## Title:
Galileo Support to ERIS Services

### Signatures and approvals on original

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<tr>
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<td>A. Ridings</td>
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</tr>
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<td>CHECKED by</td>
<td>S. Bouchired/M. Loesch</td>
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<tr>
<td>CONFIGURATION CONTROL</td>
<td>E. Canalis</td>
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</tr>
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<td>PROJECT CONTROL</td>
<td>P. Mueller-Remmers</td>
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<tr>
<td>SYSTEM ENGINEERING MANAGER</td>
<td>M. Marinelli</td>
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<td>H. DeGaujac</td>
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<td>- Addition of security and operations sections</td>
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<td></td>
<td>- Re-introduction of coding of ERIS direct uplink Message Subframe</td>
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<td>- Minor Clarification regarding the creation of ERIS direct data when the s/c is unconnected to GMS.</td>
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<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>ERIS</td>
<td>External Regional Integrity System</td>
</tr>
<tr>
<td>NSGU</td>
<td>Navigation Signal Generation Unit</td>
</tr>
<tr>
<td>TC</td>
<td>Telecommand</td>
</tr>
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<td>TM</td>
<td>Telemetry</td>
</tr>
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<td>GMS</td>
<td>Ground Mission System</td>
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<td>GCS</td>
<td>Ground Control System</td>
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**Table 1: List of Acronyms**
1 INTRODUCTION

1.1 SCOPE

This document defines the baseline ERIS concept, from data throughput, to dissemination to constellation and planning concepts. In addition, there is also an annex included which discusses and analyses possible improvements for the ERIS service beyond the current baseline.

This document outlines the system level understanding of the support to ERIS service that Galileo can provide, within the following topics:

- Requirements Analysis of ERIS service
- Baseline Implementation for ERIS
  - Functional Architecture
  - ERIS Data Dissemination
- ERIS Performance
  - Delivery of ERIS messages through Galileo
  - Delivery of indirect ERIS data
  - Availability
- Security Issues related to ERIS interface to Galileo Core System
2 DOCUMENTS

2.1 APPLICABLE DOCUMENTS

<table>
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<th>Title</th>
<th>Document No.</th>
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<td>AD1</td>
<td>Galileo System Requirements Document (GSRD)</td>
<td>ESA-APPNS-REQ-00011</td>
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<tr>
<td>AD.2</td>
<td>Galileo System Baseline Design Definition File Part 1</td>
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Table 2 List of Applicable documents

2.2 REFERENCE DOCUMENTS

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<td>GAL-ICD-GLI-SYST-A/0725</td>
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Table 3 List of Reference documents
3 REQUIREMENTS ANALYSIS OF ERIS SERVICE

The current Galileo System requirements document [AD-1] were reviewed to understand the ERIS needs more clearly. The following section highlights the main requirements related to ERIS, which are placed on Galileo Industries and summarises the restrictions placed by these requirements.

3.1 ERIS GSRD DISSEMINATION REQUIREMENTS

GSRD v4.2 [AD.1] has various references to ERIS as detailed below, with the important points in bold:

GSRD-96 System Description:

‘The Galileo Global Component will be able to provide dissemination by Galileo satellites of integrity data generated by External Region Integrity Systems. Currently, it is foreseen that such data may be up-linked to the satellites either by the Galileo Ground Segment or by the External Region systems, as may be requested by the External Region operator.’

GSRD-229: (5.1.6.1) Support to External Region Integrity Services:

The Galileo Global Component shall enable the provision of dissemination by selected Galileo satellites of Integrity Data generated by independent, External Region regional integrity services, with negotiable performance.

GSRD-231 (5.1.6.2) Integrity Up-linking

The Galileo Global Component shall enable the provision of up-linking services for the independent, External Region regional integrity services specified in Req. GSRD-229, with negotiable performance.

GSRD-233 (5.1.6.3) Direct Uplinking

The Galileo Global Component shall enable to External Regions direct access to the Galileo satellites for integrity dissemination.

GSRD-625 (5.2.7.1.1) Number of Regions (ERIS: Integrity Dissemination)

The Galileo Global Component shall be able to disseminate External Region Integrity messages to up to five regions simultaneously.

GSRD-627 (5.2.7.1.2) Number of Satellites (ERIS: Integrity Dissemination)
The Galileo Global Component shall be able to disseminate Integrity messages from External regions from at least two satellites at all times for each External region service.

GSRD-631 (5.2.7.2) Access to Integrity Dissemination

The Galileo Global Component shall offer the possibility to External regions to access the integrity dissemination capability (as specified in Req. GSRD-625, Req. GSRD-627 and Req. GSRD-629) both via direct up-link to the satellites and via an adequate interface with the Galileo ground segment.

GSRD-2552 (5.2.7.3.1) Delivery Time (Performance – Direct Uplink)

2250ms

GSRD-2554 (5.2.7.3.2) Availability (Performance – Direct Uplink)

0.995

GSRD-2555 (5.2.7.4.1) Delivery Time (Performance – Uplink via Galileo Ground Segment)

3100ms

GSRD-1760 (7.6.4) Mission Up-link Multiple Access

All Galileo satellites shall use spread-spectrum code-division multiple-access providing six simultaneous channels for Mission Up-Link signals.

GSRD-3158 (12.3.1) ERIS with Direct Uplink (ERIS Interfaces)

The Galileo Global Component shall provide the interfaces to the External Region Integrity Systems with direct up-links as specified in the requirements of AD-33 and the detailed specifications of AD-23. (AD-33 SSExtIRD, AD-23 ERIS-SS ICD)

GSRD-3159 (12.3.2) ERIS with Uplink via Galileo Ground Segment (ERIS Interfaces)

The Galileo Global Component shall provide the interfaces to External Region Integrity Systems indirect up-links via the Galileo Ground Segment as specified in the requirements of AD-33 and the detailed specifications of AD-23.
3.2 GAIN UNDERSTANDING OF GSRD REQUIREMENTS

- The ERIS service specified to GaIn in GSRD is a dissemination service of “integrity messages” to the users via “2 satellites” with a “negotiable performance” using direct or indirect uplink. GaIn interpretation is:
  - The content of the ERIS integrity message is not under GaIn control, and therefore the ERIS integrity concept is not under GaIn responsibility.
  - Considering that GaIn has to provide dissemination of an integrity service, GaIn must ensure that Galileo offers availability for this dissemination (GSRD-2554) and certain performance of transmission delay (GSRD-2555). Note that no continuity requirement for the ERIS dissemination service is specified in GSRD.
  - The “negotiable performance” is understood as affecting the guaranteed data rate (bandwidth) for each ERIS enabling to meet the GSRD specified time of delivery and availability within the capabilities of Galileo. As no clear specification is made in GSRD, GaIn is only responsible for providing a level of data-rate to 5 regions which meets the specified GSRD ERIS performance requirements.

- The dissemination of ERIS shall be guaranteed for up to 5 regions simultaneously:
  - This is assumed that each ERIS region either directly or indirectly uplinks data (not both), conversely the total number of regions is no more than 5.
  - The GSRD requests 6 uplink channels per satellite (GSRD-1760) of which 5 can be allocated to ERIS, if for example all 5 regions were uplinked directly (i.e. no indirect ERIS uplinks via Galileo).
  - The downlink is the driver to the available space for ERIS as there is limited available space compared to the uplink.
  - No assumption is made on the nature of the possible 5 ERIS (direct or indirect).

- Delivery Time and Availability
  - With the baseline defined in section 4 the delivery time and availability is detailed in section 4.4
  - Availability requirements are dependent on and improved with the GMS Uplink scheduling philosophy which considers contact to at least 3 satellites for each user and 2 satellites in case of satellite failure.
  - The requirements do not clearly state the start and end points for the delivery time, so these have been assumed. A rough analysis of these requirements alongside the TTA requirements for Safety of Life Integrity has been carried out. See section 4.4.1
4 CURRENT BASELINE IMPLEMENTATION

The currently specified baseline is summarized in this section. The Galileo support to ERIS can be split into two scenarios: An indirect scenario and a direct scenario. ERIS can disseminate its integrity data directly via its own ground systems or via GMS using the Galileo Uplink to the satellite.

4.1 FUNCTIONAL LEVEL

The current system baseline dissemination scheme for ERIS is summarized in the figures below. Further details can be found in [AD.2], [AD.3], & [AD.4]

Figure 1: System Baseline Functions for Indirect ERIS Scenario
It relies on two main functions:

- **GMS - Dissemination scheduling (GMSF3):**
  
  - This function performs the selection of the integrity and navigation messages to be uplinked, and also schedules and performs the uplinking of the multiplex of:
    - the selected navigation data,
    - the SAR, CS and ERIS integrity data received by the GCC,
    - the PRS data and
    - the selected integrity data.
  
  Integrity and Navigation dissemination is automated in routine operation. The function also handles ULS tracking of the constellation.

- **SS – Uplinked messages multiplexing (SSF3):**
  
  - This function is in charge of accommodating the ERIS messages received through the Galileo C-Band mission up-link and/or the ERIS direct up-links.
Notes:

- The current approach assumes that the direct ERIS regions follow the direct uplink schedule issued by GMS to ERIS.

### 4.2 DATA DISSEMINATION OF ERIS DATA IN CURRENT IMPLEMENTATION

The current implementation of ERIS in the Galileo system allows for all ERIS regions (up to 5) to disseminate their data through all Galileo satellites. As the satellite does not have the function to stop ERIS data automatically and to ensure no overlapping/overwriting of data, the available downlink in the L-Band is split between the 5 ERIS regions in a fixed pattern (keeping a reserved area for SAR to ensure it’s 600bits/min requirement). Therefore, the following capacity is achieved for ERIS data:

In I/NAV channel dual page:

E5b & L1 alternatively:

**ERIS Data Rate (per region) = 8 bits/second = 240bits per 30second sub-frame.**

At present as there is no indication of a possible required data-rate from a particular region, it is assumed that each region requires the same data-rate. Therefore, for each region there is 8 bits every second available on the I/NAV nominal and alert pages.

This value is a guaranteed data-rate for each region whether there are Galileo alerts present or not as it is a fixed allocation.

#### 4.2.1 ERIS Uplinks to Galileo Satellites

For both indirect and direct the ERIS Region Identify is therefore coded on 3bits and the regions are allocated as shown below:

<table>
<thead>
<tr>
<th>Value</th>
<th>Meaning</th>
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<tbody>
<tr>
<td>000</td>
<td>ERIS Region 1 ID</td>
</tr>
<tr>
<td>001</td>
<td>ERIS Region 2 ID</td>
</tr>
<tr>
<td>010</td>
<td>ERIS Region 3 ID</td>
</tr>
<tr>
<td>011</td>
<td>ERIS Region 4 ID</td>
</tr>
<tr>
<td>100</td>
<td>ERIS Region 5 ID</td>
</tr>
<tr>
<td>101</td>
<td>Not Used</td>
</tr>
<tr>
<td>110</td>
<td>Not Used</td>
</tr>
<tr>
<td>111</td>
<td>Not Used</td>
</tr>
</tbody>
</table>

*Figure 3: ERIS Region ID*
4.2.1.1 Direct Uplink from ERIS ULS

Each ERIS region can uplink their own data directly from their own uplink stations. The frame and subframe format shown below is to allow a level of consistency between the Galileo uplinks and the ERIS uplinks. The ERIS uplink is half data rate to that of Galileo and therefore the 1 second frame is half the length. Further details on the RF characteristics of this link can be found in the ERIS-SS ICD.[RD.2].

This assumes all regions have the same data rate.

<table>
<thead>
<tr>
<th>Scrambled Integrity sub-frame</th>
<th>Scrambled Message sub-frame</th>
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<tr>
<td>264 bits</td>
<td>1784 bits</td>
</tr>
<tr>
<td></td>
<td>2048 bits</td>
</tr>
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</table>

After Reed Solomon Coding and adding the synchronization word, and Idle sequence it is obtained:

<table>
<thead>
<tr>
<th>Synchronisation Word</th>
<th>Integrity Sub-frame</th>
<th>Message Sub-Frame</th>
<th>IDLE</th>
</tr>
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<tr>
<td>32</td>
<td>320</td>
<td>2040</td>
<td>21</td>
</tr>
</tbody>
</table>

2413 bits

Figure 4: ERIS Direct Uplink Frame

There are current DCNs existing which will change the above figure. (GAL-DCN-GLI-SYST-A/1719 & 1720) to the figure below, due to possible problems with false lock at the mission receiver. These DCN’s are still to be approved and are not currently baseline but are included here for completeness. This will also mean that the synchronisation word will be unique for each ERIS region and therefore the proposed synchronisation words are also listed below.

<table>
<thead>
<tr>
<th>Synchronisation Word</th>
<th>Integrity Sub-frame</th>
<th>Message Sub-Frame</th>
<th>IDLE</th>
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</thead>
<tbody>
<tr>
<td>48</td>
<td>320</td>
<td>2040</td>
<td>5</td>
</tr>
</tbody>
</table>

2413 bits
Figure 5: ERIS Direct Uplink Frame and SW definition (in case of approval of DCN’s 1719 & 1720)

<table>
<thead>
<tr>
<th>Region #</th>
<th>Satellite Receiver Channel</th>
<th>Synchronisation Word (hex)</th>
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<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>‘D5F8218A7A39’</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>‘C25563A99E63’</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>‘2B6BCB00ED0F’</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>‘0CBEDE2E809B’</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>‘7C8B4D2905EB’</td>
</tr>
</tbody>
</table>

Figure 6: ERIS Direct Integrity Sub-frame

There are current DCNs existing which will change the above figure. (GAL-DCN-GLI-SYST-A/1717 & 1718) to the figure below, due to possible problems when the satellite is in clear mode. This also brings the format in line with the current GMS uplink. These DCN’s are technically approved but still need to be formally approved and are therefore not currently baseline but are included here for completeness.

<table>
<thead>
<tr>
<th>Region ID</th>
<th>ERIS integrity data</th>
<th>Spare</th>
<th>Security Packet</th>
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<tr>
<td>3</td>
<td>8</td>
<td>53</td>
<td>200</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>264 bits</td>
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Figure 7: ERIS Direct Integrity Sub-frame (in case of approval of DCN1717 & 1718)

<table>
<thead>
<tr>
<th>Service Descriptor</th>
<th>Region ID</th>
<th>ERIS integrity data</th>
<th>Spare</th>
<th>Security Packet</th>
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<tbody>
<tr>
<td>2</td>
<td>3</td>
<td>8</td>
<td>51</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>264 bits</td>
</tr>
</tbody>
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4.2.1.2 Indirect Uplink via Galileo ULS

Each ERIS region can send its own data to Galileo Ground Station via the GMS-ERIS interface (as described in the GMS-ERIS ICD [RD-8]). GMS then includes the data
from all ERIS regions and inserts it in the Integrity sub-frame part of the main uplink frame as shown in the figure below ([RD.3] GMSSSICD-3373).

There will be 40 bits allocated in this subframe to ERIS data (40 is the maximum needed capacity in case all the 5 ERIS are indirect): A 40 bits field for ERIS data, split into 5 * 8 bits allowing 8bits per region, if a region does not send data to GMS, this field will be filled with spare bits.

<table>
<thead>
<tr>
<th>Service descriptor</th>
<th>Galileo Global Region Status</th>
<th>Integrity data for Galileo Global Region</th>
<th>ERIS integrity information</th>
<th>Spare</th>
<th>Security Packet</th>
</tr>
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<tbody>
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<td>2</td>
<td>8</td>
<td>150</td>
<td>40</td>
<td>120</td>
<td>200</td>
</tr>
</tbody>
</table>

528 bits

Figure 8: Galileo Integrity Subframe

4.2.2 Allocation for ERIS Data in Downlink

The ERIS data will be included in the I/NAV dual signal on E5b and L1 frequencies. ERIS will have a fixed field of 40 bits in each second available to be equally split between 5 regions (8 bits/region). This 40bits stays constant with or without Galileo alerts been present, ensuring that ERIS is not disrupted by Galileo alerts. Allowing a guaranteed datarate for each ERIS region, under all signal configurations.

Nominal I/NAV Page Layout ([RD.4] SISICD-2601):-

SECURITY CLASSIFICATION: UNCLASSIFIED
DATA PROTECTION LEVEL: COMPANY & PROJECT DATA

Template No.: GAL-TMP-GLI-SYST-I/0013 issue 4

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Figure 9: I/NAV Nominal Page Layout

I/NAV Alert Page Layout ([RD.4] SISICD-2603) :-

<table>
<thead>
<tr>
<th>Even/odd=0</th>
<th>Type</th>
<th>Data i (1/2)</th>
<th>Tail</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>112</td>
<td>6</td>
<td>120</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Even/odd=1</th>
<th>Type</th>
<th>Data i (2/2)</th>
<th>ERIS</th>
<th>Spare</th>
<th>CRC i</th>
<th>Region Status</th>
<th>Tail</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>38</td>
<td>40</td>
<td>2</td>
<td>24</td>
<td>8</td>
<td>6</td>
<td>120</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Even/odd=0</th>
<th>Type</th>
<th>Data j (1/2)</th>
<th>Tail</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>112</td>
<td>6</td>
<td>120</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Even/odd=1</th>
<th>Type</th>
<th>Data j (2/2)</th>
<th>ERIS</th>
<th>Spare</th>
<th>CRC i</th>
<th>Region Status</th>
<th>Tail</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>38</td>
<td>40</td>
<td>2</td>
<td>24</td>
<td>8</td>
<td>6</td>
<td>120</td>
</tr>
</tbody>
</table>

Figure 10: I/NAV Alert Page Layout

The ERIS bit structure (40bits) for the E5b and L1 channel shall be formatted according to the values stated in the following figure ([RD.4] SISICD-2149):

<table>
<thead>
<tr>
<th>ERIS Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERIS 1</td>
</tr>
<tr>
<td>8 bits</td>
</tr>
<tr>
<td>ERIS 2</td>
</tr>
<tr>
<td>8 bits</td>
</tr>
<tr>
<td>ERIS 3</td>
</tr>
<tr>
<td>8 bits</td>
</tr>
<tr>
<td>ERIS 4</td>
</tr>
<tr>
<td>8 bits</td>
</tr>
<tr>
<td>ERIS 5</td>
</tr>
<tr>
<td>8 bits</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 bits</td>
</tr>
</tbody>
</table>

Figure 11: ERIS Field bit Structure

Each region is designated a number (1-5) and uses the same position in the uplink and downlink as shown in the figure above. This allows the satellite to recognise the region in the indirect uplink.

4.2.3 End-to-End ERIS Data Dissemination

In order to achieve the scheme for ERIS data in the previous sections the following dissemination functions are considered.
4.2.3.1 Uplinking functions

4.2.3.1.1 Indirect scenario

- Each ERIS region shall send 8bits/second of Integrity Data to GMS for uplink at a defined time epoch synchronised with GST.
- The GMS shall multiplex the received regional data and create the Uplink Integrity Subframe as defined in section 4.2.1.2. If not all 5 regions send data at a certain epoch the GMS shall fill the spare ERIS fields will a sequence of 0’s [0000 0000]… This sequence shall be identified by the ERIS user as ‘Satellite not broadcasting data for ERIS region’.
- GMS sends status information to ERIS

4.2.3.1.2 Direct Scenario

- The GMS shall send the Direct Uplink Contact Plan to ERIS
- ERIS shall send 8 bits/sec to the allocated Galileo satellites as defined in the Direct Uplink Contact plan and with the format defined in section 4.2.1.1.

4.2.3.2 Handling of ERIS data On-board

![Diagram of ERIS Data Input and Output to Satellite]

Figure 12: ERIS Data Input and Output to Satellite

The satellite receives up to 5 different uplinks from ERIS ULS’, and the Galileo C-Band uplink including indirect ERIS data when ‘connected’. The satellite is required to
multiplex this data and put it into the ERIS bit field on the downlink as described in earlier sections.

The satellite (NSGU) does this in the following way and as depicted in the figure below:

- **If valid direct ERIS data** (8 bits per channel) has been received via the C-band up-link the NSGU shall add this data to the appropriate position in the 40 bit page field.

- **In the absence of direct ERIS data** for any channel the NSGU shall add the **indirect** ERIS data from the Galileo integrity packet to the appropriate position in the 40 bit page field.

- **In the absence of both direct and indirect data** for any ERIS region the NSGU shall insert 8 zero bits in the appropriate position in the 40 bit page field.

![Figure 13: Example of satellite ERIS data multiplexing](image)
4.3 PLANNING ASPECTS

To allow each ERIS region to know which satellites they can directly uplink to and within what time a planning process is considered. An agreement is to be made with ERIS to ensure that they strictly follow these plans at the start of their service. In case of security breaches the authentication keys can be changed on board to block a region or potential attacker if required.

GMS devises the uplink contact plan by selecting satellites visible to each region to use for a given time period and ensuring that all users in the region receive ERIS data from at least 3 satellites (2 in case of satellite failure).

4.3.1 Planning Process

There are two types of plans GMS create which consider the ERIS data transmission:

- Direct Uplink Plan – distributed to ERIS
- Indirect Uplink Plan – internal to GMS

1) ERIS Direct Uplink Contact Plan [SCH_ErisDirectUplkContactPlan] :

This plan is sent to ERIS regions to tell them which satellites are available for them to disseminate information to their users for Direct Uplink.

The Sch_ErisDirectUplkContactPlan is the contact plan to allow regions to disseminate regional integrity data from their own Uplink Stations through direct uplink to Galileo satellites. This plan defines time periods of connection for an external regions to visible satellites. The parameters within this interface should include the following:

a) Contact plan Identifier
b) Schedule period of plan (nominal 10 days)
c) For each ERIS region
d) For each satellite that can be used to disseminate data on at least one ERIS region and accessed by at least one ERIS direct antenna:

 e) Satellite ID
 f) Start and end of contact times

This plan is sent in XML format.

2) Indirect ERIS Uplink Plan

The GMS carries out it’s uplink scheduling for all satellites in the constellation to ensure that the integrity conditions are met.
This is part of overall uplink schedule planning that is carried out for Galileo Integrity within the GMS. With every uplink of Galileo Integrity there is an ERIS field uplinked whether it contains ERIS data or ERIS spare data.

4.3.2 Satellite Functionality for ERIS control

The ERIS service is an external service supported by Galileo and not under the control of Galileo, with direct access to the satellite. Therefore, as with the support to SAR service, Galileo shall be able to interrupt this service if necessary (SDSD-13269). The GMS ensures that the SAR and ERIS data can be interrupted in the indirect uplink when data goes via the GMS (GMSREQ-10805). For direct uplink there are 3 ways in which ERIS data can be interrupted and not downlinked:

1. The C-Band Authentication ensures that only authorised ERIS can access the satellite. The authentication keys can be changed within the PLSU to stop the ERIS region uplink data being accepted by the satellite.
2. The Mission receiver channel allocated to the ERIS region can be switched off via telecommand.
3. The NSGU can reject the regions data and not include it in the downlink, instead adding ERIS spare data, this is done by the use of a telecommand initiated by Galileo operations.
These functions are considered to be used in special cases for contingency planning, as ERIS region are expected to strictly follow the contact plans given. The satellite is also protected against other sources of uplink due to its security protections on-board. Therefore, the satellite can interrupt the ERIS service through normal security functions.

### 4.3.3 Replanning in case of Satellite Failure

In GMS Ext IRD [RD.10] requirement GMSEIFREQ-539 considers the re-issue of the Direct-Uplink Contact Plan in case of satellite failure. Currently the requirement states that this plan should be reissued in less than 10minutes. It has been agreed that 10minutes is not necessary and also too constraining on the GMS design.

This requirement has been reworded removing the time constraint for replanning (GAL-DCN-GLI-SYST-A/0418 iss3.1). To justify this removal the GMS are required to consider their planning with at least 3 satellites in view to all region users. The nominal requirement as stated in GMSREQ (GMSREQ-11534) states that 2 satellites shall be available for ERIS dissemination per regional user. Therefore, with 3 satellites per regional user this is robust to single satellite failures, and therefore it is adequate to reissue the plan as normal (daily) and wait for the satellite to either disappear out of the region area, or be replaced, or brought back on line.

The direct uplink contact plan is sent to ERIS every day and therefore, each new plan will consider any failures in the system and try to reallocate satellites to regions.

### 4.4 ERIS PERFORMANCE

#### 4.4.1 Delivery of ERIS messages through Galileo

##### 4.4.1.1 Delivery of indirect ERIS data

The table below shows the apportionment of the time through the Galileo GCC with regards to the flow of ERIS indirect data from ERIS through the GCC to the ULS, to the satellite and finally to the user input. These values are based on figures used to calculate the Global region Integrity data Time to Alert.

The table below shows that the system is compliant to the GSRD requirements GSRD-2555 requiring the Delivery of ERIS data through Galileo to be 3100ms.

It is assumed that the start point of this 3100ms is the delivery of the last ERIS data bit to the MNE-GCC. The end point is the delivery of the last bit of the ERIS data in the Galileo downlink to the user.
### Table 4: ERIS Indirect TTA allocation

<table>
<thead>
<tr>
<th>Duration (ms)</th>
<th>Total duration</th>
<th>Cumulative Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERIS data delivery</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>System Margin</td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td>MNE GCC (input=last bit of the ERIS message)</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>GCC RT LAN</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>MGF</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>GCC RT LAN</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>MKMF SM</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Spare 2</td>
<td>125</td>
<td></td>
</tr>
<tr>
<td>MDDN GCC-ULS</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>ULS (start cycle transmission at T0+3600ms):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latency time at ULS</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>ULS : Serialisation time (Uplink time-critical subframe duration)</td>
<td>133</td>
<td></td>
</tr>
<tr>
<td>Uplink transmission : Integrity uplink ULS to Satellite propagation delay</td>
<td>96</td>
<td>96</td>
</tr>
<tr>
<td>On-board processing and transmission time</td>
<td>152</td>
<td>152</td>
</tr>
<tr>
<td>Satellite clock drift</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Satellite latency time</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Message length: Serialisation time</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Downlink transmission: Integrity downlink propagation delay at 10° User receiver elevation angle</td>
<td>94</td>
<td>94</td>
</tr>
</tbody>
</table>

| | | | |
| | | | \(3094\) |

### 4.4.1.2 Delivery of direct ERIS data

The on-time delivery of ERIS data to the satellite from ERIS ULS’ is the responsibility of the ERIS ULS. To be on-time the ERIS ULS shall meet the following requirement from the SSextIRD (SSEIFREQ-254 & DCN: GAL-DCN-GLI-SYST-A/1076 iss4.3):

The Regional ULS up-linking shall start transmission of the first data bit of the ERIS Integrity Sub-Frame before GST one-second Time-mark minus \((400 – TB)\)ms, where TB is the time, in ms, corresponding to the number of bits, NB, which must be in the buffer for a given elevation at the start of tracking. TB is in the range 0<=TB<=19ms.

GSRD-2555 requires that Galileo delivers the ERIS direct data to the user within 2250ms. There is no definition of the start time of this time allocation and it is therefore assumed that the point at which Galileo receives the first ERIS data is the start point. Therefore, the chain of events assumed for compliance to the GSRD requirements is time from satellite input to satellite output, and downlink transmission (using same value as in table in last section).
Preliminary analysis using the value from the table above shows that Galileo can state compliance to this delivery time requirement with the above assumptions.

| On-board processing and transmission time | 152 ms |
| Satellite clock drift | 1 ms |
| Message Length | 1000 ms |
| Downlink Transmission | 94 ms |
| **Total (without margin)** | **1247 ms** |

**Table 5: ERIS Direct Delivery Time**

4.4.2 Availability
See [AD.5] for availability study of the ‘support to ERIS’ service.

4.5 ERIS SECURITY ISSUES

The ERIS systems are external to the Galileo Core system and are therefore not under the control of Galileo, and therefore the security issues have to be analysed in terms of protecting Galileo Core system.

There are two areas to consider in terms of protection:

The ERIS to satellite interface

As ERIS has direct access to the satellites, ERIS must ensure the same solution for authentication as that used for the GMS to satellite link is considered.

The ERIS to GMS ground interface

The GMS receives real time and non-real time information from ERIS. Both of these dataflows are required to go through a protected network as described in the GMS-ERIS ICD [RD-8]. This is the same for all external interfaces connecting with the GMS.
5 ADVANTAGES OF BASELINE IMPLEMENTATION
The baseline implementation above allows for following benefits:

- Maximum use of available downlink to useful data.
  - Only with a fixed allocation for all 5 regions can the whole available ERIS field for ERIS data be used, with a reduction in number of regions or any type of dynamic allocation identifiers would be required to tell the user when his data was present and where in the field he should look.

- Guaranteed service to all regions, including possibility to achieve Galileo Integrity type TTA levels.
  - The baseline design allows a guaranteed service independent of the Galileo Integrity status.
  - Within the constraints of the available bits/sec/region an ERIS integrity alert can meet the Galileo Global Integrity TTA for the ERIS alert.

- Independent of region definition
  - As the regions for ERIS are still to be defined it is difficult to make assumptions on what the regions may look like. Although ESA have defined possible regions sizes for analysis, there are currently no defined co-ordinates for regions or regional ULS’ positions.
  - The regions size defines the number of regions any one satellite may ‘see’ at any one time, and therefore the contact scheduling to be carried out by GMS. Any change to the assumed regions size will have a large impact on these areas, and makes it very difficult to carry out dissemination analysis for all scenarios.

- Minimisation of complexity on board
  - Enabling the ERIS data to flow transparently through the satellite payload as with Galileo Integrity alerts ensures no further complexity is added to the on-board functions.
  - There is no requirement to store ERIS data on-board and therefore, less management of the data on board.

- Minimisation of complexity on-ground
  - 240bits/downlink subframe every 30seconds for all regions
    - As shown in the next section this dataflow is a useful level for a possible integrity service.
    - This dataflow is guaranteed in nominal operations and therefore ERIS can plan its uplinking knowing this is their allocated dataflow which will
not be interrupted or disregarded by the satellite, assuming they keep to their Direct Uplink Contact Plan.

- Increased safety between regions with minimum effort.
  - Allocating a fixed section of the downlink to each region ensures that other regions cannot override a regions data.

5.1 POSSIBLE LEVEL OF SERVICE TO ERIS WITH BASELINE

ERIS Regions are expected to define their own integrity service to fit within the baseline defined in the section above. To allow an assessment to be made to illustrate the possible levels of service that could be provided it has been requested to compare against Galileo type integrity. This is possibly not the best solution for ERIS and an assessment of their needs would be required to be carried out to understand the level of performance required by each region.

Galileo Safety of Life (SoL) Integrity is defined in Integrity Tables, which are transmitted over an I/NAV subframe of 30seconds, and Integrity Alerts, which are transmitted within a time-to-alert of 6seconds for Safety of Life Integrity.

Galileo Integrity data has to consider all satellites in a constellation up to 36 which is unlikely to be the case for ERIS as ERIS regions only cover a portion of the earth with only a subset of satellites in view at any one time. Nevertheless, the following shows the level of performances that could be produced for ERIS according to the limitations in the bandwidth.

Integrity Tables:

A Galileo Integrity tables consists of 252bits for the Table (and 11bits for other overheads (Authentication size depends on the chosen method)), as shown below. This covers 36satellites as a requirement on Galileo System to allow for future expansion.

<table>
<thead>
<tr>
<th>SV1</th>
<th>SV2</th>
<th>SV3</th>
<th>...</th>
<th>SVN</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNF</td>
<td>IF</td>
<td>SNF</td>
<td>IF</td>
<td>SNF</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

ERIS could for example consider only the operating constellation of 30 satellites and meet the same 30seconds per integrity table as for Galileo ((3+4)*30 +11 = 221bits) (excluding full Authentication).

Therefore, **each region could uplink a reduced integrity table exactly the same as the Galileo Integrity Table**, with the same definition of SISMA (SNF/IF), and with a reduced number of satellites (still considering all expected operational satellites) and a reduced Authentication **within 30 seconds**.

Nb. This level of SISMA (IF) is most likely not necessary for ERIS.
Integrity Alerts:

Galileo Integrity Alerts flags are coded on 4 bits per satellite ([RD.4] SISICD-2271 for the satellite new SISMA value to be transmitted Galileo has to get this alert to the user within 6 seconds of receiving the information on the satellite failure. This is called their Time to Alert (TTA).

If ERIS considered an alert to be 4 bits in length it seems feasible to meet a TTA of 6 seconds for 2 satellites due to the way the satellite treats the ERIS data, and a TTA of (30/2+6) 21 seconds for the whole constellation (30 satellites)

Alternatively, considering Integrity Alerts of 1 bit instead of 4 bits (ie a NOK/OK flag) and to allow the ERIS to send an alert for 30 satellites, the alert would be 33 bits in length (3 bits for Clever Word and 1 bit per satellite for Integrity (NOK/OK) flag). This alert would therefore be transmitted over 5 seconds. This would potentially allow for a TTA of 11 seconds.

For 27 satellites (number of main operational satellites), the alert would be transmitted over 4 seconds. Potentially allowing for a TTA of 10 seconds.

The above analysis does not take into account any possible start bits that may be needed to be included to allow the user to know when the start of the message occurs due to splitting of the message.
6 ANNEX A: ANALYSIS OF POSSIBLE IMPROVEMENTS TO THE ERIS SERVICE

Note: The Galileo Core System baseline for ERIS service is described in the main sections 4 and 5 of this document. This section shows work carried out to look at further enhancements to ERIS and is in no way intended to be considered as part of the Galileo IOV baseline.

This section considers the following studied improvements:

- Optimization of the up-link scheduling algorithm in order to maximize the available capacity per ERIS and the improvements on bandwidth achievable
- Closer control on-board the satellite of the up-link schedule implementation.

The following section describes study work carried out in order to assess the feasibility to reduce the number of ERIS regions using each satellite and improvements which would be required on the on-board control.

This optimization analysis is a study only and is not currently considered as part of the contractual work and technical baseline of the Galileo Core system.

6.1 OPTIMISATION OF THE UPLINK SCHEDULING ALGORITHM

This optimisation study covers the following aspects:

- The assumptions taken to carry out the optimisation study
- The results of the study considering constellation geometry and region geography allowing for the reduction in the number of regions using each satellite in the constellation to be analysed
- The resulting increased bandwidth per region

6.1.1 Assumptions Considered for ERIS Optimisation

To allow a proper analysis of the possible level of service Galileo could provide to ERIS certain assumptions on the ERIS systems have to be made. The following assumptions have been agreed by ESA to be used to understand the limitations and possibilities of optimizing the support to ERIS.

1. Region Size and location

- Currently assumed to be 5 large regions covering the 5 main continents.
  - R1: Africa
  - R2: Asia
  - R3: Oceania
  - R4: North America
  - R5: South America
2. Number of indirect/direct uplink
   - 3 kinds of scenarios envisaged: 5 indirect/0 direct; 0 indirect/5 direct; 3 indirect/2 direct

3. An ERIS region can only directly or indirectly disseminate data, and not both.

4. Position of direct uplink ULS
   - 2 per region with at least two operational antennas and 1 for handover. Location: Approximately centre of the regions.
   - The following existing stations have been assumed for the ERIS direct ULS as shown in the figures following. These were picked purely due to their geographical position; their technical/political status was not checked for this analysis.

<table>
<thead>
<tr>
<th>Region</th>
<th>Name</th>
<th>Latitude (deg)</th>
<th>Longitude (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Africa</td>
<td>Arlit</td>
<td>18.78</td>
<td>7.37</td>
</tr>
<tr>
<td></td>
<td>Malindi</td>
<td>-3</td>
<td>40.19</td>
</tr>
<tr>
<td>2 Asia</td>
<td>Arti</td>
<td>56.43</td>
<td>58.56</td>
</tr>
<tr>
<td></td>
<td>Yaku</td>
<td>62.03</td>
<td>129.68</td>
</tr>
<tr>
<td>3 North America</td>
<td>Atlanta</td>
<td>33.93</td>
<td>-84.11</td>
</tr>
<tr>
<td></td>
<td>Whitehorse</td>
<td>60.75</td>
<td>-135.22</td>
</tr>
<tr>
<td>4 Oceania</td>
<td>Manilla</td>
<td>14.64</td>
<td>121.08</td>
</tr>
<tr>
<td></td>
<td>Perth</td>
<td>-31.8</td>
<td>115.89</td>
</tr>
<tr>
<td>5 South America</td>
<td>Bogota</td>
<td>4.64</td>
<td>-74.08</td>
</tr>
<tr>
<td></td>
<td>La Plata</td>
<td>-34.91</td>
<td>-57.93</td>
</tr>
</tbody>
</table>

Table 6: Chosen Ground Stations for ERIS Direct Uplink
Figure 15: Region 1: Africa assumed Direct ERIS-UlS Locations

Figure 16: Region 2: Asia assumed Direct ERIS-UlS Locations
Figure 17: Region 3:- Oceania assumed Direct ERIS ULS locations

Figure 18: Region 4:- North America assumed Direct ERIS ULS locations
Figure 19: Region 5:- South America assumed Direct ERIS- ULS Locations

5. Data rate (R) constant over time and same for all ERIS
   - note: the fact that some ERIS could request data rates different from the others is discarded for simplification purpose

6. Masking angles
   - Masking Angle to be considered are 10deg and 5 deg* for Galileo ULS and ERIS ULS and 10deg for User
   - This is for ERIS ULS for direct uplink and Galileo ULS for indirect uplink
   - It has been agreed that for the ULS’s (ERIS and Galileo) both 5deg and 10deg masking angles will be considered in the framework of the analysis.

(*) Acquisition of satellites is performed at 5deg, although Galileo performance is only guaranteed at 10deg.)
6.1.2 Optimisation of ERIS regional bandwidth
This section looks at the uplinking algorithms and how they can be optimised to reduce the number of ERIS regions using each satellite, with the assumptions laid out in the last section. The direct uplink and indirect uplink are looked at separately.

6.1.2.1 Assumptions

GMS-REQ 11534: External integrity dissemination
The GMS shall ensure that for each external region at least two satellites are connected in order to disseminate integrity messages to users belonging to that region.

Unlike the global system, GMSREQ does not specifically require:
- that the 2 integrity paths shall be independent
- that the 2 links shall be provided even if a single satellite failure, antenna failure or ULS failure occurs.

As a first approach, it is assumed that the integrity constraints defined for the global system are also applicable to ERIS.

6.1.2.1.1 DIRECT UPLINK
In case of direct uplink, the ERIS regions are using their own sites, the GMS ULS and antenna failures are therefore irrelevant.

The integrity constraint can therefore be reduced to:
“A minimum of 2 connected satellites shall be ensured for any user of each region, including in case of a single satellite failure”

This means that in nominal conditions, a minimum of 3 connected satellites must be ensured for any user of each region.

Note: as it is assumed for this analysis that the regions have only 2 sites each, it is obvious that the regions are not robust to a site failure. (not under Galileo system responsibility). The individual ERIS regions must consider contingency planning/redundancy in case of site failure.

6.1.2.1.2 INDIRECT UPLINK
In case of indirect uplink, the ERIS regions use the Galileo uplink stations.

The allocation must ensure a minimum of 2 connected satellites for any user of each region, including in case of a single satellite, antenna or ULS failure.
This means that in nominal conditions, a **minimum of 3 independent connected satellites** must be ensured for any user of each region. In case of indirect uplink, we have the additional constraint that these 3 minimum links must be from 3 different ULS in order to be robust to a ULS failure.

### 6.1.2.2 Direct Uplink Simulation results (preliminary):

In case of direct uplink, a satellite can only be allocated to a region if seen by at least one of its uplink stations.

It has been established that with the current scenario, most satellites are seen by two different regions and that a given satellite can be seen by a maximum of 4 different regions.

On average, the visibility of the satellites is as follows:

- Number of satellites seen by no regions: 0
- Number of satellites seen by 1 region: 4
- Number of satellites seen by 2 regions: 16
- Number of satellites seen by 3 regions: 5
- Number of satellites seen by 4 regions: 2

It is also worth mentioning that given the size of each region, the satellites visible by one user can be totally different from the satellites seen by another user located at the other end of the region.

The optimisation strategy consists in allocating a given satellite to a maximum number of n regions (with n starting at 1) and checking the integrity constraint for each user of the 5 regions. If the integrity constraint is not fulfilled, n is incremented.

To decide which satellite to allocate to a region, the following simple algorithm was used as a first approach:

For x = 1 to 5
  
  Determine the list of satellites seen by x regions
  
  If n>=x
    Allocate the satellites to the x regions
  
  Else
    Allocate the satellites to the first n regions which have the lowest number of allocated satellites
  
End if
End for

### 6.1.2.2.1 Allocate up to 1 region per satellite

By restricting connection to 1 region for each satellite, a maximum of 5 satellites can be allocated to each region.
With the simple satellite to region allocation algorithm described in the previous section, a few users (especially on the border of the regions) are left with only one or no connected satellite.

By using a more optimised algorithm, it is actually possible to ensure a minimum of 1 link per user for any region.

**Conclusion: If we allow 1 ERIS per satellite, we can ensure a minimum of 1 link per user.**

### 6.1.2.2.2 Allocate up to 2 regions per satellite

By allowing 2 regions per satellite, a minimum of 9 satellites can be allocated to each region.

With the simple satellite to region allocation algorithm described in the previous section, quite a significant number of users (especially on the border of the regions) can only see one or two connected satellites.

With a more complex algorithm, it is actually possible to ensure a minimum of 2 links per user for any region.

**Conclusion: If we allow 2 ERIS per satellite, a minimum of 2 integrity links per user can be ensured. This allocation is not robust in the event of a satellite failure.**

### 6.1.2.2.3 Allocate up to 3 regions per satellite

By allowing 3 regions per satellite, it becomes possible to allocate 9, 10 or even 11 satellites per region.

**Note:** at certain epoch, we are limited by the fact that the regional stations can only see a maximum of 9 satellites.

Again, 3 links per user can be ensured most of the time, except for a few epochs where only 2 links can be ensured.

Whatever the algorithm used, it is not possible to ensure a minimum of 3 links per user of each region:
- it is possible to ensure a minimum of 3 links for any users belonging to South America, Asia or Oceania
- but it is not possible to ensure a minimum of 3 links for a few users of the African and North American regions.

This is due to the choice of location of the regional stations.

**SECURITY CLASSIFICATION:** UNCLASSIFIED  
**DATA PROTECTION LEVEL:** COMPANY & PROJECT DATA
Example 1: North America

Satellites visible by user (-20, -110) of region 3 (North America) at date 210 min:

3  4  5  23  24  25

Satellites visible by at least 1 of the 2 regional station of region 3 (North America) at the same date:

1  2  3  10  11  17  18  25  26  27

Example 2: Africa

Satellites visible by user (-50, -20) of region 1 (Africa) at date 858 min:

16  17  18  23  24  25

Satellites visible by at least 1 of the 2 regional stations of region 1 (Africa) at the same date:

3  4  5  6  10  11  18  25  26

Conclusion: It is possible to ensure of minimum of 3 links for any user in the regions Asia, Oceania and South America by allowing up to 3 regions per satellite. However, with the current choice of regional stations, it is impossible to ensure a minimum of 3 links for any user in the regions North America and Africa, whatever the number of regions per satellite.

6.1.2.2.4 Allocate up to 4 regions per satellite

Allowing 4 regions per satellite will not solve the visibility problem encountered in the previous section.

6.1.2.3 INDIRECT UPLINK Results (preliminary)

Preliminary Results:

- One given satellite can be seen by a maximum of 5 regions.

- Nb of satellites seen by all users of the region Africa : from 19 to 23
- Nb of satellites seen by all users of the region Asia : from 15 to 20
- Nb of satellites seen by all users of the region N. America : from 17 to 21
- Nb of satellites seen by all users of the region Oceania : from 19 to 22
- Nb of satellites seen by all users of the region S. America : from 18 to 23
6.1.3 Conclusions of Optimisation of Uplink Scheduling

The work carried out and described in this section shows that with intelligent Uplink Scheduling Algorithm a reduction in the number of regions per satellite could be achieved, considering the assumptions listed in section 6.1.1. The analysis shows that if ERIS is only directly uplinking 3 regions per satellite could be considered if a dynamic allocation of satellites was permitted. (Current baseline is a fixed allocation of bandwidth per region)

When assessing the level of optimisation of the previous section the following issues should be considered:

6.1.3.1 Region Size assumption:
The analysis is highly dependent on the region size. The region size considered in the analysis used large regions covering a large majority of the earth’s surface. Therefore, until further definition of the regions is established, the above analysis is heavily dependent on these assumptions. For example, if there were 5 small regions in a small area (e.g, 5 countries in south America) then it would be common for satellites over the south America region to receive all 5 region data.

6.1.3.2 Mix of Direct & Indirect

The analysis has not considered both direct and indirect in the same scenario. It has been shown that it is possible that only 3 regions directly uplink to a satellite. This does not remove the possibility that the other 2 regions may choose to use indirect methods through the satellite.

6.1.3.3 Improvement in ERIS data rate

A reduction in the number of regions using a satellite should allow for an increase in ERIS data per region. If a fixed allocation of ERIS is considered as in the baseline configuration described in section 4 but the number of regions per satellite is reduced due to intelligent uplink scheduling the following improvements can be made to each regions data-rate.

Nb. In the downlink the capacity available for ERIS data is 40bits/second. For the baseline configuration this is split into 5 fields of 8bits.

5 regions per satellite: (Baseline)
For completeness the current baseline solution is shown.

For 5 regions per satellite it is shown in section 4 (assumes equal number of bits per region) that there is 8bits/second/satellite available. There is no need for any type of mask as the regions are ordered.

4 regions per satellite:
For a maximum 4 regions per satellite (for all satellites) the 40bits (assuming equal number of bits per region) could be split as follows. As you may note a region mask is needed to tell the user which regions data is been transmitted. ‘ERIS Mask’ is a 5bit field set up to flag the presence of a particular region data: ‘0’ no data, ‘1’ data. This allows for no extra bits per seconds for each region compared to the current baseline.

For 40 bits in E5b & L1:

<table>
<thead>
<tr>
<th>ERIS Data</th>
<th>ERIS Mask</th>
<th>ERIS 1</th>
<th>ERIS 2</th>
<th>ERIS 3</th>
<th>ERIS 4</th>
<th>Spare</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>8 bits</td>
<td>8 bits</td>
<td>8 bits</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40 bits</td>
</tr>
</tbody>
</table>

3 regions per satellite:
For a maximum 3 regions per satellite (for all satellites).
This allows for only an extra 3 bit/sec for each region than the current baseline.
For 40 bits in E5b & L1:

<table>
<thead>
<tr>
<th>ERIS Data</th>
<th>ERIS Mask</th>
<th>ERIS 1</th>
<th>ERIS 2</th>
<th>ERIS 3</th>
<th>Spare</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 bits</td>
<td>11 bits</td>
<td>11 bits</td>
<td>11 bits</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40 bits</td>
</tr>
</tbody>
</table>

It has been shown that to ensure dissemination requirements 2 regions per satellite is not feasible.

6.1.3.4 Additional Functions Required from Current baseline
To allow for less than 5 regions per satellite the following complexity would be added to Galileo Core System:

At satellite level the following additional functions would be required:
- The satellites would need to add to the ERIS mask any direct uplinks and go on to recreate the mask for the downlink,
- A function to control/block on-board ERIS direct uplink every epoch would be needed (see section 6.2)

At GMS level the following additional functions would be required:
The above functions are not part of the Galileo Core System Baseline and a large cost, schedule and technical impact on the System would have to be considered if implemented.

6.2 IMPROVEMENTS IN ERIS DATA ON-BOARD CONTROL

To allow the ERIS regions and the satellites to know which regions can uplink to which satellites and within what times a further improvement can be made in the planning process. This also takes into consideration that a level of control on-board is expected to ensure unauthorized access to satellites is restricted. This would only be required if we wanted regular control of the ERIS direct uplink on-board the satellite, as any unexpected attacks would be considered as part of normal security functions. If the optimisation of the number of regions per satellite was considered, further control would also be needed to guarantee the downlink bandwidth to the regions using the satellite.

The following section describes the planning process and the functionality which would be required to control ERIS regions data on board.

The GMS sends information to GCS as part of the Mid-Term plan. This ERIS content of the midterm plan would be used to allow the satellites to know when to allow ERIS regions to transmit to it, by the GCS creating the short term plan and sending contact plans to the satellite to tell it whether to block a ERIS region and when.

These improvements are only considered as an example and are not part of the current Galileo Core System Baseline. These improvements would cause significant impacts to the program.

6.2.1 Planning Process

There are two types of plans GMS create which consider the ERIS data transmission:

1. ERIS Direct Uplink Contact Plan [SCH_ErisDirectUplkContactPlan] :
   See section 4.3 for details of this plan as this is considered in the current baseline.

2. Mid Term Plan:
   The GMS currently sends this plan to GCS and is used as the primary input to the short term planning created at GCS. The duration of the mid-term plan is expected to be 2 weeks and will be generated on a weekly basis.
For ERIS access data the following parameters would be needed to allow control of the ERIS uplink to the satellites on a regular basis:

- Satellite ID of Satellites that are to be accessed
- ERIS ULS contact period for each satellite (start and end time of contact)
- ERIS ULS foreseen for that uplink satellite

For what concerns ERIS this could then allow the satellite to know which region is allowed to access the satellite at what time. This would allow for the satellite to ensure that no unauthorised access of the satellite occurs and that the authorised ERIS region is granted its allocated bandwidth.

The flowchart below shows the possible process taken for the whole Galileo/ERIS system for further control of ERIS data on-board.
Figure 20: Possible Extended System Level Planning process

6.2.2 Satellite Functionality for ERIS control
To allow the above proposed improvement in the control of ERIS data on-board the following function would be required on-board:

This would be considered as a new function not currently considered on-board:

The satellite shall be able to block the downlink of any ERIS data received by direct uplink from ERIS Uplink Stations, by the use of ERIS contact plans uplinked through telecommand from the ground control system.

The GMS creates and sends ERIS contact plans to GCS via the GMS-GCS interface GCS sends confirmation of successful contact plan dissemination.
The above functions are not part of the Galileo Core System Baseline and a large cost, schedule and technical impact on the System would have to be considered if implemented.
7 DISTRIBUTION LIST

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<th>Name (first name, surname)</th>
<th>Company</th>
<th>Mail address</th>
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</thead>
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<tr>
<td>Igor Stojkovic</td>
<td>ESA</td>
<td><a href="mailto:Igor.Stojkovic@esa.int">Igor.Stojkovic@esa.int</a></td>
</tr>
<tr>
<td>M. Loesch</td>
<td>Galn</td>
<td><a href="mailto:Martin.loesch@galileo-industries.net">Martin.loesch@galileo-industries.net</a></td>
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