# Galileo Open Service Performance

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# Galileo Services

- Galileo Initial Service provision started on 15 December 2016.
  - Minimum Performance Levels (MPL) announced in the Service Definition Documents, publicly available
- GSA is the Galileo Service Provider since 1 July 2017
- MPLs and performance reports available at GNSS Service Centre webpage: https://www.gsc-europa.eu/

| Service | Description | |
|---|---|---|
| **Open Service (OS)** | Freely accessible service for positioning and timing | |
| **Public Regulated Service (PRS)** | Encrypted service designed for greater robustness and higher availability | |
| **Search and Rescue Service (SAR)** | Assists locating people in distress and confirms that help is on the way | |
| **High Accuracy Service (HAS)** | Delivers high accuracy services, freely accessible | |
| **Commercial Authentication Service (CS)** | Delivers authentication services for commercial applications | |

# Galileo Service Definition

−Public Programme Reference Documents concerning OS:



Signal In Space Interface Control Document (OS SIS ICD)
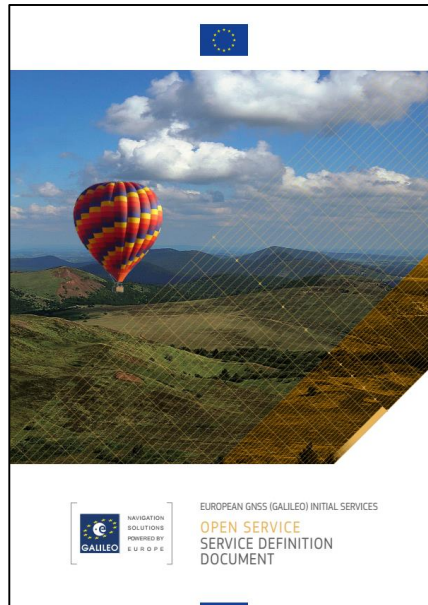


Service Definition Document (OS-SDD)
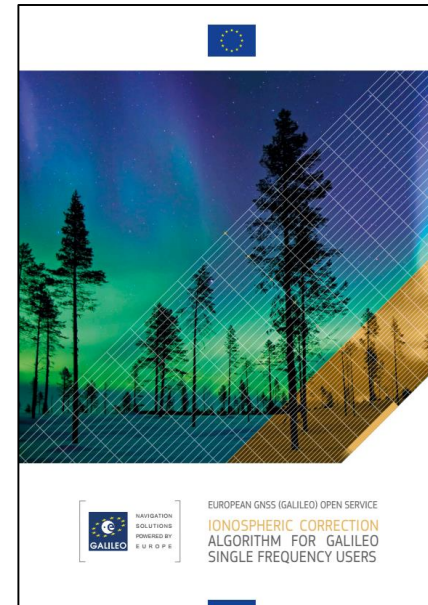


Ionospheric Correction Algorithm for Galileo Single Frequency Users

# Galileo Open Service performance monitoring
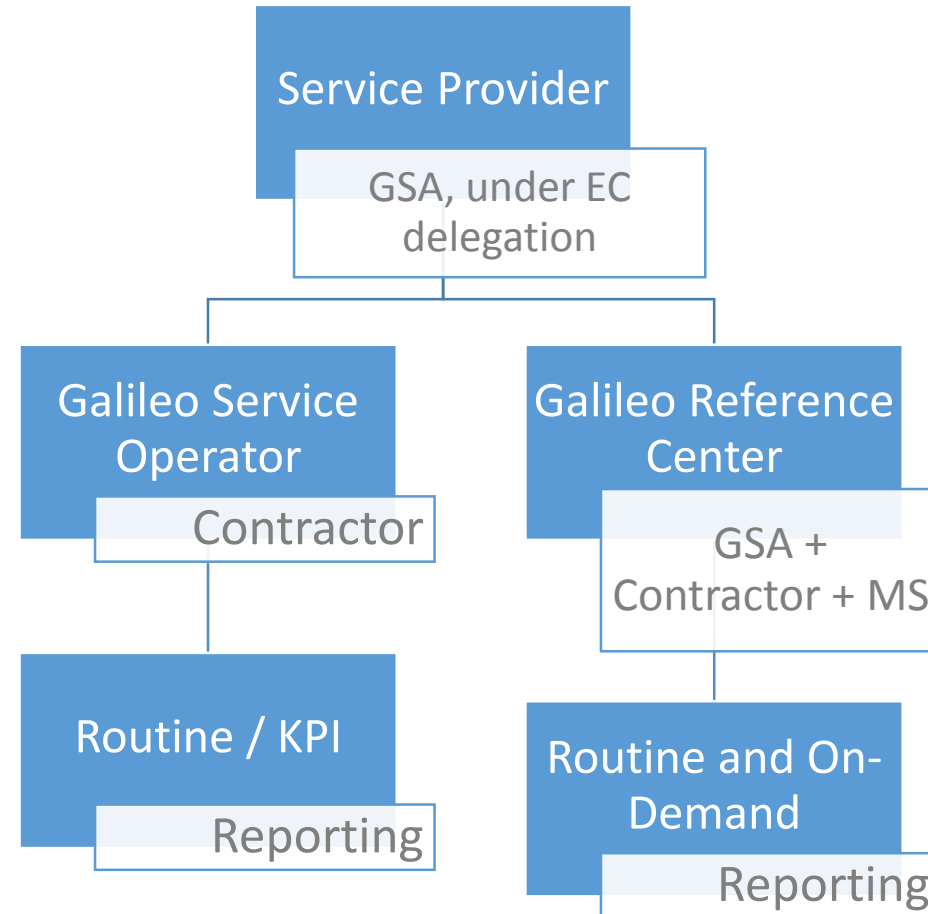
# GRC Mission

- Perform **independent monitoring** and assessment of service provision

- When feasible, assess the compatibility and **interoperability** between Galileo and other GNSS

- Provide service **performance expertise** to Programme

- Support **investigations** of service **performance** and service degradations

- Archive service performance data over nominal operational lifetime of system

- Integrate **data and products** from EU **Member States**, Norway and Switzerland (MS)

# GRC Architecture and Operational Concept

**Core Facility**
- Situated in the Netherlands
- Stand-alone capabilities

**MS Contributions**
- Data
- Products
- Expertise

# Member States' Contributions

- To establish long-term relationships to provide access to a range of facilities and expertise for Galileo service performance monitoring in order to enhance the performance of the GRC

- The GRC should benefit from but also contribute to maintaining the long term competence and expertise at the level of Member States;

- Member States' contributions include:
  – Worldwide network of reference stations
  – Reference products
  – Timing labs
  – Radio telescopes
  – Laser ranging
  – Vehicles, vessels and airplanes

# GRC Operational Concept

- Fully independent of the system and of the Galileo Service Operator (GSOp)

    – both technical solution and operations

- Automatic processes for continuous monitoring and data processing

    – Galileo Open Service is monitored against Key Performance Indicators (KPIs) and Figures of Merit
        – Based on the **OS SDD** and Galileo Service Operator **KPIs**

- Evaluate basic monitoring parameters for Galileo signals against values specified in Galileo **OS SiS ICD**

- Perform dedicated campaign-based analyses

    – Also making use of data, products, facilities and expertise contributed by MS

# User Range Error (June 2018)

The SV Ranging accuracy is computed as the 95% value of the URE over one month.



June 2018: Ranging Accuracy for SF Users

June 2018: Ranging Accuracy for DF Users
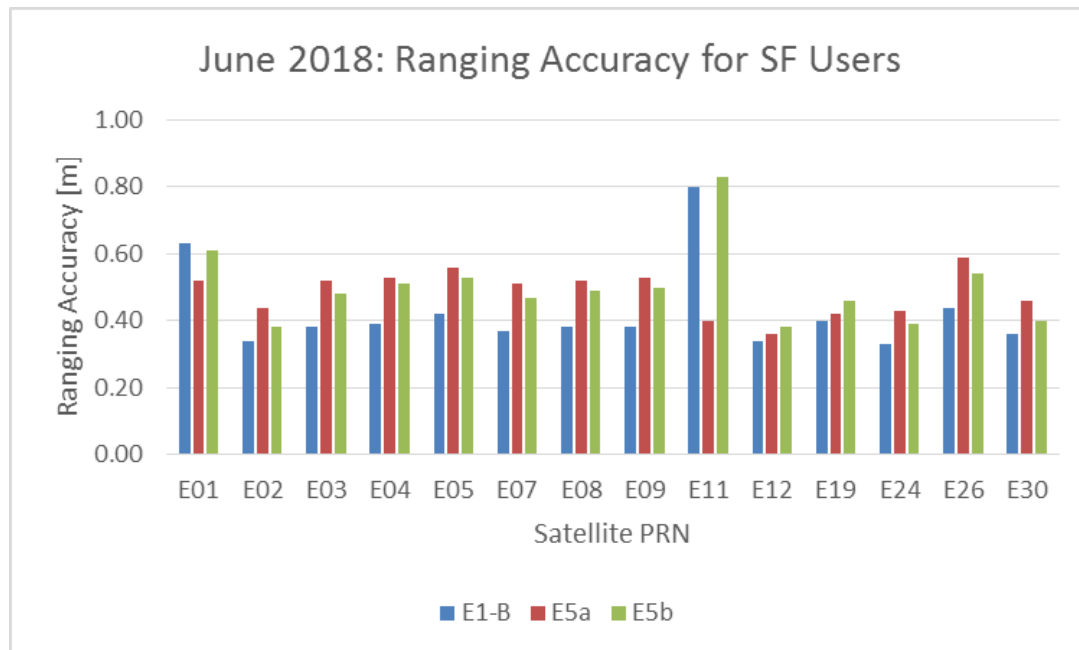
Worst accuracy value: 0.83m

Worst accuracy value: 0.78m

All results from "The Galileo Reference Centre and Its Role in the Galileo Service Provision," 69th IAC, Bremen, 1-5 October 2018
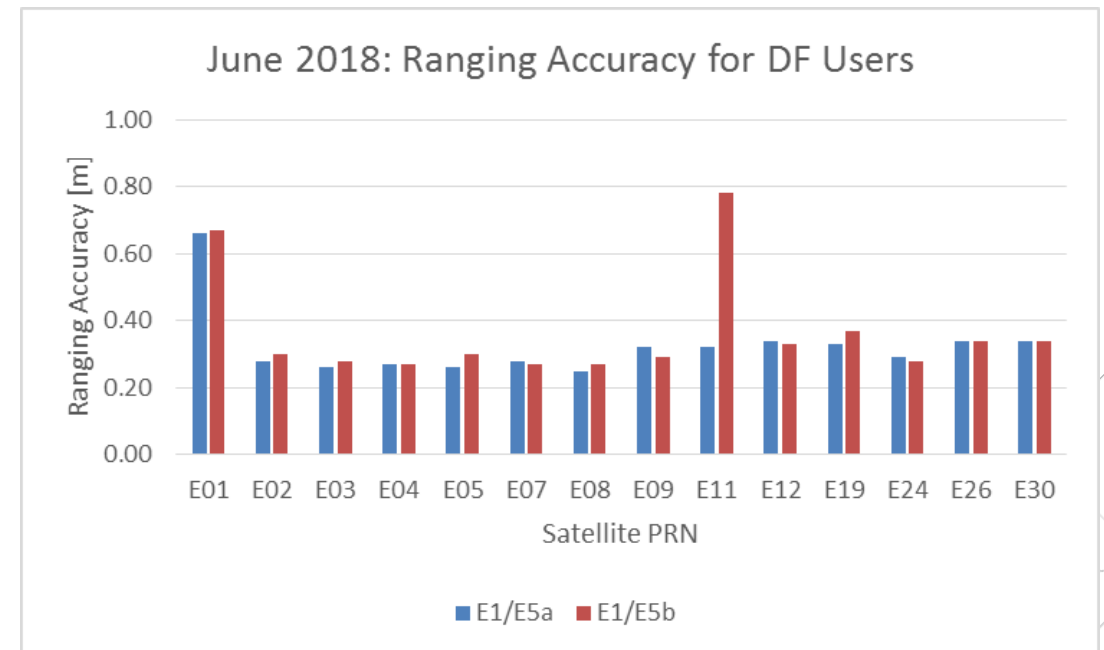
# Ranging Availability (June 2018)

| PRN | E1-B | E5a | E5b | MPL (SDD) |
|-----|------|-----|-----|-----------|
| E01 | 100.00 | 100.00 | 100.00 | 87.00 |
| E02 | 100.00 | 100.00 | 100.00 | 87.00 |
| E03 | 100.00 | 100.00 | 100.00 | 87.00 |
| E04 | 100.00 | 100.00 | 100.00 | 87.00 |
| E05 | 100.00 | 100.00 | 100.00 | 87.00 |
| E07 | 100.00 | 100.00 | 100.00 | 87.00 |
| E08 | 100.00 | 100.00 | 100.00 | 87.00 |
| E09 | 100.00 | 100.00 | 100.00 | 87.00 |
| E11 | 100.00 | 100.00 | 100.00 | 87.00 |
| E12 | 100.00 | 100.00 | 100.00 | 87.00 |
| E19 | 100.00 | 100.00 | 100.00 | 87.00 |
| E24 | 100.00 | 100.00 | 100.00 | 87.00 |
| E26 | 100.00 | 100.00 | 100.00 | 87.00 |
| E30 | 100.00 | 99.79 | 100.00 | 87.00 |

Single Frequency Users

| PRN | E1/E5a | E1/E5b | MPL (SDD) |
|-----|--------|--------|-----------|
| E01 | 100.00 | 100.00 | 87.00 |
| E02 | 100.00 | 100.00 | 87.00 |
| E03 | 100.00 | 100.00 | 87.00 |
| E04 | 100.00 | 100.00 | 87.00 |
| E05 | 100.00 | 100.00 | 87.00 |
| E07 | 100.00 | 100.00 | 87.00 |
| E08 | 100.00 | 100.00 | 87.00 |
| E09 | 100.00 | 100.00 | 87.00 |
| E11 | 100.00 | 100.00 | 87.00 |
| E12 | 100.00 | 100.00 | 87.00 |
| E19 | 100.00 | 100.00 | 87.00 |
| E24 | 100.00 | 100.00 | 87.00 |
| E26 | 100.00 | 100.00 | 87.00 |
| E30 | 99.79 | 100.00 | 87.00 |

Dual Frequency Users

# Timing KPIs (June 2018)

## GST-UTC Dissemination Accuracy (left) and Availability (right)

|  | Accuracy [ns] | MPL (SDD) |
|---|---|---|
| Monthly | 8.65 | - |
| Yearly | 7.80 | 30 |

GST-UTC Dissemination Accuracy

|  | Availability [%] | MPL (SDD) |
|---|---|---|
| Monthly | 100 | 87 |
| Yearly | 100 | 87 |

GST-UTC Dissemination Availability

## GGTO Accuracy (left) and Availability (right)

|  | Accuracy [ns] | MPL (SDD) |
|---|---|---|
| Monthly | 7.91 | - |
| Yearly | 5.90 | 20 |

GGTO Dissemination Accuracy
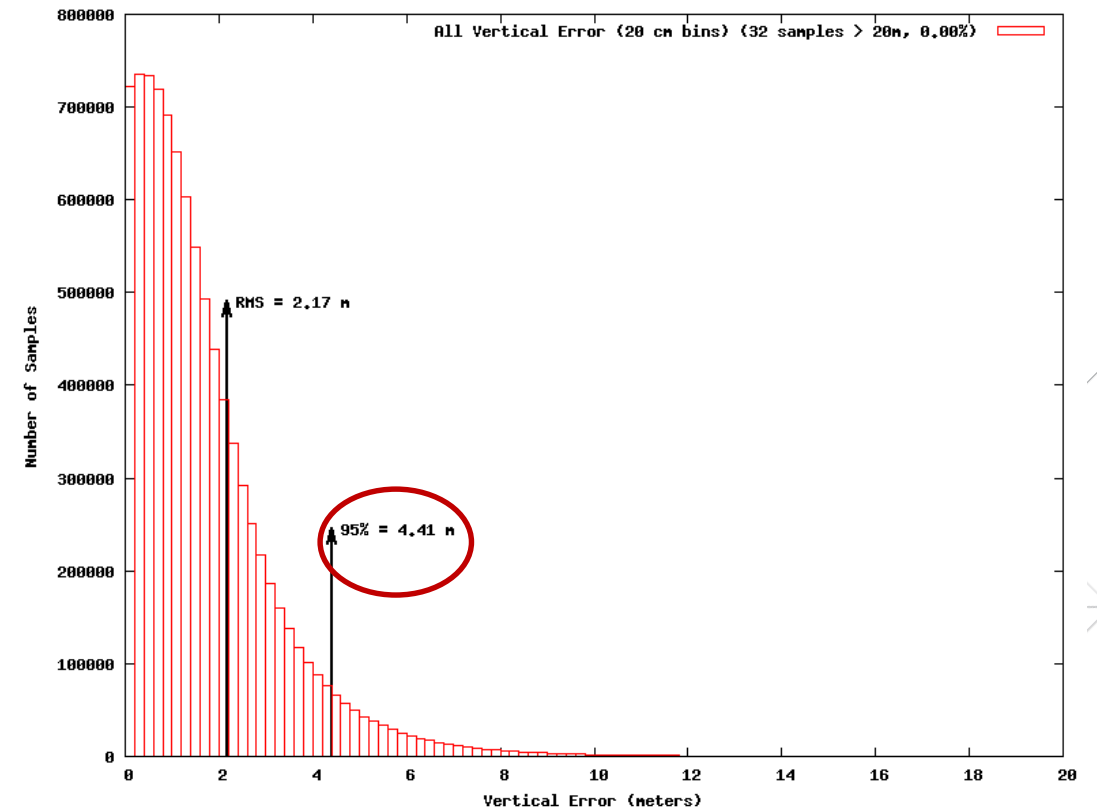
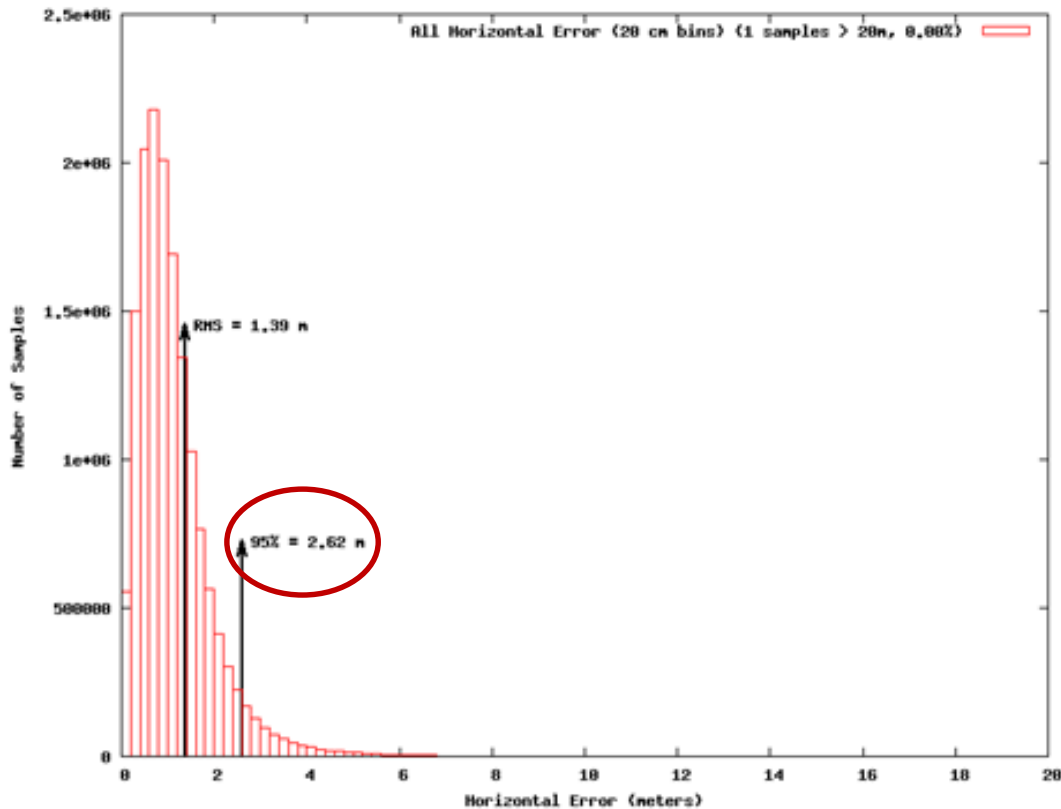|  | Availability [%] | MPL (SDD) |
|---|---|---|
| Monthly | 90.09 | - |
| Yearly | 90.09 | - |

GGTO Dissemination Availability

# Hor. and Vert. Pos. Error (June 2018)

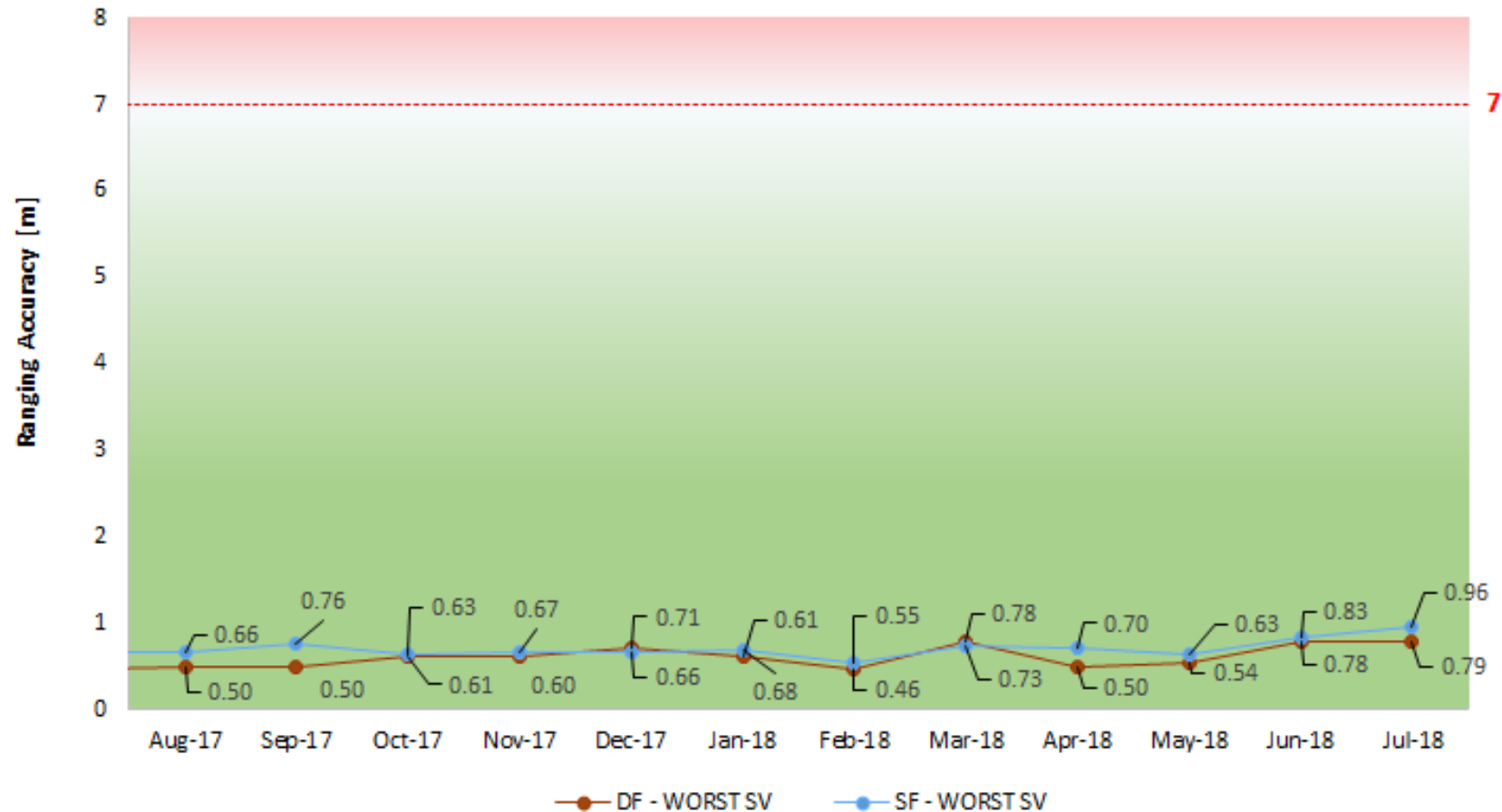HPE (left) and VPE (right) distributions for F/NAV – Similar performance is obtained for I/NAV

# One year trends – Ranging Accuracy



**MPL on Ranging Accuracy - Any Satellite**

Ranging Accuracy values: always below 1m (MPL: 7m – see SDD)

# One year trends – UTC Diss. Accuracy



**GST-UTC Time Offset Dissemination Accuracy [ns] - MPL**
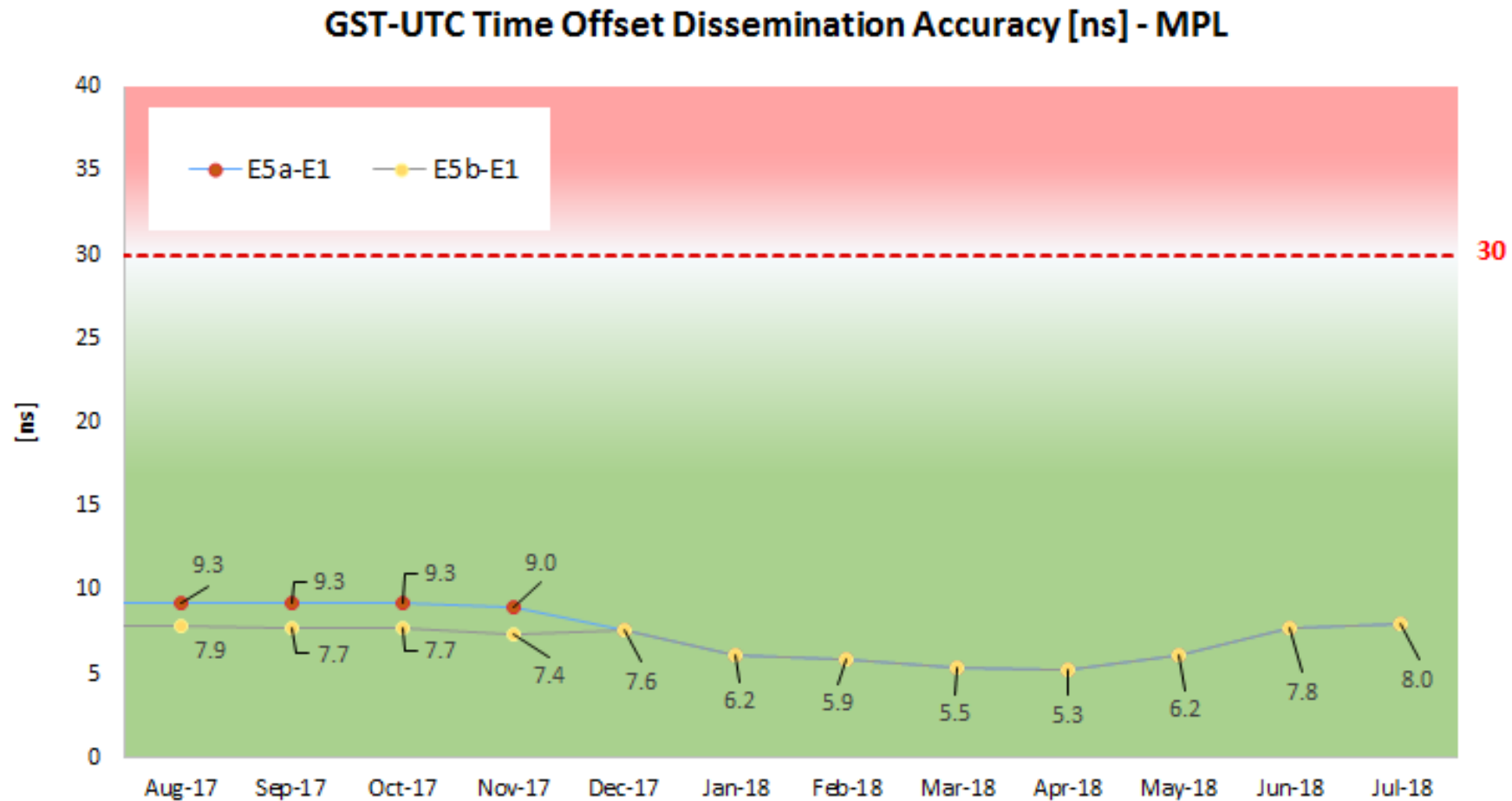
GST-UTC Dissemination Accuracy: always below 10ns (MPL: 30ns – see SDD)

# One year trends – GGTO Accuracy

**GST-GPS Time Offset (GGTO) Determination Accuracy [ns] - MPL**
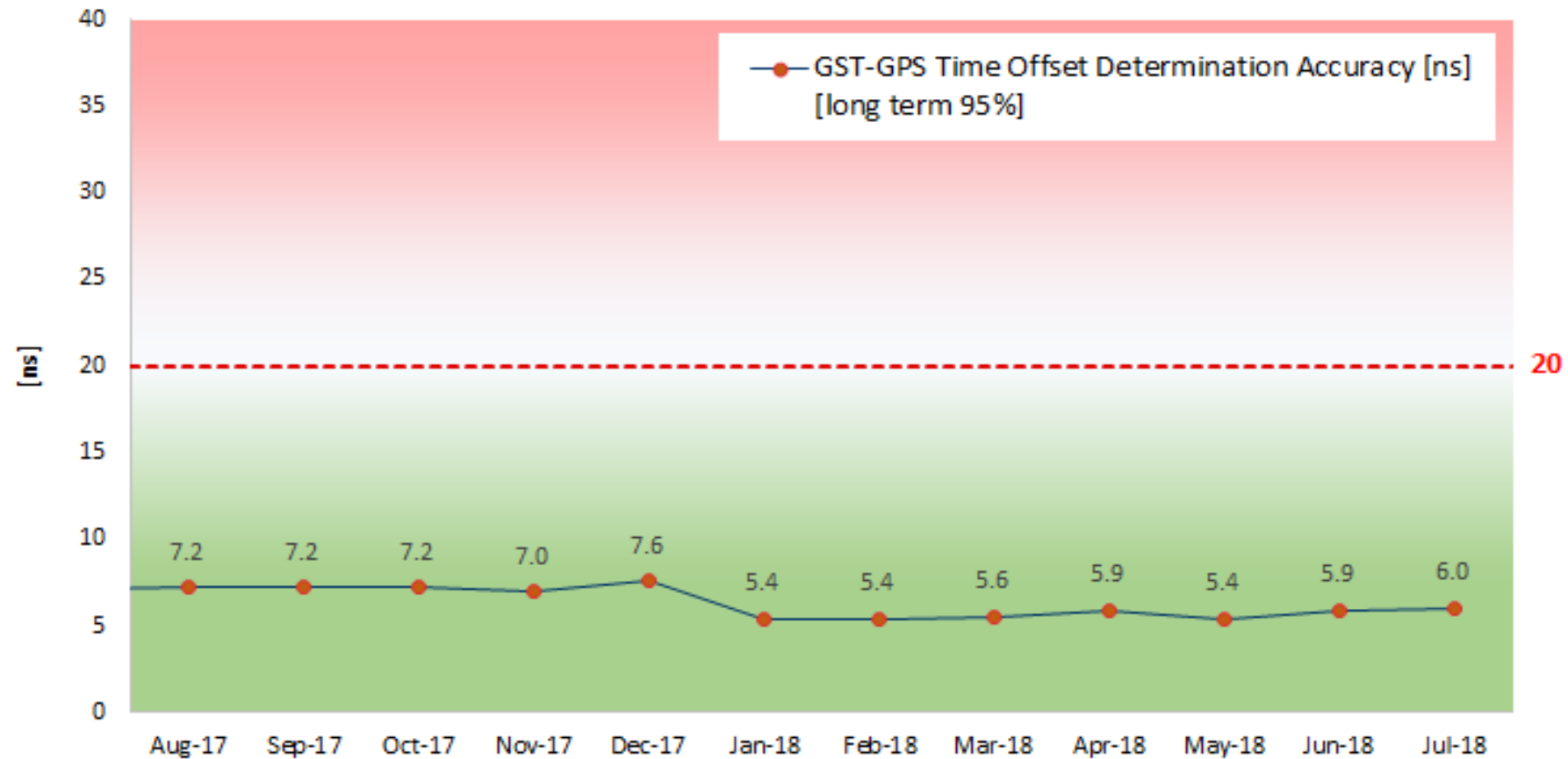


GGTO Dissemination Accuracy: always below 8ns (MPL: 20ns – see SDD)

# Ranging Accuracy (from 2014)
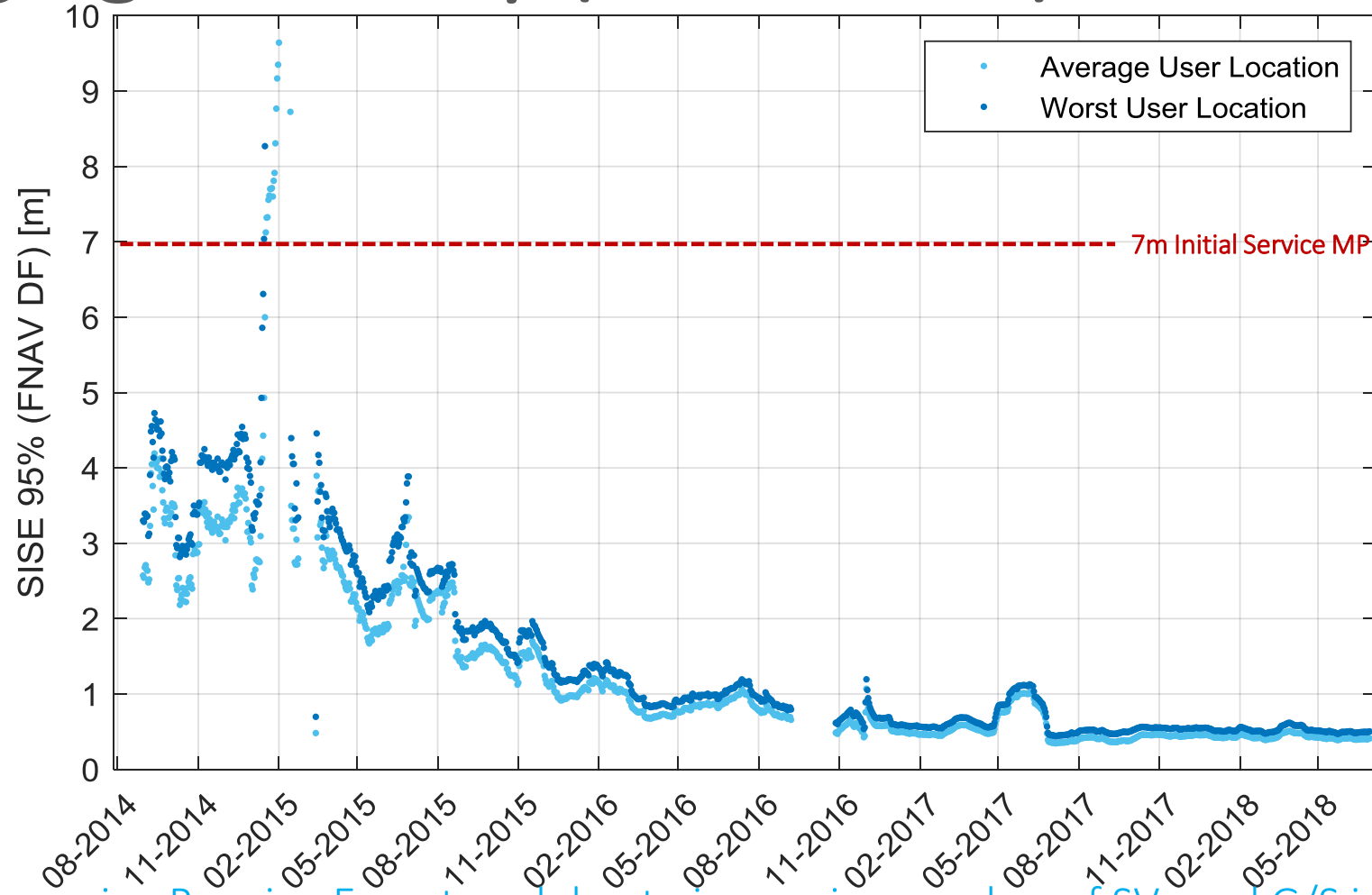


Decreasing Ranging Error trend due to increasing number of SVs and G/S improvements

(Figure from G. Galluzzo et al., "Measuring Galileo Performance Navigation and Timing Performance Figures of Merit – Part 2," Inside GNSS Sep/Oct 2018)

# Conclusions

- Galileo Reference Centre is responsible for independent monitoring of Galileo service performance

- GRC has stand-alone Core Facility and benefits from expertise/assets from Member states

- Performance of Galileo is excellent

  – All navigation minimum performance levels met

  – Transparent reporting on achieved results through www.gsc-europa.eu

| | | Jul 17 | Aug 17 | Sep 17 | Oct 17 | Nov 17 | Dec 17 | Jan 18 | Feb 18 | Mar 18 | Apr 18 | May 18 | Jun 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Positioning | Ranging accuracy | | | | | | | | | | | | |
| | Ranging availability | | | | | | | | | | | | |
| | Per Satellite Availability | | | | | | | | | | | | |
| Time | UTC dissemination uncertainty | | | | | | | | | | | | |
| | UTC dissemination availability | | | | | | | | | | | | |
| Multi-constellation | GST-GPS time offset uncertainty | | | | | | | | | | | | |
| | GST-GPS time offset availability | | | | | | | | | | | | |

# Thank you
# for your attention

# Linking space to user needs

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