST is one of the position data sentences defined by NMEA. It provides pseudorange noise statistics.

GSV
GSV is one of the position data sentences defined by NMEA. It includes IDs of all satellites that are theoretically in view from a user receiver.

Hybridisation
For the purposes of this document, a term used for the method of integrating GNSS with other complementary sensors and systems. The diverse source of data is processed within the locator unit to improve one or more of service coverage, integrity and accuracy. The sources of hybridisation data could include Inertial Measurement Units (IMUs), location database or map, speed sensors and terrestrial positioning signals.

Integrity
Integrity is defined as the ability to provide users with warnings within a specified time and at specified probability (risk) when the output from the locator unit should not be used, as its accuracy falls outside a predefined threshold.

Locations database
A database of information relevant to a given location (set of coordinates). The information meets the requirements of a specified application. It could, for example, be a station name and permissible stopping points along the platforms.

Locator
A locator is an on-train system that provides train location, speed and timing information to support a range of on-train and back-office applications.

Map-matching
A means of checking if an estimate of location determined by GNSS is reasonable by comparing the estimate with a database of known positions of the track.

Multipath
Multipath is caused when satellite signals are reflected before being received at the user antenna. The reflection increases the distance travelled between satellite and receiver leading to range errors which will then propagate through into position errors.

PVT
Train position, speed and time.
RMC
RMC is one of the position data sentences defined by NMEA. It contains latitude, longitude, speed, bearing, time and fix status.

Service coverage
Service coverage refers to the proportion of the railway network for which a train’s position can be reported at the required level of accuracy and confidence. It is the characterisation of a lack of service coverage that determines whether an application can operate with GNSS alone, or whether augmentation or hybridisation is required.

It is in the nature of the railway and GNSS processing that geographic limitations to service coverage are present, and the acceptable loss of service depends upon the needs of the application.

Wi-Fi
Any Wireless Local Area Network (WLAN) product based on the Institute of Electrical and Electronics Engineers’ (IEEE) 802.11 specifications.
### Abbreviations and Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-GNSS</td>
<td>Assisted GNSS.</td>
</tr>
<tr>
<td>ATOC</td>
<td>Association of Train Operating Companies.</td>
</tr>
<tr>
<td>ATP</td>
<td>Automatic Train Protection.</td>
</tr>
<tr>
<td>BTS</td>
<td>Base Transceiver Station.</td>
</tr>
<tr>
<td>CAN</td>
<td>Controller Area Network.</td>
</tr>
<tr>
<td>CCTV</td>
<td>Closed Circuit Television.</td>
</tr>
<tr>
<td>CIS</td>
<td>Customer Information System.</td>
</tr>
<tr>
<td>COMPASS</td>
<td>Combined Positional Alternative Signal System.</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial-Off-The-Shelf.</td>
</tr>
<tr>
<td>CRPA</td>
<td>Controlled Reception Pattern Antennas.</td>
</tr>
<tr>
<td>DOP</td>
<td>Dilution of Precision.</td>
</tr>
<tr>
<td>DR</td>
<td>Dead Reckoning.</td>
</tr>
<tr>
<td>EDAS</td>
<td>EGNOS Data Access System/Service.</td>
</tr>
<tr>
<td>EGNOS</td>
<td>European Geostationary Navigation Overlay Service.</td>
</tr>
<tr>
<td>eLORAN</td>
<td>Enhanced LORAN (LOng RAnge Navigation).</td>
</tr>
<tr>
<td>EMC</td>
<td>Electromagnetic Compatibility.</td>
</tr>
<tr>
<td>EMI</td>
<td>Electromagnetic Interference.</td>
</tr>
<tr>
<td>EMU</td>
<td>Electric Multiple Unit.</td>
</tr>
<tr>
<td>ERTMS</td>
<td>European Rail Traffic Management System.</td>
</tr>
<tr>
<td>FOC</td>
<td>Freight Operating Company.</td>
</tr>
<tr>
<td>GLONASS</td>
<td>GLObal NAvigation Satellite System.</td>
</tr>
<tr>
<td>GNSS</td>
<td>Global Navigation Satellite System.</td>
</tr>
<tr>
<td>GPRS</td>
<td>General Packet Radio Service.</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System.</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile communications.</td>
</tr>
<tr>
<td>ID</td>
<td>Identification.</td>
</tr>
<tr>
<td>IMU</td>
<td>Inertial Measurement Unit.</td>
</tr>
<tr>
<td>I/O</td>
<td>Input / Output.</td>
</tr>
<tr>
<td>IP</td>
<td>Ingress Protection.</td>
</tr>
<tr>
<td>LPP</td>
<td>LTE Positioning Protocol.</td>
</tr>
<tr>
<td>LRK</td>
<td>Long Range Kinematic.</td>
</tr>
</tbody>
</table>
**Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications**

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<tr>
<th>Abbreviation</th>
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<tbody>
<tr>
<td>LTE</td>
<td>Long-Term Evolution.</td>
</tr>
<tr>
<td>MCB</td>
<td>Miniature Circuit Breaker.</td>
</tr>
<tr>
<td>MCG</td>
<td>Mobile Communications Gateway.</td>
</tr>
<tr>
<td>NMEA</td>
<td>National Marine Electronics Association.</td>
</tr>
<tr>
<td>OMA</td>
<td>Open Mobile Alliance.</td>
</tr>
<tr>
<td>OTMR</td>
<td>On Train Monitoring Recorder.</td>
</tr>
<tr>
<td>PCMCIA</td>
<td>Personal Computer Memory Card International Association.</td>
</tr>
<tr>
<td>PIS</td>
<td>Passenger Information System.</td>
</tr>
<tr>
<td>PND</td>
<td>Personal Navigation Device.</td>
</tr>
<tr>
<td>PPS</td>
<td>Pulse Per Second.</td>
</tr>
<tr>
<td>PVT</td>
<td>Position, Speed and Time.</td>
</tr>
<tr>
<td>RAIM</td>
<td>Receiver Autonomous Integrity Monitoring.</td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency.</td>
</tr>
<tr>
<td>RFID</td>
<td>Radio-Frequency Identification.</td>
</tr>
<tr>
<td>ROSCO</td>
<td>Rolling Stock Company – own, lease and, in some cases, maintain rail vehicles.</td>
</tr>
<tr>
<td>RSSB</td>
<td>Rail Safety and Standards Board</td>
</tr>
<tr>
<td>RTK</td>
<td>Real Time Kinematic.</td>
</tr>
<tr>
<td>SBAS</td>
<td>Satellite, or Space, Based Augmentation Service.</td>
</tr>
<tr>
<td>SD</td>
<td>Secure Digital.</td>
</tr>
<tr>
<td>SDO</td>
<td>Selective Door Operation.</td>
</tr>
<tr>
<td>SIL</td>
<td>Safety Integrity Level.</td>
</tr>
<tr>
<td>SISNeT</td>
<td>Signal In Space over the Internet.</td>
</tr>
<tr>
<td>SPARK</td>
<td>Sharing Portal for Rail Knowledge.</td>
</tr>
<tr>
<td>SUPL</td>
<td>Secure User Plane Location.</td>
</tr>
<tr>
<td>TOC</td>
<td>Train Operating Company.</td>
</tr>
<tr>
<td>TTF</td>
<td>Time to Fix.</td>
</tr>
<tr>
<td>TTFF</td>
<td>Time to First Fix.</td>
</tr>
<tr>
<td>UPS</td>
<td>Uninterruptible Power Supply.</td>
</tr>
<tr>
<td>USB</td>
<td>Universal Serial Bus.</td>
</tr>
<tr>
<td>WSP</td>
<td>Wheel Slip Protection/Prevention.</td>
</tr>
<tr>
<td>WSS</td>
<td>Wheel Speed Sensor.</td>
</tr>
</tbody>
</table>
Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

References

The Catalogue of Railway Group Standards gives the current issue number and status of documents published by RSSB. This information is also available from www.rssb.co.uk/railway-group-standards.

RGSC 01 Railway Group Standards Code
RGSC 02 Standards Manual

Documents referenced in the text

Railway Group Standards
GE/RT8015 Electromagnetic Compatibility between Railway Infrastructure and Trains
GE/RT8270 Assessment of Compatibility of Rolling Stock and Infrastructure
GM/RT2100 Requirements for Rail Vehicle Structures
GM/RT2111 Rolling Stock Subsystem and Interfaces to AC Energy Subsystem
GM/RT2130 Vehicle Fire, Safety and Evacuation
GM/RT2132 On-board Energy Metering for Billing Purposes
GM/RT2149 Requirements for Defining and Maintaining the Size of Railway Vehicles
GM/RT2304 Equipotential Bonding of Rail Vehicles to Running Rail Potential
GM/RT2472 Requirements for Data Recorders on Trains

RSSB documents
GE/GN8573 Guidance on Gauging
GE/GN8577 Guidance on the Application of Selective Door Operating Systems
GE/GN8579 Guidance on Digital Wireless Technology for Train Operators
GK/GN0602 Guidance on Train Rooftop Antenna Positioning
Research Report T510 Obtaining data to assess the dependability of GNSS information and accuracy of odometry
Research Report T671 Communication and positioning system in the GB rail industry
Research Report T740 The analysis of GPS data from the railway network.
Research Reports T892 Research title: Data analysis for a cost-effective GPS-based locator with simple augmentations. Referenced research deliverables:
T892_D1.1: Position-Dependent Applications in the Rail Domain
T892_D1.2: Requirements analysis for locator technology in GB Railways
T892_D2: Locator Interface Specification
T892_D8: GPS Buyers' Guide
T892_D9: Data Analysis Report
Research Report T990 Research title: Development of a strategy on train positioning
## Guidance on the Use of On-Train Satellite Positioning Technology Based Locator for Railway Applications

### Other references

<table>
<thead>
<tr>
<th>Reference</th>
<th>Description</th>
</tr>
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<tbody>
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</tr>
<tr>
<td>BS EN 15380-4:2013</td>
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</tr>
<tr>
<td>BS EN 50121-3-1:2006</td>
<td>Railway applications. Electromagnetic compatibility. Rolling stock. Train and complete vehicle</td>
</tr>
<tr>
<td>BS EN 50153:2014</td>
<td>Railway applications. Rolling Stock. Protective provisions relating to electrical hazards</td>
</tr>
<tr>
<td>BS EN 50155:2007</td>
<td>Railway applications – Electronic equipment used on rolling stock</td>
</tr>
<tr>
<td>BS EN 60077-1:2002</td>
<td>Railway applications — Electric equipment for rolling stock. General service conditions and general rules</td>
</tr>
<tr>
<td>BS EN 60529:1992+A2:2013</td>
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</tr>
<tr>
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</tr>
<tr>
<td>OM-20000094</td>
<td>OEMV Family of Receivers – Firmware Reference Manual (Novatel)</td>
</tr>
</tbody>
</table>