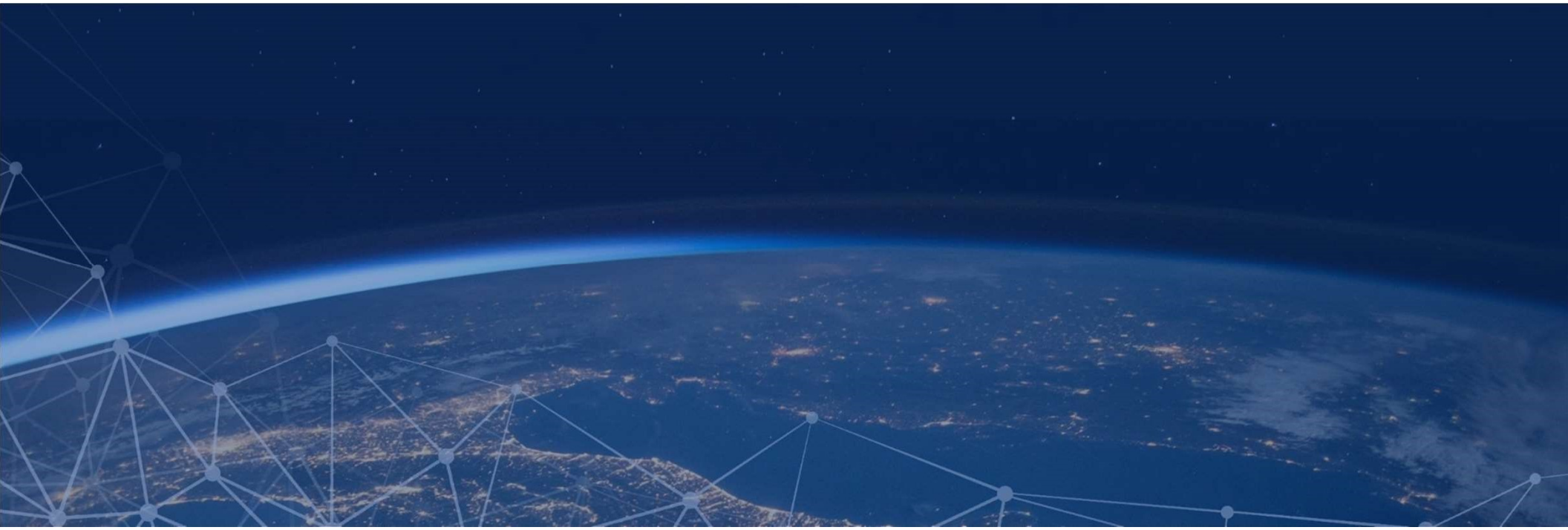


Utilising current and new Galileo Services for 3D Surveys

7th International FIG Workshop on 3D Cadastres 11-13 October 2021, New York, USA

Peter BUIST, Lennard HUISMAN, Marco PORRETTA, Alvaro MOZO

EUSPA
European Union Agency for the Space Programme

Outline

- Status of Galileo
- New Galileo Services
- Galileo for Surveying

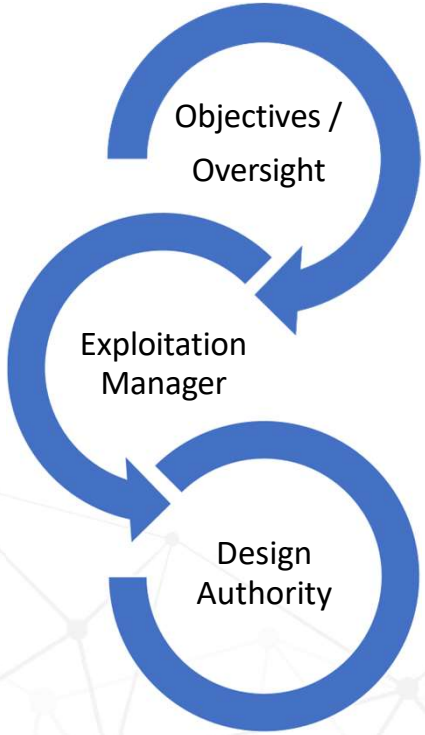
Outline

- **Status of Galileo**
- New Galileo Services
- Galileo for Surveying

A Broader Angle

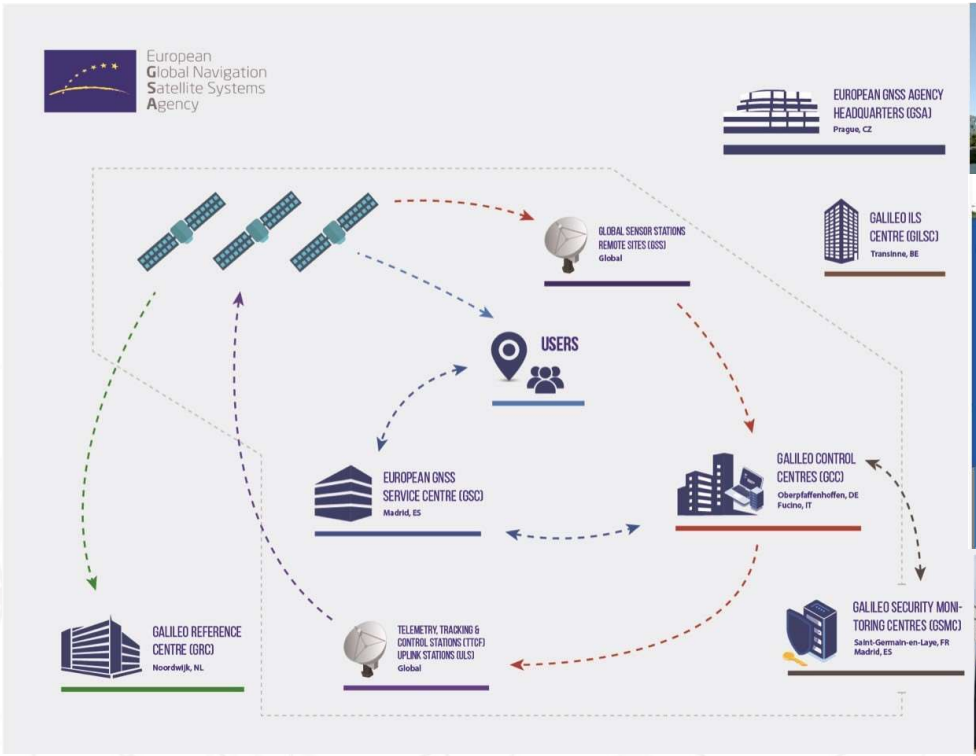
- New integrated EU Space Programme established by the new Space Regulation covering the period up to 2027

Partners Working Together

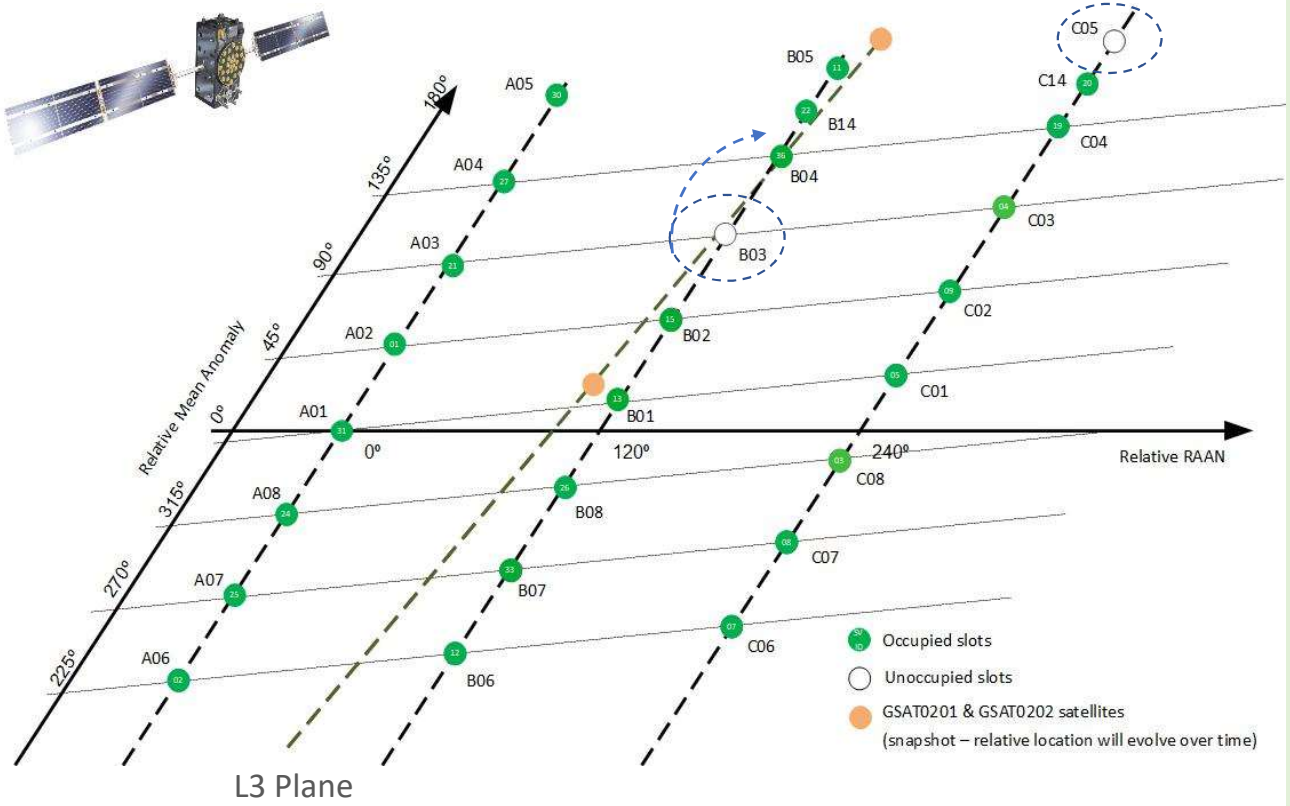


- Framework Partnership Agreement

Galileo Ground Segment Status



Galileo Constellation Status



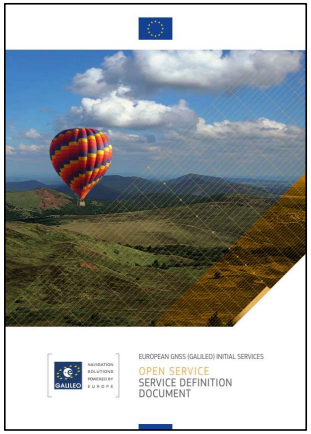
L3 Plane

- **Space Segment** (22/09/2021):
- 26 Satellites in Orbit
- 22 in service for Navigation
- 24 in service for SAR
- 2 Auxiliary not in Service
- 1 Inactive Spare
- 2 Nominal Slots free for next launches

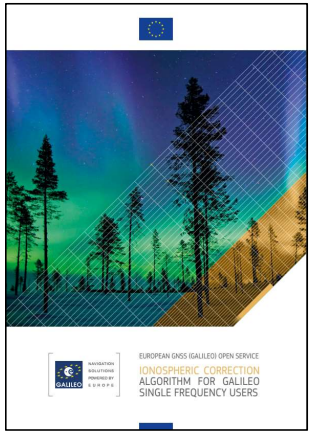
Galileo Service Definition

- Public Programme Reference Documents concerning OS:

Signal In Space Interface Control Document (OS SIS ICD)



Service Definition Document (OS-SDD)

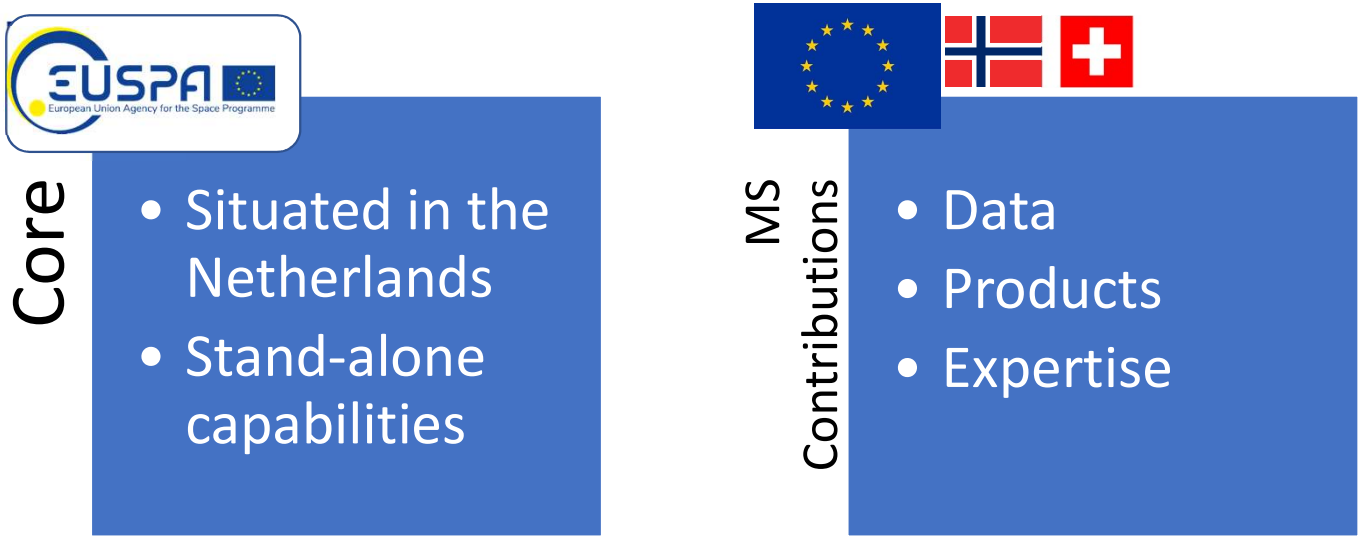


Ionospheric Correction Algorithm for Galileo Single Frequency Users

Galileo Reference Centre (GRC)

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

GRC Architecture and Operational Concept

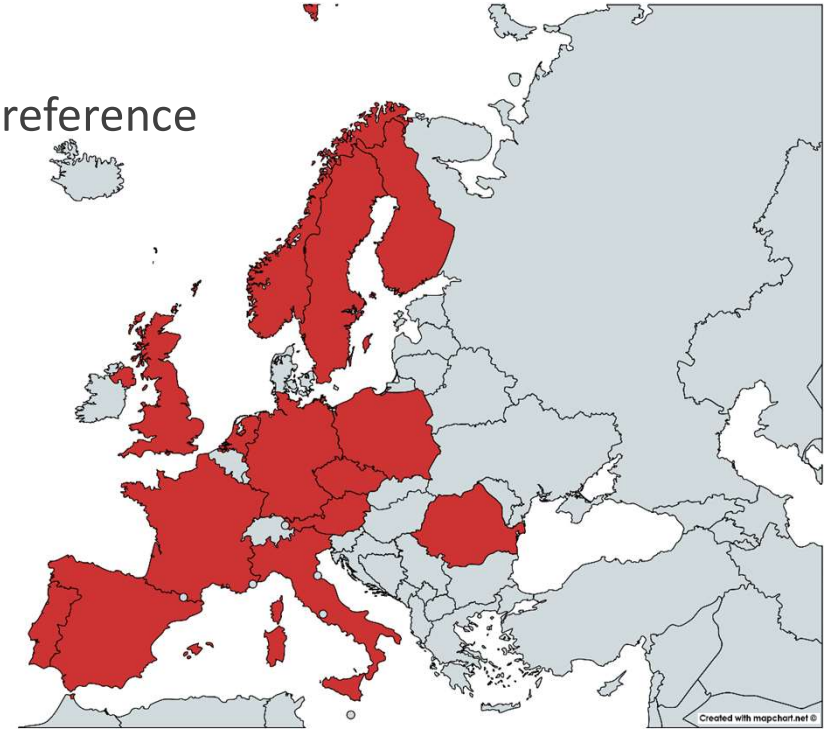


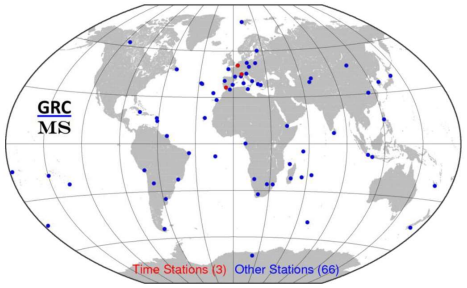
Member States' Contributions

- 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 competences and expertise at the level of Member States;

Member States' Contributions

- 23 organisations from 14 countries
- Including
  - Worldwide network of reference stations
  - Reference products
  - Timing labs
  - Radio telescopes
  - Laser ranging
  - Vehicles, vessels and airplanes

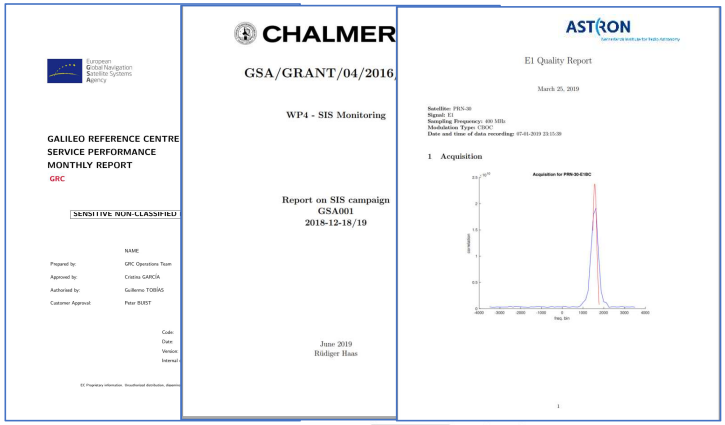


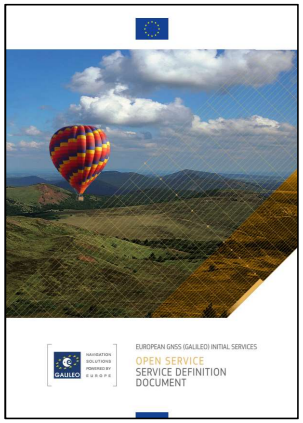


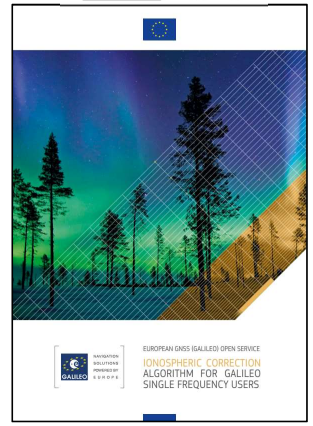
Galileo Monthly Performance Reports

- GRC reports are for internal Programme use
- Delivered monthly, covering Galileo performances for 1 month
  - Latency of 3 weeks
    - Time needed to obtain final orbit, clock and bias products
  - KPIs reported:
- Complemented with MS reports
- Main source of information for public quarterly report available through GSC website

GRC Performance & cross check reports





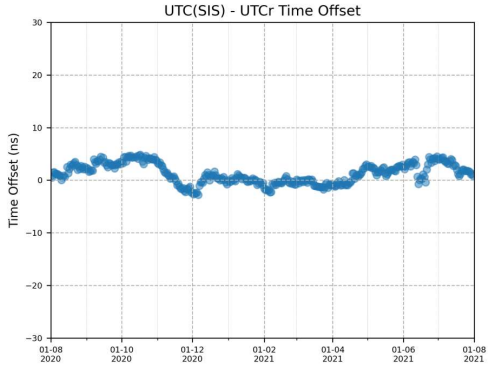


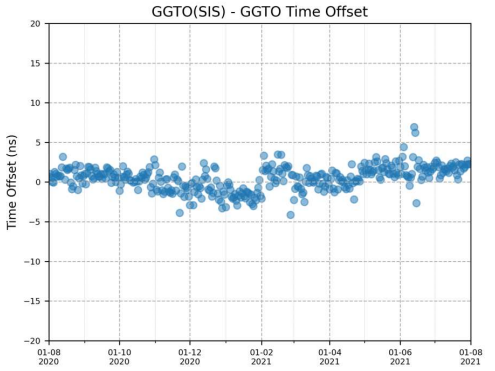
Galileo Service Status

- Navigation Minimum Performance Levels met in the period of reporting (April, May and June), constellation average of ranging accuracy better than 38 cm (single frequency) and 15 cm (double frequency) and availability of positioning above 99.90%, at worst user location
- Excellent timing accuracy (4.3ns UTC, 2.9ns GGTO)
- High availability of healthy signals during the period

Galileo OS Performance: Navigation

Definition		Committed Target	Worst Case from Aug 2020 to Apr 2021	May 2021	June 2021	July 2021
Ranging accuracy (DF, 95%)	Worst Satellite month	**< 7.0 m**	**0.44**	**0.38**	**0.34**	**0.28**
	Constellation Average	**< 2.0 m**	**0.21**	**0.14**	**0.14**	**0.15**
Ranging accuracy (SF, 95%)	Worst Satellite month	**< 7.0 m**	**1.27**	**0.60**	**0.58**	**0.60**
	Constellation Average	**< 2.0 m**	**0.34**	**0.31**	**0.30**	**0.28**
Availability of F/NAV Global PDOP ≤ 6		**≥ 77%**	**99.18%**	**99.99%**	**99.96%**	**99.99%**
Availability of Positioning at Average User Location (**)	Dual Frequency	**≥ 77%**	**99.22%**	**100%**	**99.99%**	**100%**
	Single Frequency	**≥ 77%**	**99.21%**	**100%**	**99.99%**	**100%**
Availability of Positioning at Worst User Location (**)	Dual Frequency	**≥ 70%**	**99.15%**	**100%**	**99.93%**	**100%**
	Single Frequency	**≥ 70%**	**99.13%**	**100%**	**99.90%**	**100%**
"Per Slot" Availability of SiS (*) (OS, healthy SF/DF – OS-SDD MPL)		**> 87%**	**≥ 98.17%**	**≥ 99.41%**	**≥ 99.46%**	**≥ 99.46%**
UTC Time Diss. Uncertainty (*) (DF, 95% over last 12 months – OS SDD MPL)		**< 30 ns**	**13.6**	**4.2**	**4.3**	**4.3**
Availability of UTC dissemination (%)		**> 87%**	**99.22%**	**100%**	**100%**	**100%**
GST-GPS time offset uncertainty (*) (95% over last 12 months – OS SDD MPL)		**< 20 ns**	**12.35**	**2.6**	**2.9**	**2.9**





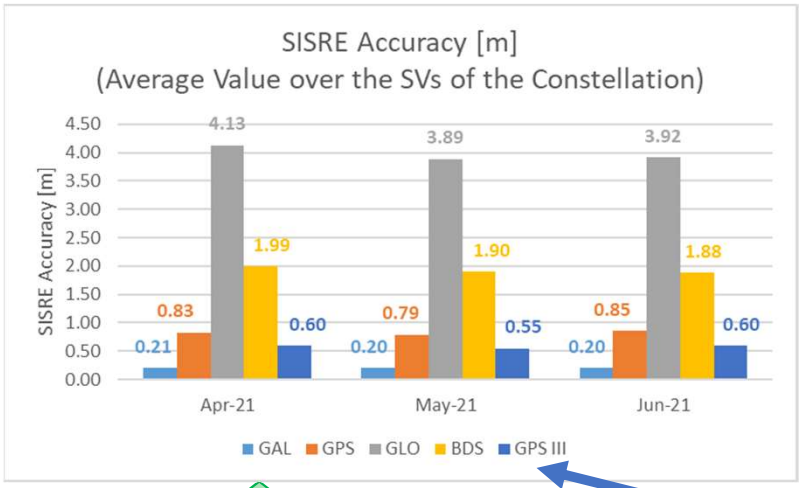
(*) MPL is annually normalized

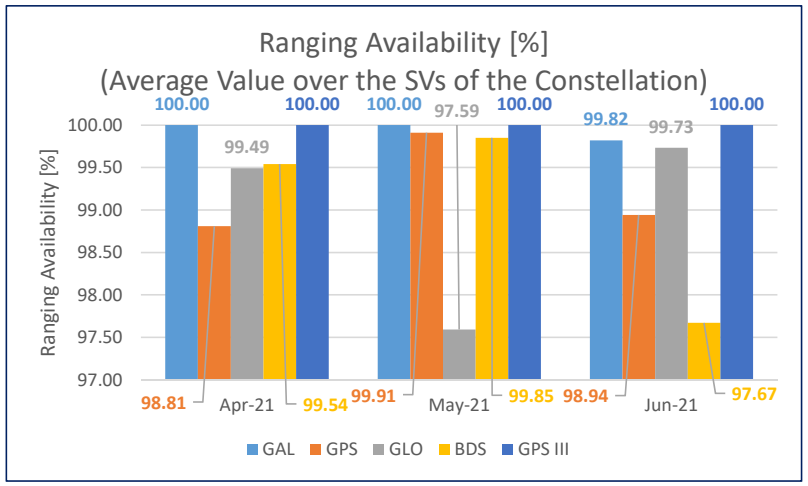
(**) 95% Horizontal Position Error ≤ 7.5m
95% Vertical Position Error ≤ 15m

Galileo OS Performance

Definition	Committed Target	Item	From Aug 2020 to Apr 2021	May 2021	June 2021	July 2021
Ranging accuracy (DF, 95%)	**< 7.0 m**	Best Satellite	0.14 [m]	0.14 [m]	0.14 [m]	0.15 [m]
		Which Satellite(s)	GSAT-0214 GSAT-0205	GSAT-0208	GSAT-0215	GSAT-0210 GSAT-0219 GSAT-0221
		Which DF	E1-E5b	E1-E5b	E1-E5b	E1-E5b
		When	January 2021 March 2021			
Ranging accuracy (SF, 95%)	**< 7.0 m**	Best Satellite	0.18 [m]	0.20 [m]	0.22 [m]	0.21 [m]
		Which Satellite	GSAT-0207 GSAT-0212	GSAT-0206	GSAT-0207	GSAT-0205
		Which SF	E1	E1	E1	E1
		When	June 2020			

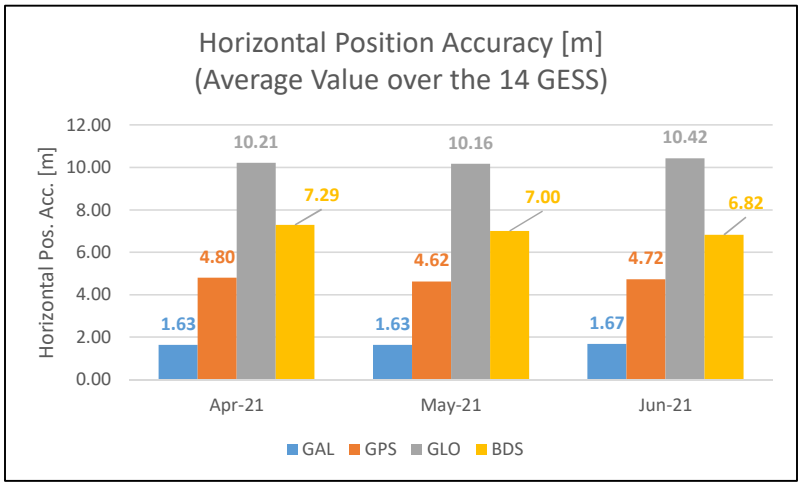
Benchmark with other GNSS (1/3)

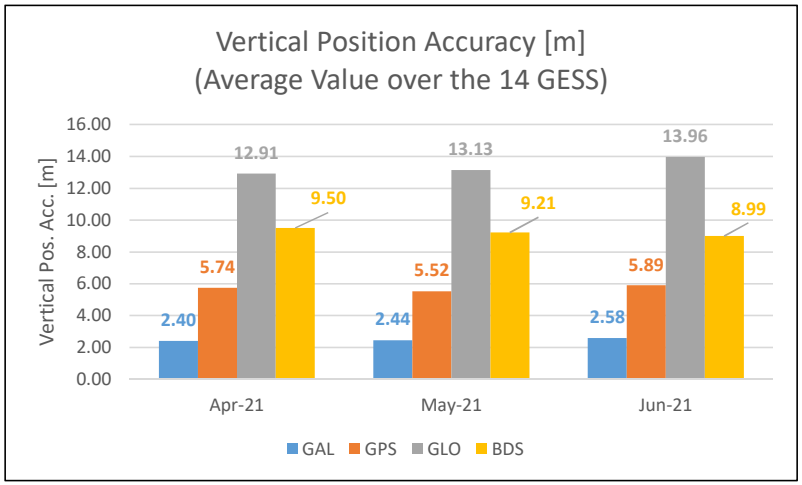




- Excellent accuracy (including wrt GPS III), good availability

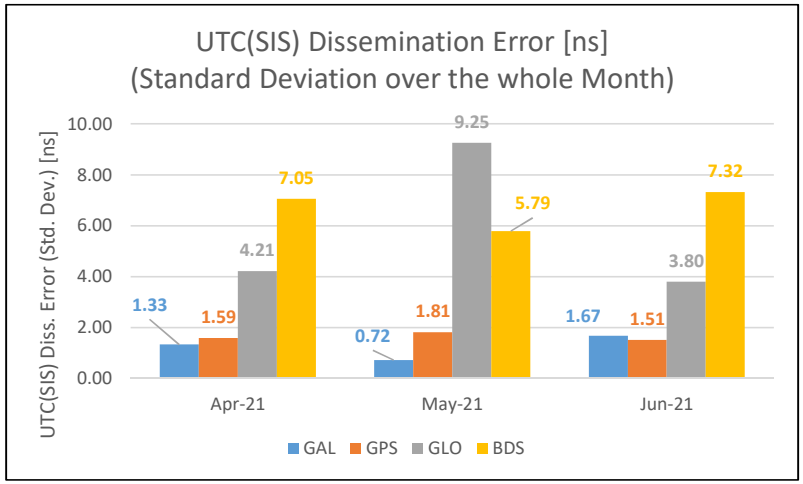
Benchmark with other GNSS (2/3)





- Excellent PVT accuracy, both horizontal and vertically

Benchmark with other GNSS (3/3)



- Excellent timing

Outline

- Status of Galileo
- **New Galileo Services**
- Galileo for Surveying

Galileo Services

Galileo Open Service (OS):

More satellites, Galileo signal design and multi- frequency capability contribute to **better availability, reliability and accuracy (especially in harsh environment)**

Galileo High Accuracy Service (HAS):

The only constellation offering **''Free'' global high accuracy service (<20cm)** directly from satellites **without dependency of Internet** or additional communication channels

Galileo Authentication Services:

Galileo will also offer **increased robustness to spoofing** thanks to its **Commercial Authentication Service (CAS)** and the **Open Service Navigation Message Authentication (OS-NMA)**

High-precision GNSS: recap

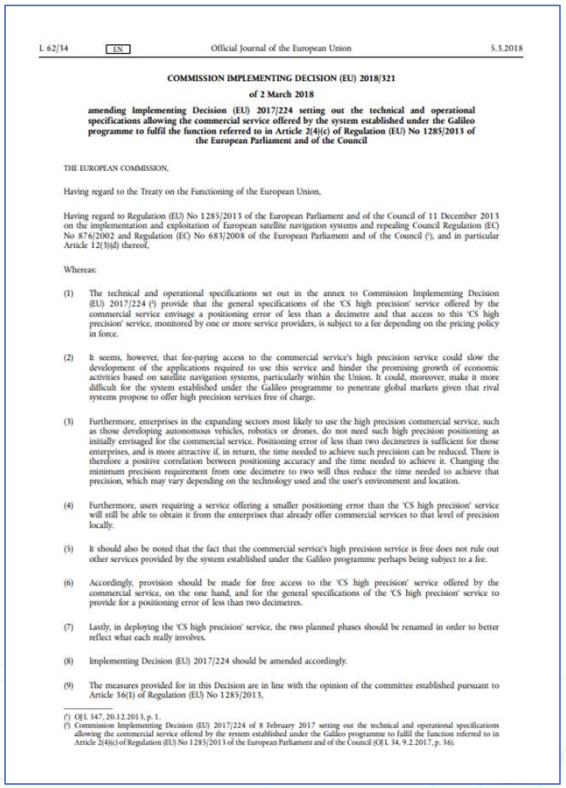
- Real time Kinematic (RTK)
  - Permanent reference station broadcasting dual frequency data
  - Relies on finding the correct integer ambiguities:
    - ambiguity fixed solution: centimeter accuracy
    - Initialization takes a few seconds to minutes, depending on the distance to the reference station and atmospheric conditions
- Precise Point Positioning (PPP)
  - Stand-alone GNSS receiver processing, using
    - Carrier phase and pseudo-range observations (no differencing)
    - Additional GNSS satellite orbit & clock (biases and atmospheric) products
  - High accuracy (dm) anywhere on the globe
  - Convergence time: up to a few tens of minutes

Galileo HAS Background

EC Imp Decision (EU) 2017/224 (8-02-2017) amended by (EU) 2018/321 (2-03-2018)

Implementation of the Galileo Commercial service as:

- **CS High Precision or HAS Service**: Free service. High Accuracy corrections, accuracy down to 20 cm using E6-B.
- **CS Authentication or CAS Service:** Authentication through access to encrypted codes (using a private crypto key), using E6-B for the access data and E6-C component (pilot).



L 62/34 EN Official Journal of the European Union 5.3.2018

COMMISSION IMPLEMENTING DECISION (EU) 2018/321

of 2 March 2018

amending Implementing Decision (EU) 2017/224 setting out the technical and operational specifications allowing the commercial service offered by the system established under the Galileo programme to fulfil the function referred to in Article 2(4)(c) of Regulation (EU) No 1285/2013 of the European Parliament and of the Council

THE EUROPEAN COMMISSION,

Having regard to the Treaty on the Functioning of the European Union,

Having regard to Regulation (EU) No 1285/2013 of the European Parliament and of the Council of 11 December 2013 on the implementation and exploitation of European satellite navigation systems and repealing Council Regulation (EC) No 876/2002 and Regulation (EC) No 683/2008 of the European Parliament and of the Council (1), and in particular Article 12(5)(d) thereof,

Whereas:

(1) The technical and operational specifications set out in the annex to Commission Implementing Decision (EU) 2017/224 (2) provide that the general specifications of the 'CS high precision' service offered by the commercial service envisage a positioning error of less than a decimetre and that access to this 'CS high precision' service, monitored by one or more service providers, is subject to a fee depending on the pricing policy in force.

(2) It seems, however, that fee-paying access to the commercial service's high precision service could slow the development of the applications required to use this service and hinder the promising growth of economic activities based on satellite navigation systems, particularly within the Union. It could, moreover, make it more difficult for the system established under the Galileo programme to penetrate global markets given that rival systems propose to offer high precision services free of charge.

(3) Furthermore, enterprises in the expanding sectors most likely to use the high precision commercial service, such as those developing autonomous vehicles, robotics or drones, do not need such high precision positioning as initially envisaged for the commercial service. Positioning error of less than two decimetres is sufficient for those enterprises, and is more attractive if, in return, the time needed to achieve such precision can be reduced. There is therefore a positive correlation between positioning accuracy and the time needed to achieve it. Changing the minimum precision requirement from one decimetre to two will thus reduce the time needed to achieve that precision, which may vary depending on the technology used and the user's environment and location.

(4) Furthermore, users requiring a service offering a smaller positioning error than the 'CS high precision' service will still be able to obtain it from the enterprises that already offer commercial services to that level of precision locally.

(5) It should also be noted that the fact that the commercial service's high precision service is free does not rule out other services provided by the system established under the Galileo programme perhaps being subject to a fee.

(6) Accordingly, provision should be made for free access to the 'CS high precision' service offered by the commercial service, on the one hand, and for the general specifications of the 'CS high precision' service to provide for a positioning error of less than two decimetres.

(7) Lastly, in deploying the 'CS high precision' service, the two planned phases should be renamed in order to better reflect what each really involves.

(8) Implementing Decision (EU) 2017/224 should be amended accordingly.

(9) The measures provided for in this Decision are in line with the opinion of the committee established pursuant to Article 36(1) of Regulation (EU) No 1285/2013,

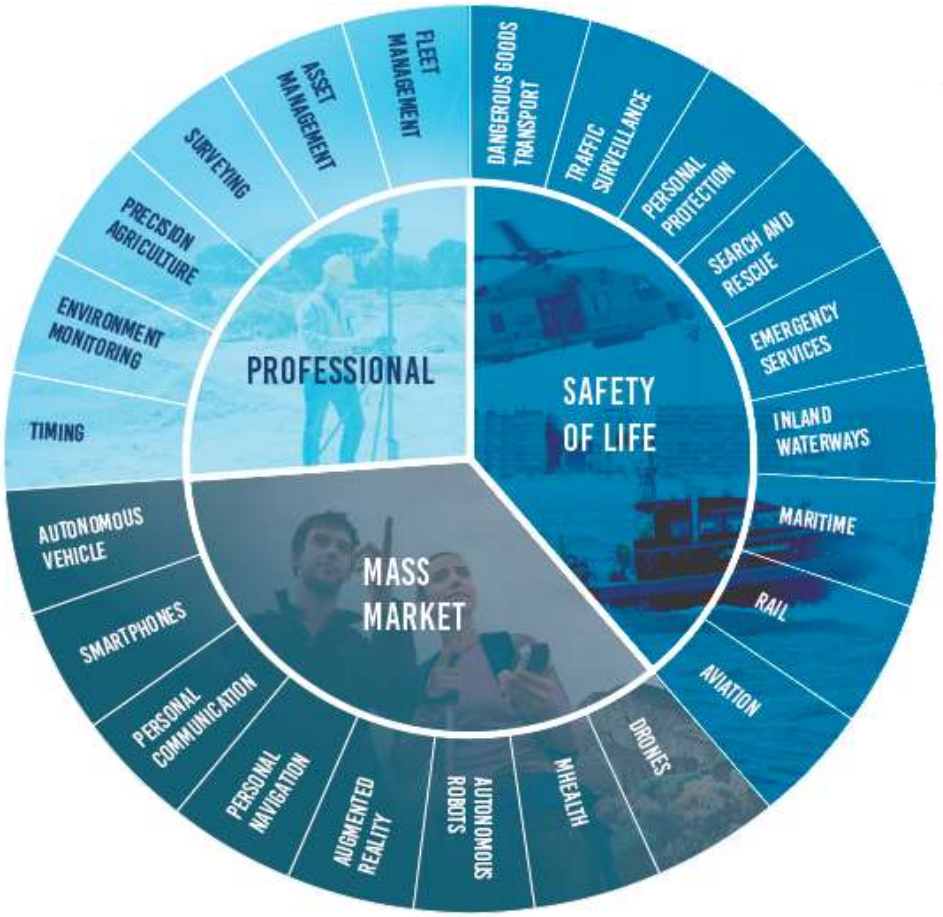
(1) OJ L 347, 20.12.2013, p. 1.
(2) Commission Implementing Decision (EU) 2017/224 of 8 February 2017 setting out the technical and operational specifications allowing the commercial service offered by the system established under the Galileo programme to fulfil the function referred to in Article 2(4)(c) of Regulation (EU) No 1285/2013 of the European Parliament and of the Council (OJ L 34, 9.2.2017, p. 36).

Main characteristics of Galileo HAS

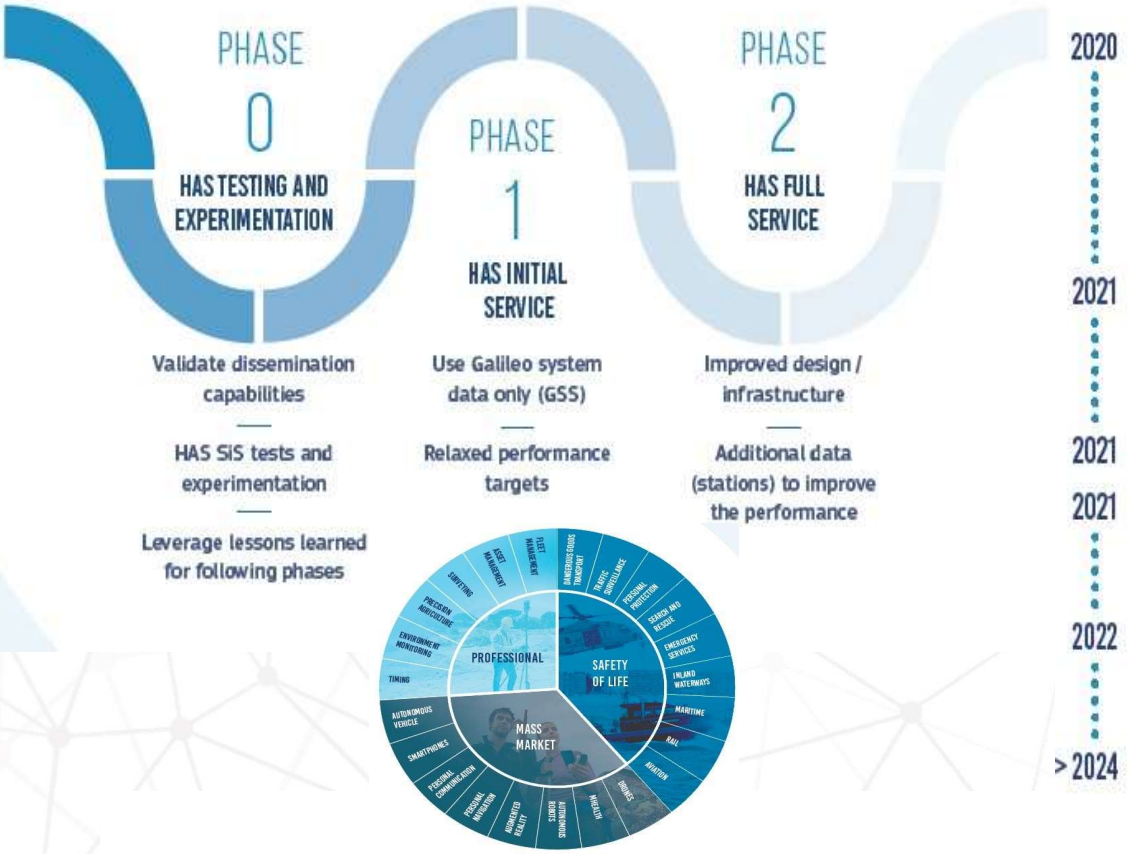
HAS	SERVICE LEVEL 1	SERVICE LEVEL 2
COVERAGE	Global	European Coverage Area (ECA)
TYPE OF CORRECTIONS	PPP - orbit, clock, biases (code and phase)	PPP - orbit, clock, biases (code and phase incl. atmospheric corrections
FORMAT OF CORRECTIONS	Open format similar to Compact-SSR (CSSR)	Open format similar to Compact-SSR (CSSR)
DISSEMINATION OF CORRECTIONS	Galileo E6B using 448 bits per satellite per second / terrestrial (internet)	Galileo E6B using 448 bits per satellite per second / terrestrial (internet)
SUPPORTED CONSTELLATIONS	Galileo, GPS	Galileo, GPS
SUPPORTED FREQUENCIES	E1/E5a/E5b/E6; E5 AltBOC L1/L5; L2C	E1/E5a/E5b/E6; E5 AltBOC L1/L5; L2C
HORIZONTAL ACCURACY 95%	<20 cm	<20 cm
VERTICAL ACCURACY 95%	<40 cm	<40 cm
CONVERGENCE TIME	<300 s	<100 s
AVAILABILITY	99%	99%
USER HELPDESK	24/7	24/7

Target applications of HAS

- Galileo HAS addresses both traditional and emerging markets and applications

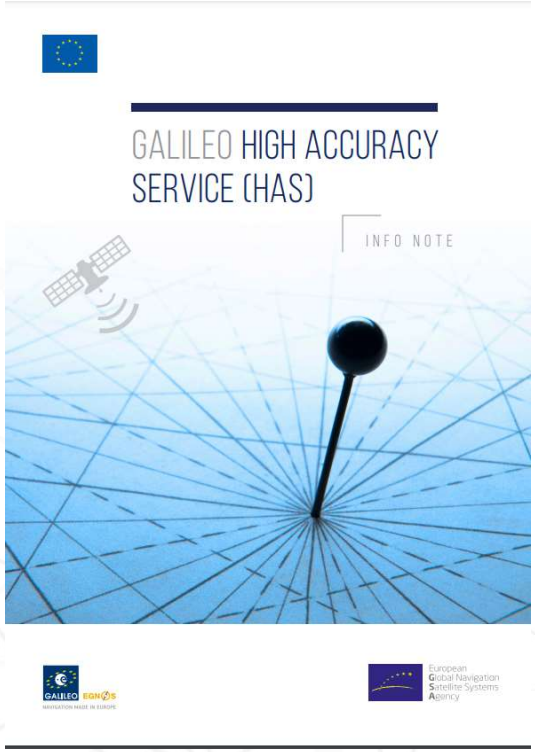


Galileo HAS… moved forward



MILESTONE
User Consultation Platform • The User Consultation Platform (UCP) is a forum for interaction between users of position, navigation and time solutions and the organisations and institutions dealing, directly and indirectly, with Galileo and EGNOS. The platform serves as a key tool for gathering user requirements and validating the Galileo HAS target performance • The UCP 2020 will be held during European Space Week on 7-11 December 2020 (https://www.euspaceweek.eu/)
Call for Expression of Interest • Participating in the HAS SiS ICD public consultation • Expressing interest in participating in ad-hoc HAS SiS testing campaigns • Providing feedback on specific HAS user requirements
HAS PO Testing
HAS SiS ICD Publication • Following the finalisation of the testing phase, the first version of the HAS message specification document is planned to be published
HAS Initial Service Declaration • After the necessary service validation activities, the HA Service will be declared available and the HA Service Definition Document will be published
HAS Full Service Operational Capability

HAS Info and status

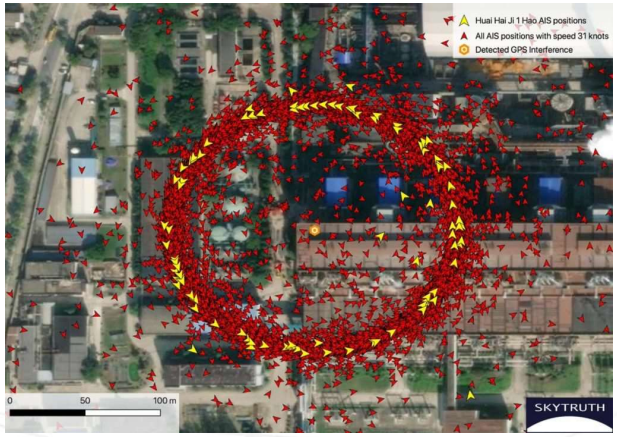


- Overview of the **main characteristics** of the service, along with information on features such as **service levels**, **target performance**, an **implementation roadmap**, and an overview of the **target markets** for the service
- First testing steps concluded: Dummy data transmission, generation of corrections with no broadcast, first transmission of corrections
  - Supported by GRC
  - Promising initial results

EUSPA-GAL-GRC-PFR-A14629_1.0_Galileo Services for 3D Surveys

OS-NMA: It's a matter of Trust

- OSNMA over-the-air testing since November 2020 without affecting standard OS users.
  - Supported by GRC
- Different OS-NMA configurations and processes (key renewal, revocation, etc.) have been successfully tested.
- Next steps: OS-NMA ICD/guidelines/keys publication and start of "Public Observation Phase"
- Commercial Authentication Service (including signal authentication) assisted concept consolidated and under prototyping



The Galileo Emergency Warning Service

- Global coverage
- No ‘mobile’ connection required - Resilience to ground destruction
- Uses existing Open Service signal spare capacity
- Multi-hazard (tornadoes, earthquakes, nuclear disaster or
- industrial disaster, terrorist attacks, …)
- On-demand broadcast of an alert message + associated guidance by Local Civil Protection Authorities
- Complementary to existing systems
- Reach out to population in a timely manner, whatever the size of the area

- Geo-location information encoded in the message to target only the relevant population
- Synergies with Copernicus Emergency Management Service and its other system capabilities
- An interoperable solution studied in cooperation with Japan and India

SAR …The Return

Remote Activation of Beacons

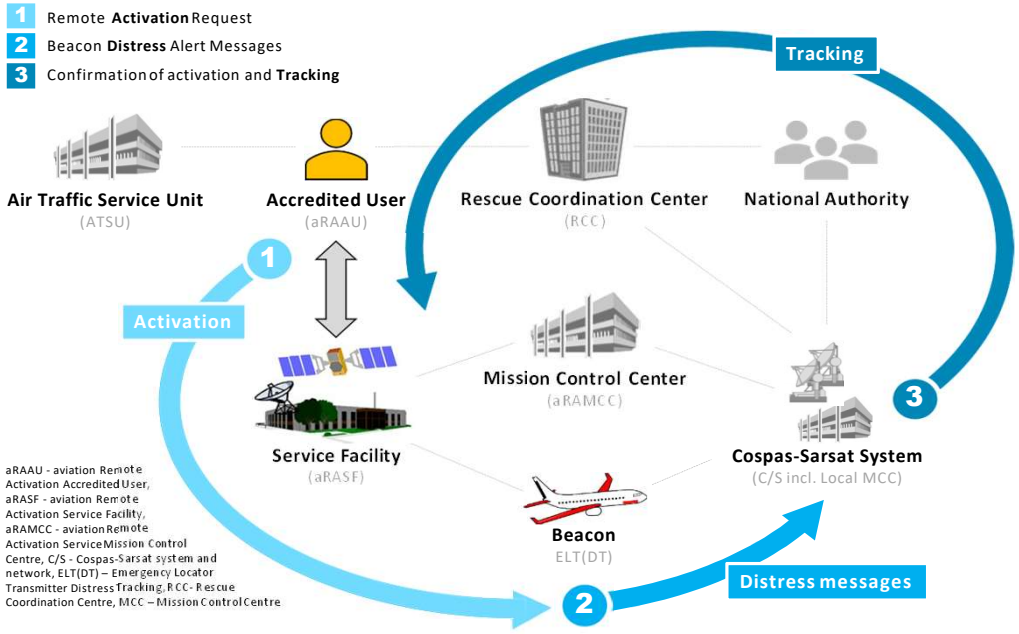
- EUROCAE standard approved
- Rescue Coordination Centre (RCC) (or airline) can contact Galileo to remotely activate a beacon via the Return Link Message (RLM) of Galileo
- Use cases: Aviation: aircraft disappearance, Un-responsive crew; Maritime: overdue vessel

Two-way (distress) communication

- Enabled by the long RLM; based on
- predefined Q&A helping the rescue mission

Distress Position Sharing

- RCC can contact Galileo to share the position of a beacon
- user in distress with other nearby users

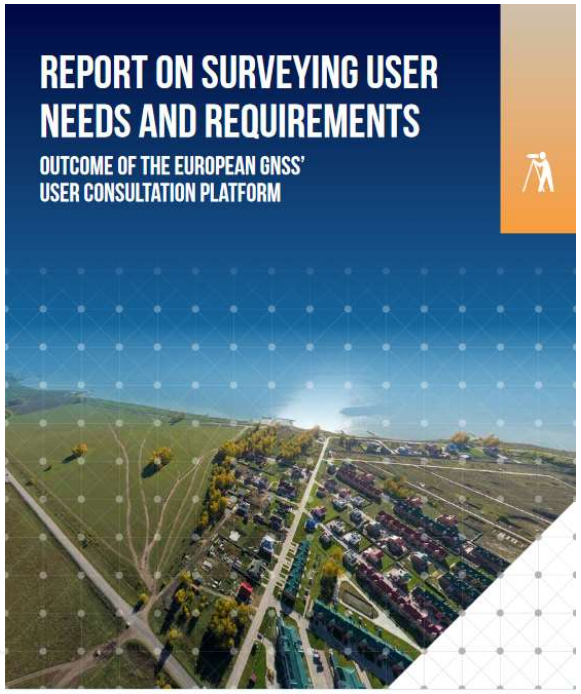


G2G Service Portfolio and High Level Mission

- Advanced Timing Services
- Space Service Volume
- ARAIM – coming back to serving SoL
- Emergency Warning Services
- Search And Rescue
- Ionosphere Prediction Service
- Signals Evolution – increased performance at user level (reduced power consumption, TTFF, accuracy authentication, etc.)
- SAR 2nd Generation Beacons
- PRS evolutions

Outline

- Status of Galileo
- New Galileo Services
- **Galileo for Surveying**
  - **Galileo only RTK: field test**
  - **Outlook HAS & OS-NMA**

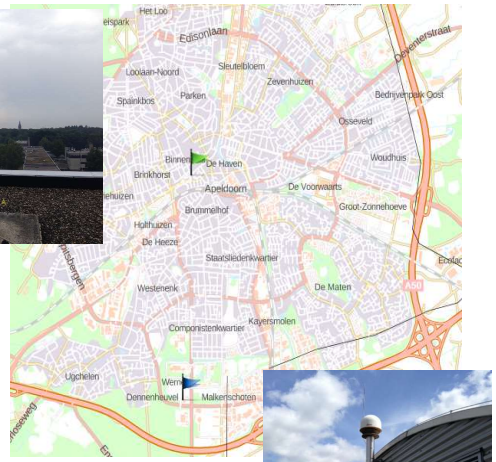


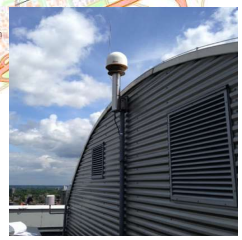
Motivation: Galileo-only RTK

- Galileo has declared the initial services in 2016
- The content of the Open Services and the expected availability and accuracy are described in a service definition document
- Explore the possibility of using Galileo as a stand-alone system, for RTK surveying. Question raised:
  - Can we plan a time slot where it is possible to do Galileo only RTK?
  - Can we do a cadastral boundary reconstruction of the GRC in Noordwijk (NL)?

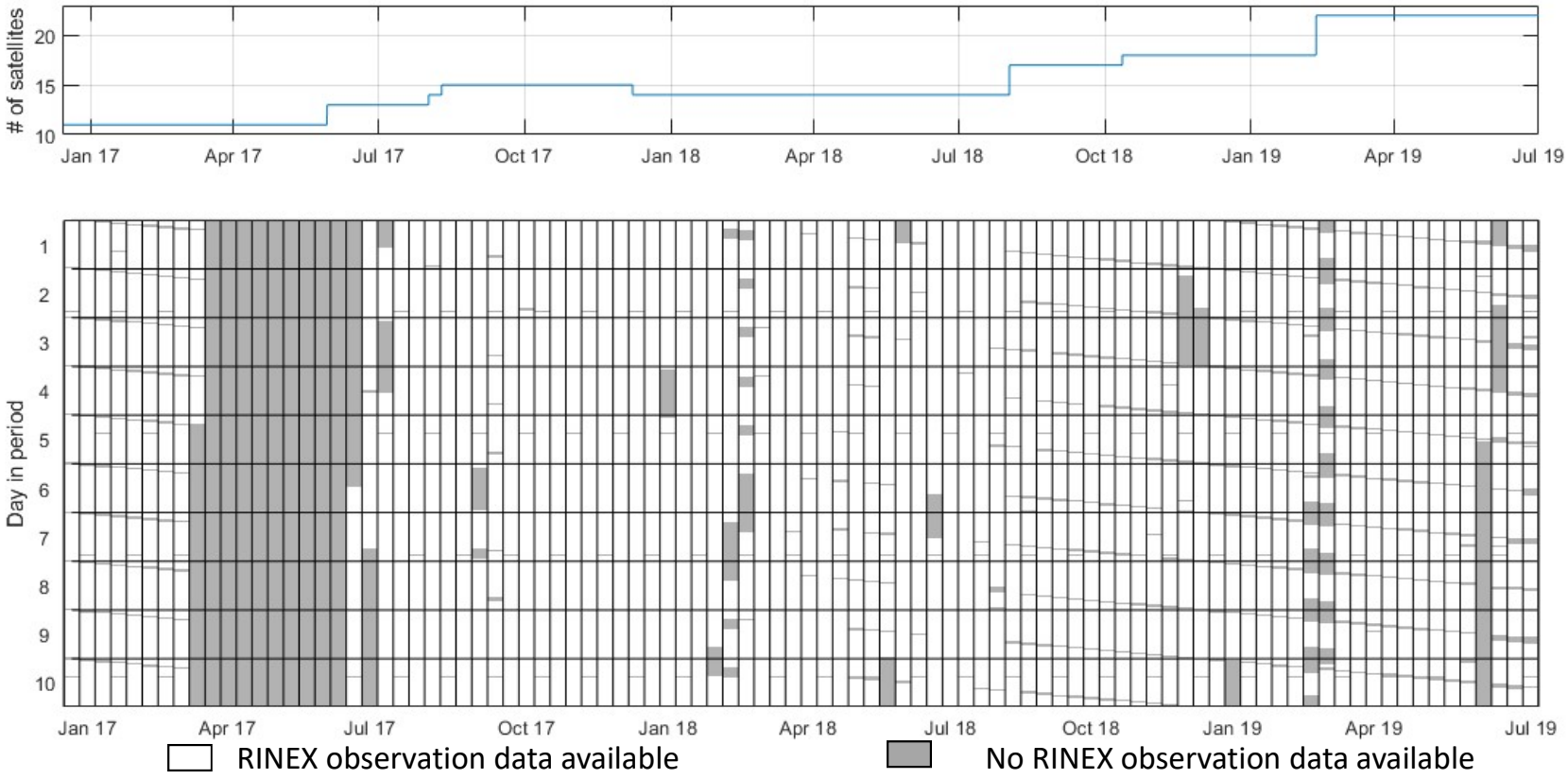
Experiment setup

- Single baseline (3.5 km, identical receivers and antennas at Kadaster in Apeldoorn (NL): Leica GR 50 and AR20 LEIM)
- RTKLIB library with minor modification to handle Galileo navigation messages and E5b signals.
- Post-processed as if RTK with ambiguity resolution
- 1 Hz data
- Triple frequency solutions (E1/E5a/E5b)
- Processing restarted every 15 minutes



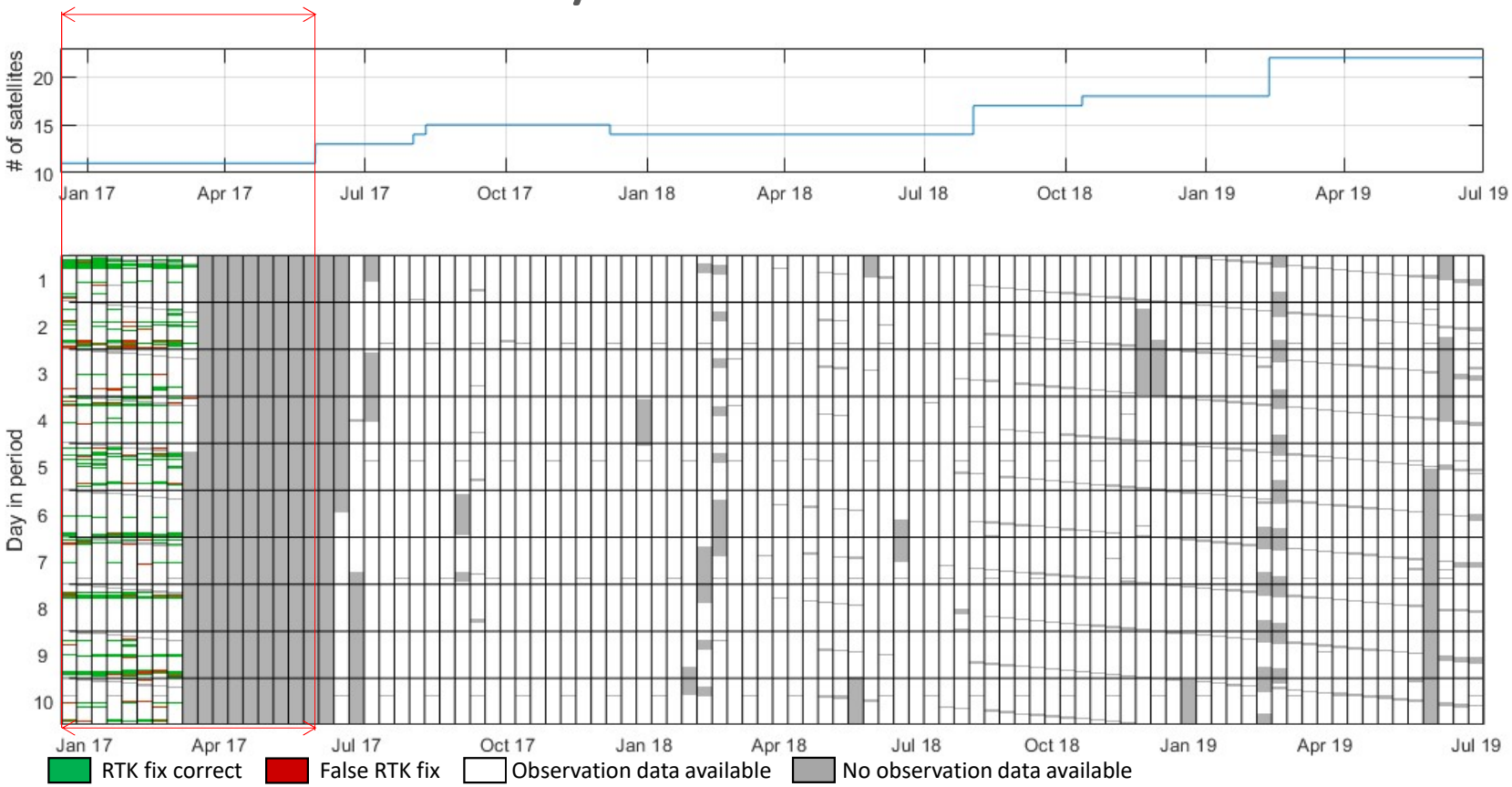


Observation and satellite data availability



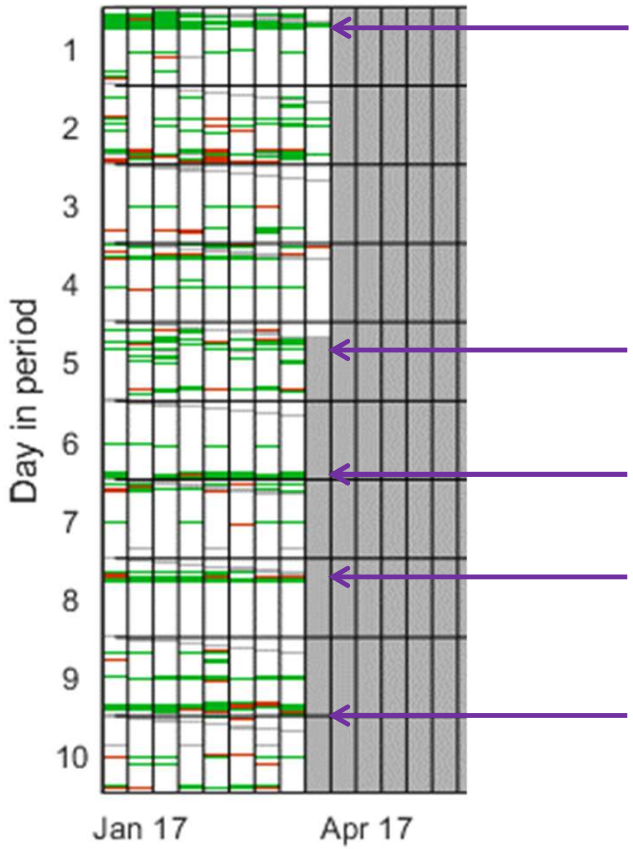
- The top graph show the number of operational Galileo satellites
- The bottom graph shows the availability of RINEX observation data
- The vertical axis shows the number of days in a 10 sidereal days Galileo geometry repetition period (start date 2016-12-15).
- The horizontal axis show the start of an Galileo repetition period from 2016-12-15 until 2017-07-31.
- Each cell in the plot is a sidereal day.

RTK availability 2016-12-15 to 2017-05-29



- This graph shows the availability of RTK fixes.
- A green line indicates that a correct Galileo only RTK fix was possible for a 15 minute interval.
- A red line indicates that a incorrect Galileo only RTK fix was achieved in the 15 minute interval.

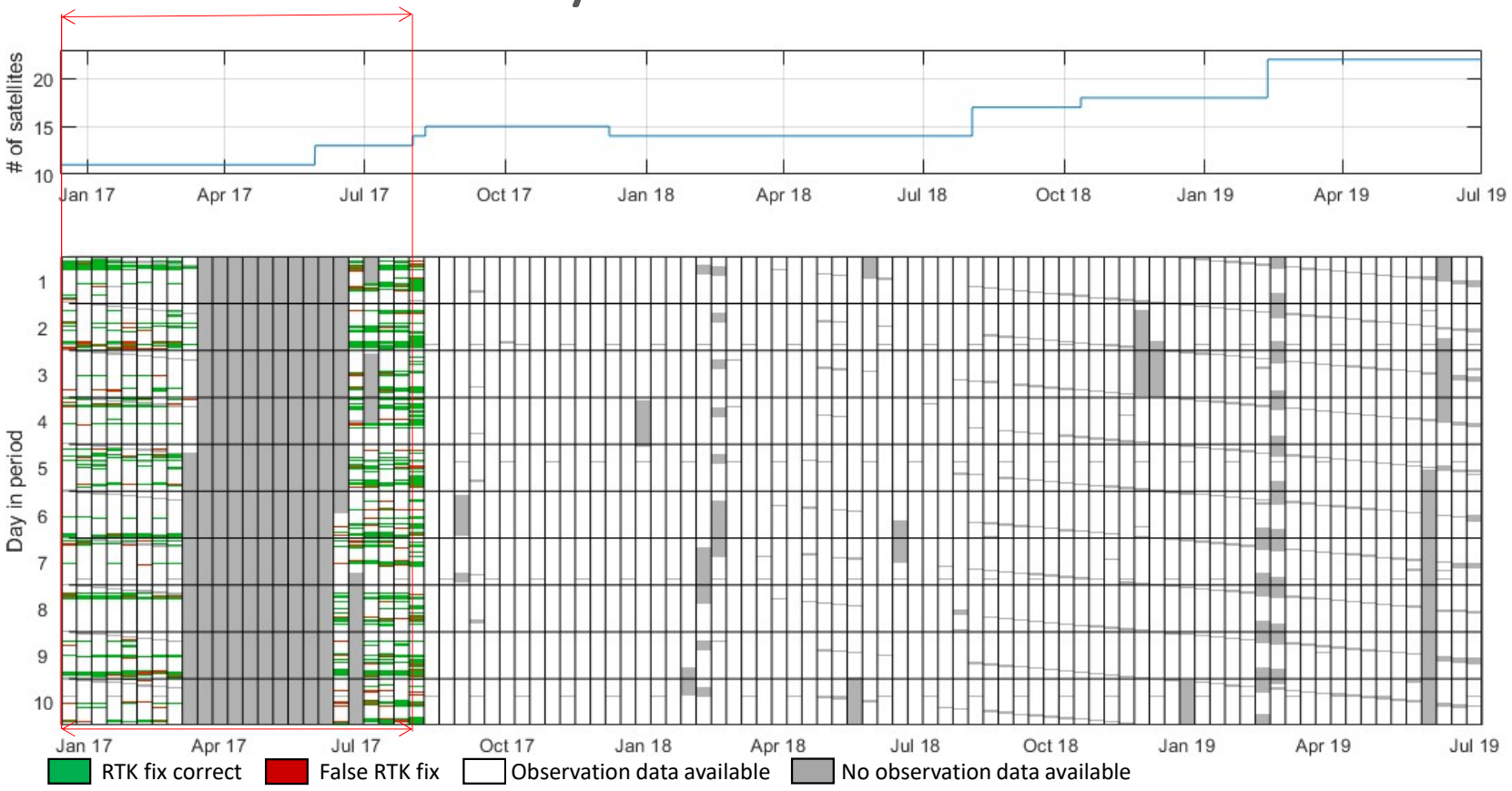
RTK availability 2016-12-15 to 2017-05-29



- A green line indicates that a correct Galileo only RTK fix was possible.
- A red line indicates that a incorrect Galileo only RTK fix was achieved.
- The criterion for a 'RTK fix' session is that a fix was possible at least 60 seconds of the 15 minute interval.
- The criterion for a 'RTK fix correct' session is that the median of the 3D position error of fixed epochs is less than 0.05 meter.
- The availability is limited but repeatable.

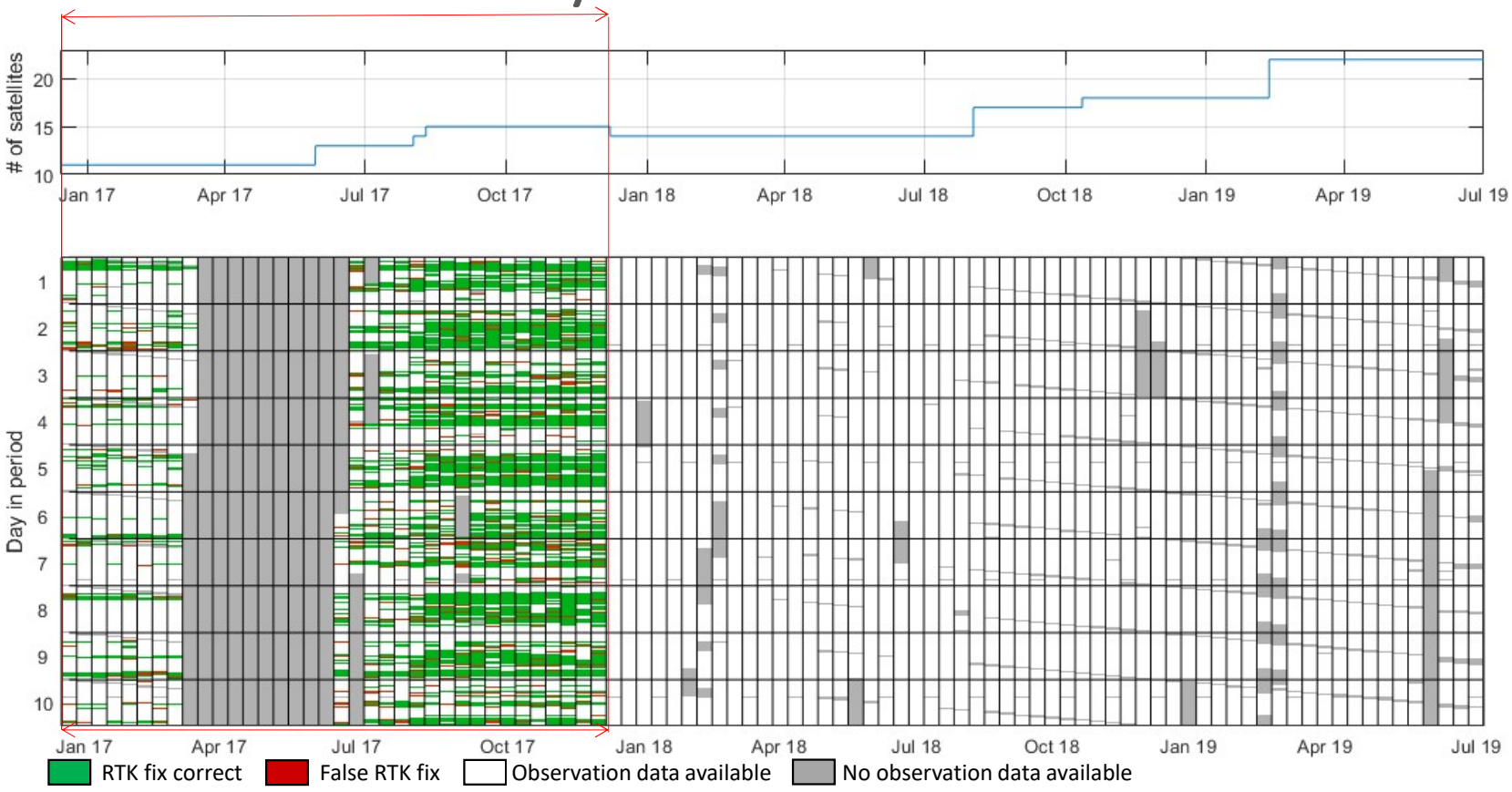
RTK fix correct | False RTK fix | Observation data available | No observation data available

RTK availability 2016-12-15 to 2017-08-01



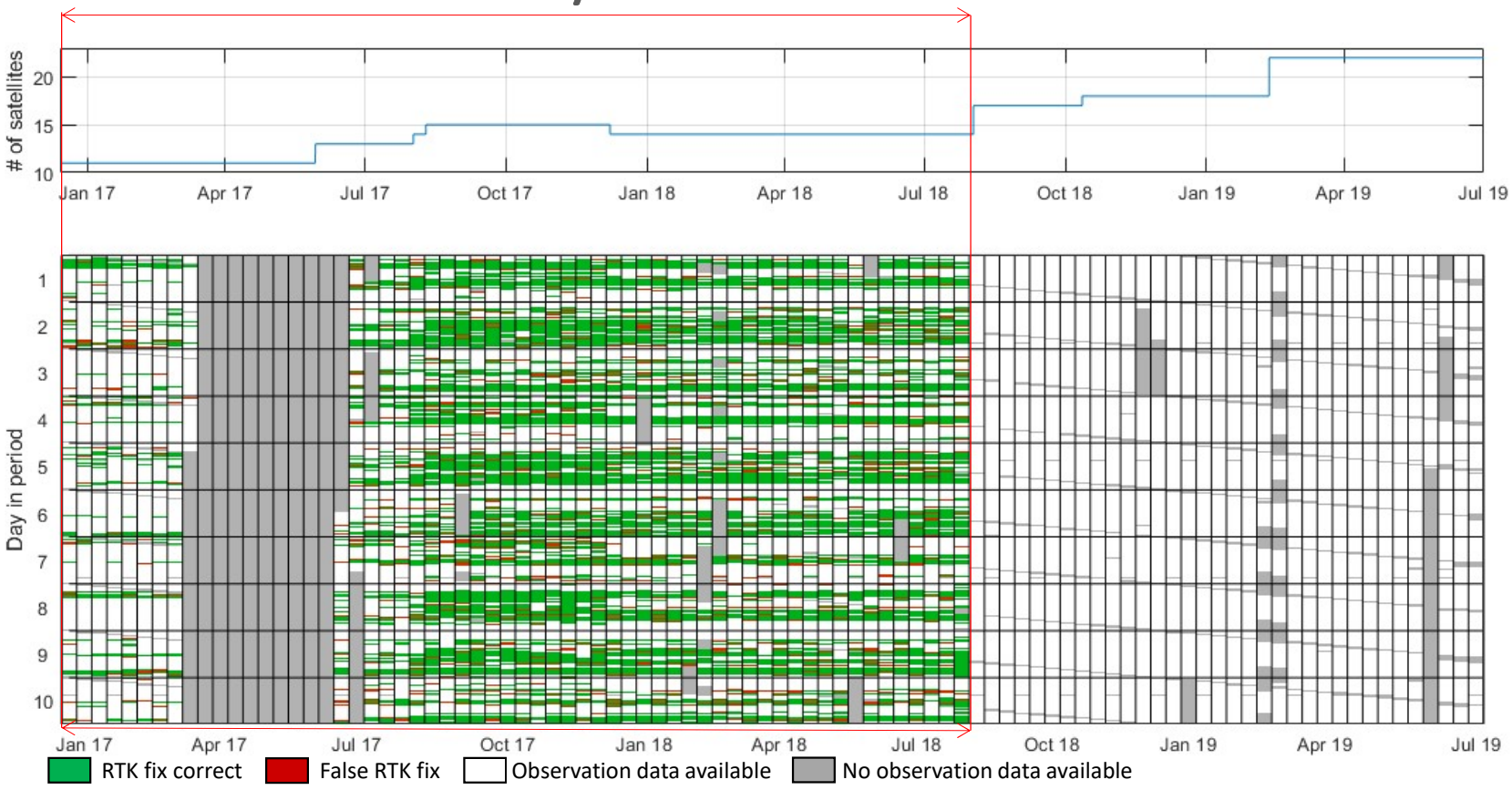
- This graph shows the availability of RTK fixes.
- A green line indicates that a correct Galileo only RTK fix was possible for a 15 minute interval.
- A red line indicates that a incorrect Galileo only RTK fix was achieved in the 15 minute interval.
- The availability increases with more satellites.
- The system remains stable.

RTK availability 2016-12-15 to 2017-12-08



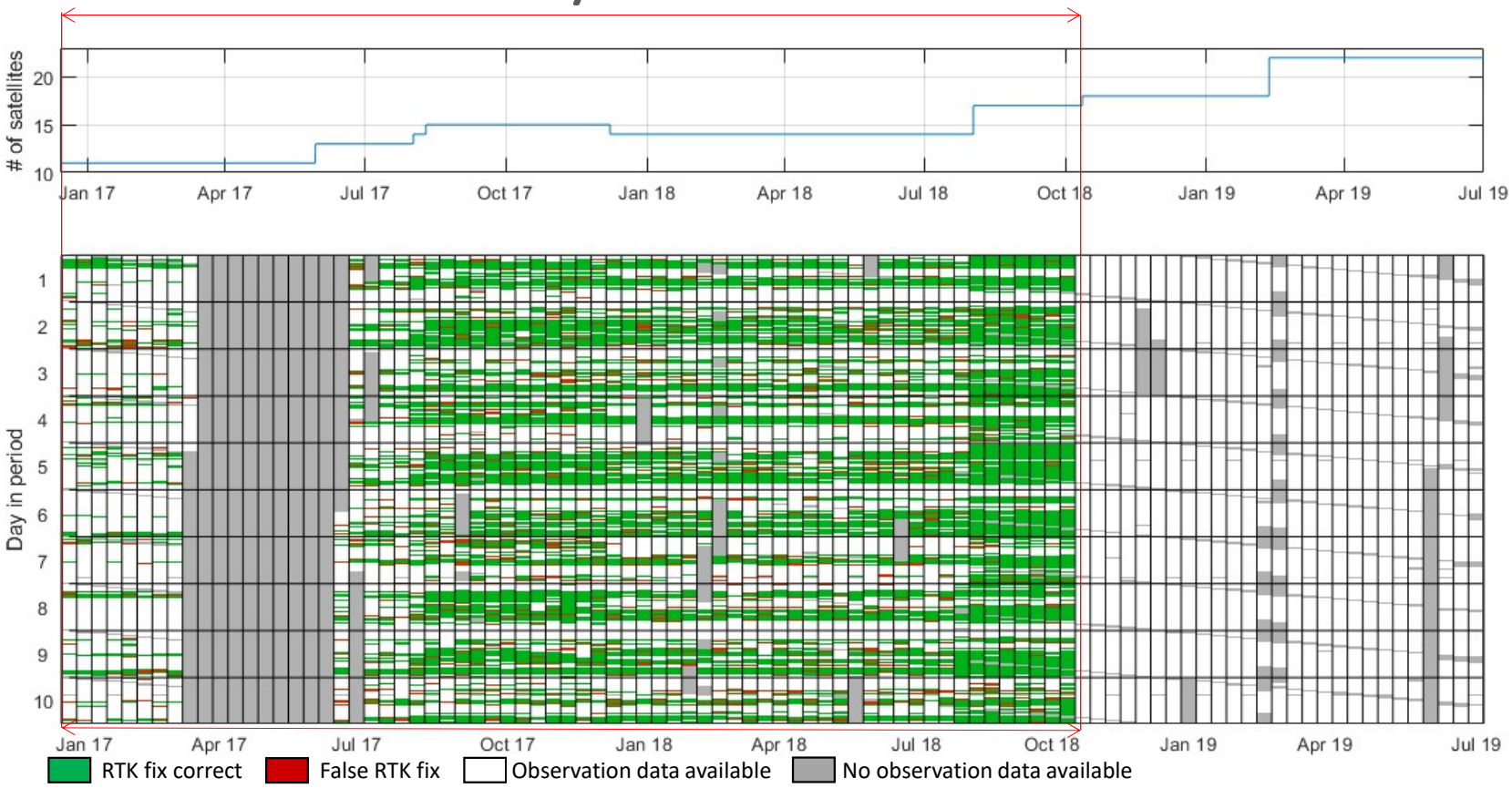
- The availability increases further with more satellites.
- The system remains stable.

RTK availability 2016-12-15 to 2018-08-02



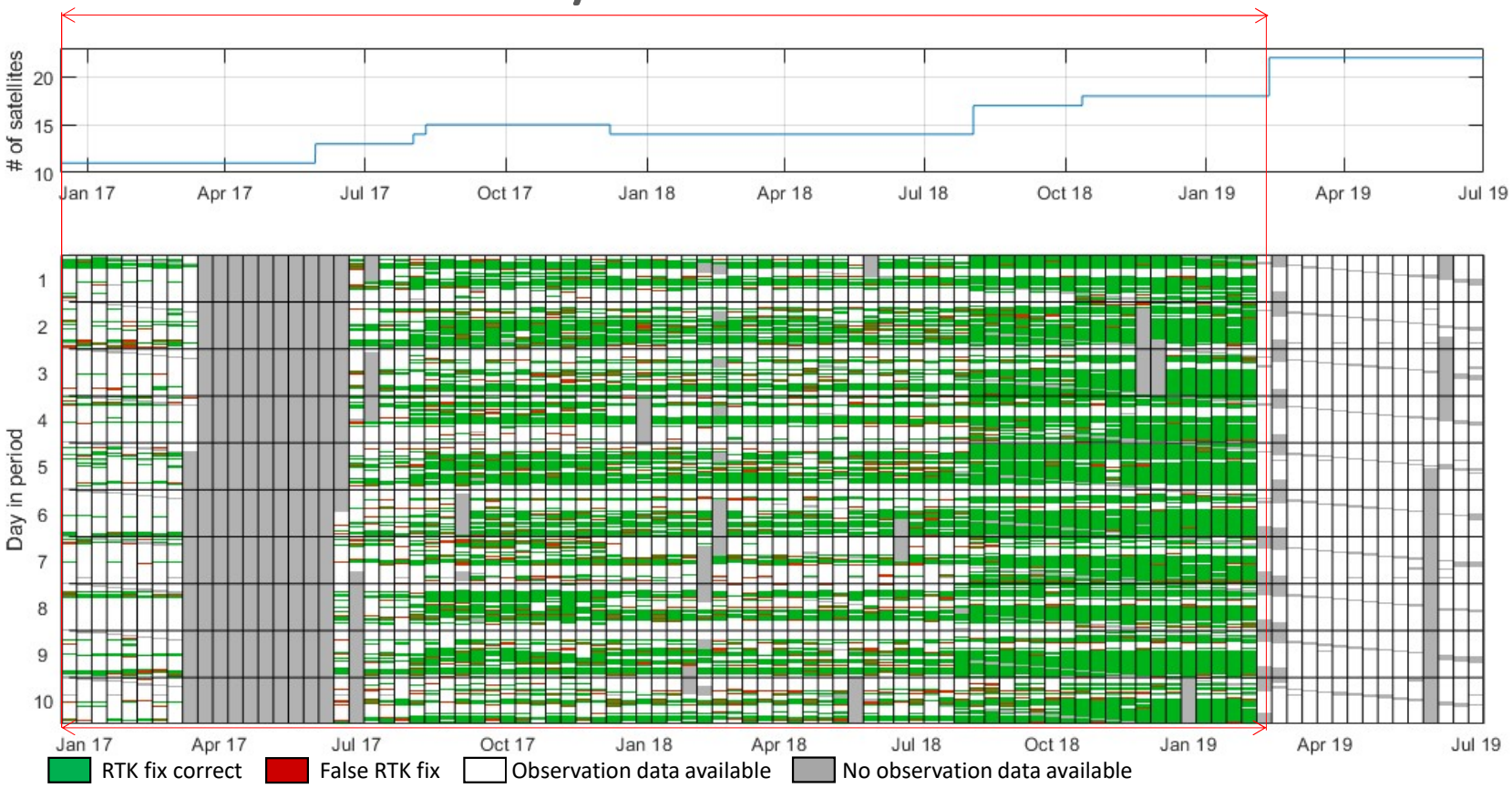
- The availability is slightly decreased with one satellite less.
- The system remains stable.

RTK availability 2016-12-15 to 2018-10-12



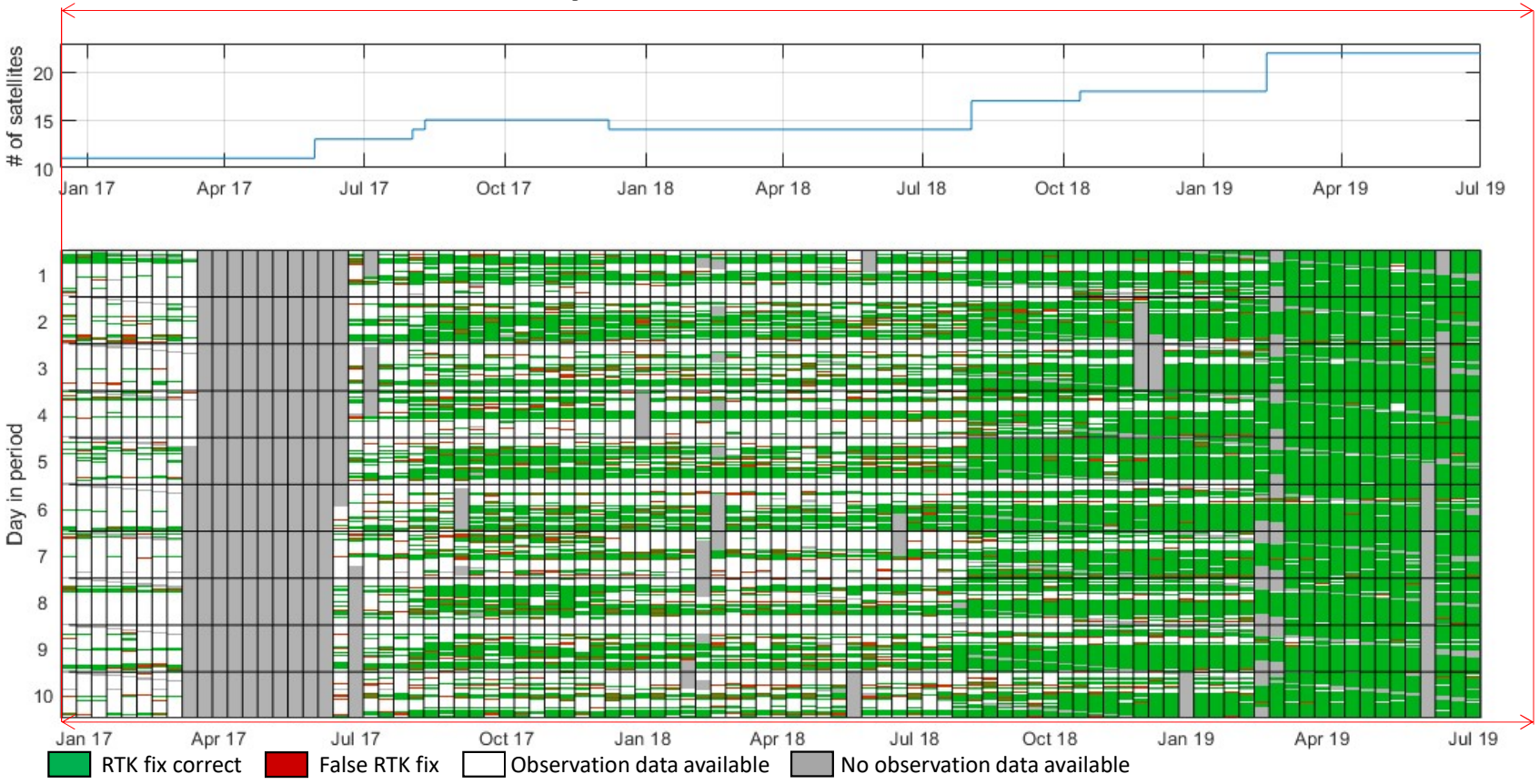
- A fix is available more often than not.

RTK availability 2016-12-15 to 2019-02-11



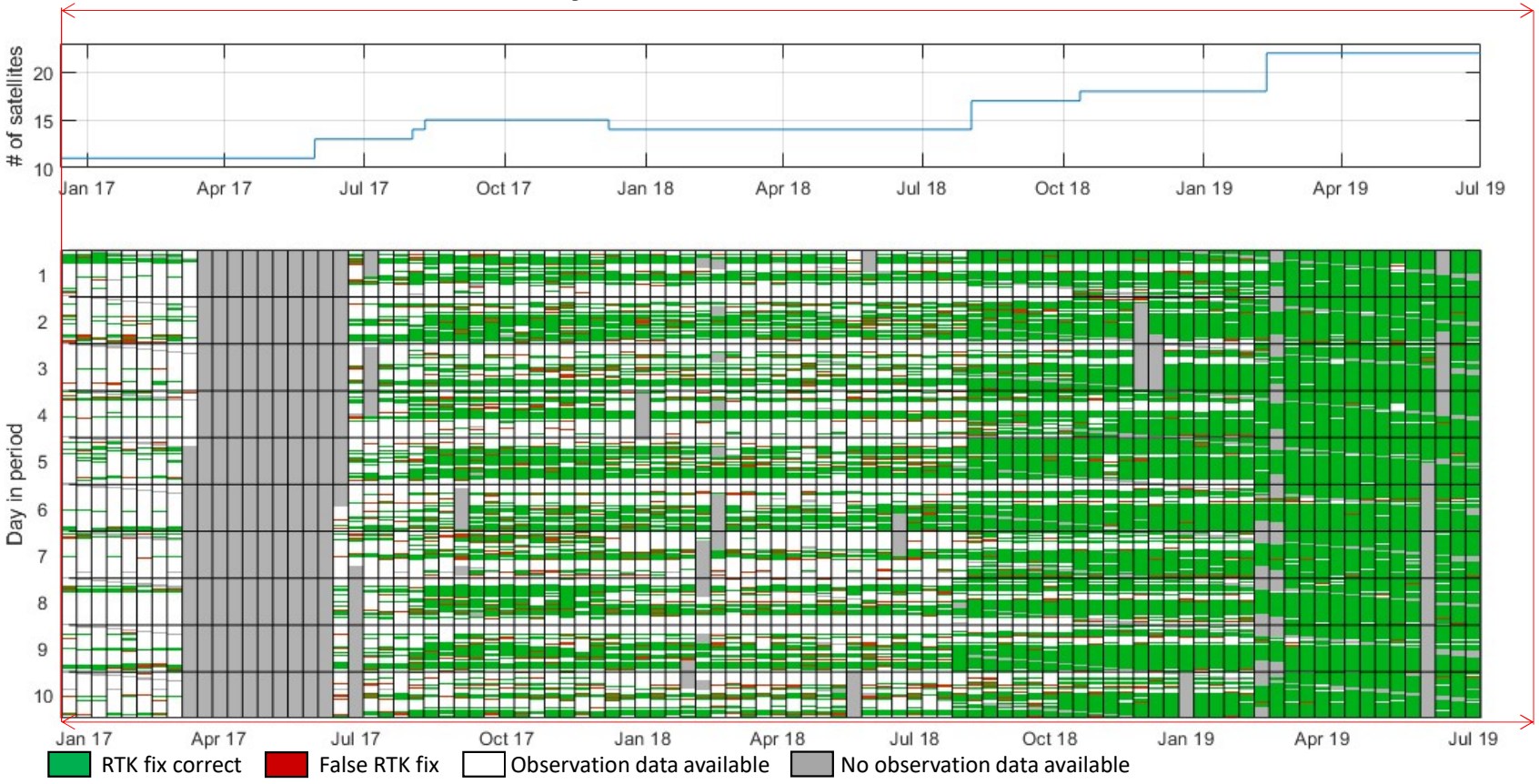
- A fix is available more often than not.

RTK availability 2016-12-15 to 2019-06-30



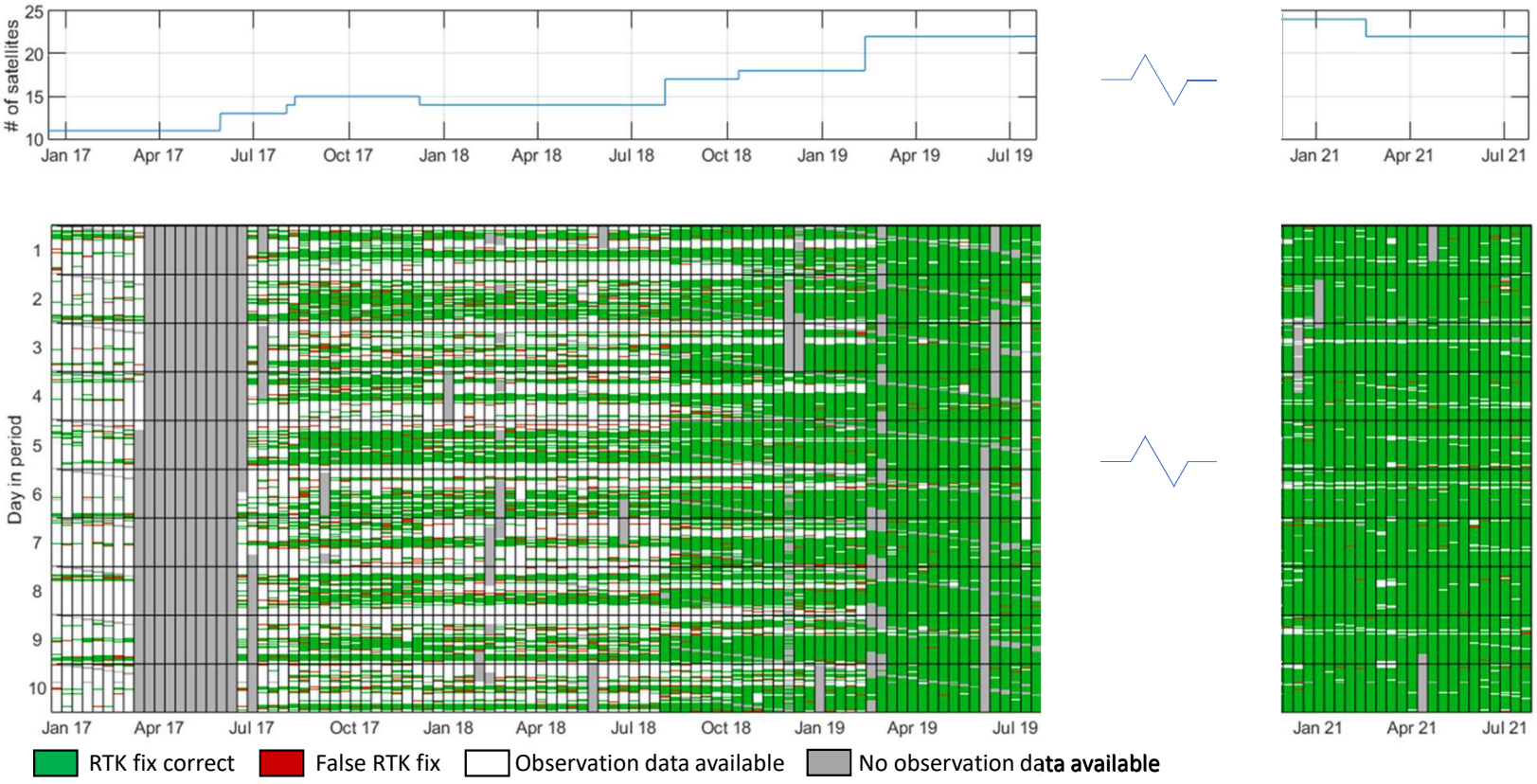
- A fix is available almost every 15 minutes.
- False fixes are rare.

RTK availability 2016-12-15 to 2019-06-30



- A fix is available almost every 15 minutes.
- False fixes are rare.

RTK availability 2016-12-15 to 2021-07-30



- Number of satellites remained stable from Summer 2019 - Summer 2021
- Therefore Galileo-only RTK availability remained high
  - A fix is available almost every 15 minutes.
  - False fixes are rare.

Galileo only RTK summary

- Can we plan a time slot where it is possible to do Galileo only RTK?
  - Galileo only RTK is possible starting from Galileo initial services declaration.
  - Availability of RTK fixes depends on the number of satellites.
  - Availability is repeatable with same satellite geometry.
- Next Cadastral boundary reconstruction of the GRC in Noordwijk (NL) using Galileo only RTK

October 7th 2019

Cadastral boundary reconstruction of the Galileo Reference Centre (GRC) in Noordwijk (NL) using Galileo only RTK

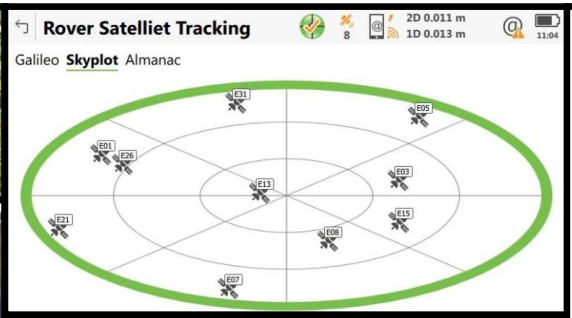
RTK Data Link Status

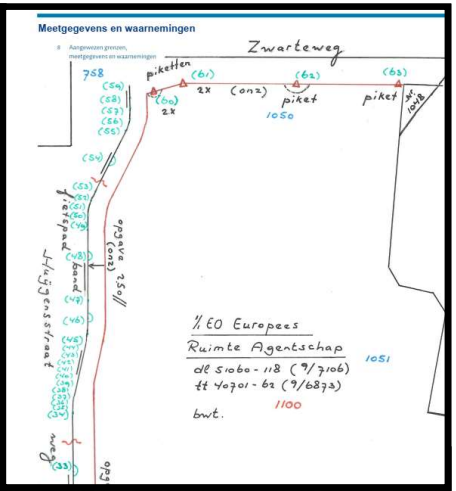
2D 0.010 m
1D 0.012 m

Algemeen Apparaat RTK basis Connectiviteit

RTK data formaat	**RTCM v3 (MSM)**
GAL gebruikt E1/E5a	**06/08**
GAL gebruikt E5b/ABOC	**08/08**
Laatst ontvangen	**0.5 sec**
In laatste minuut	**100 %**
RTK netwerk	**Geen**

OK Data Tab

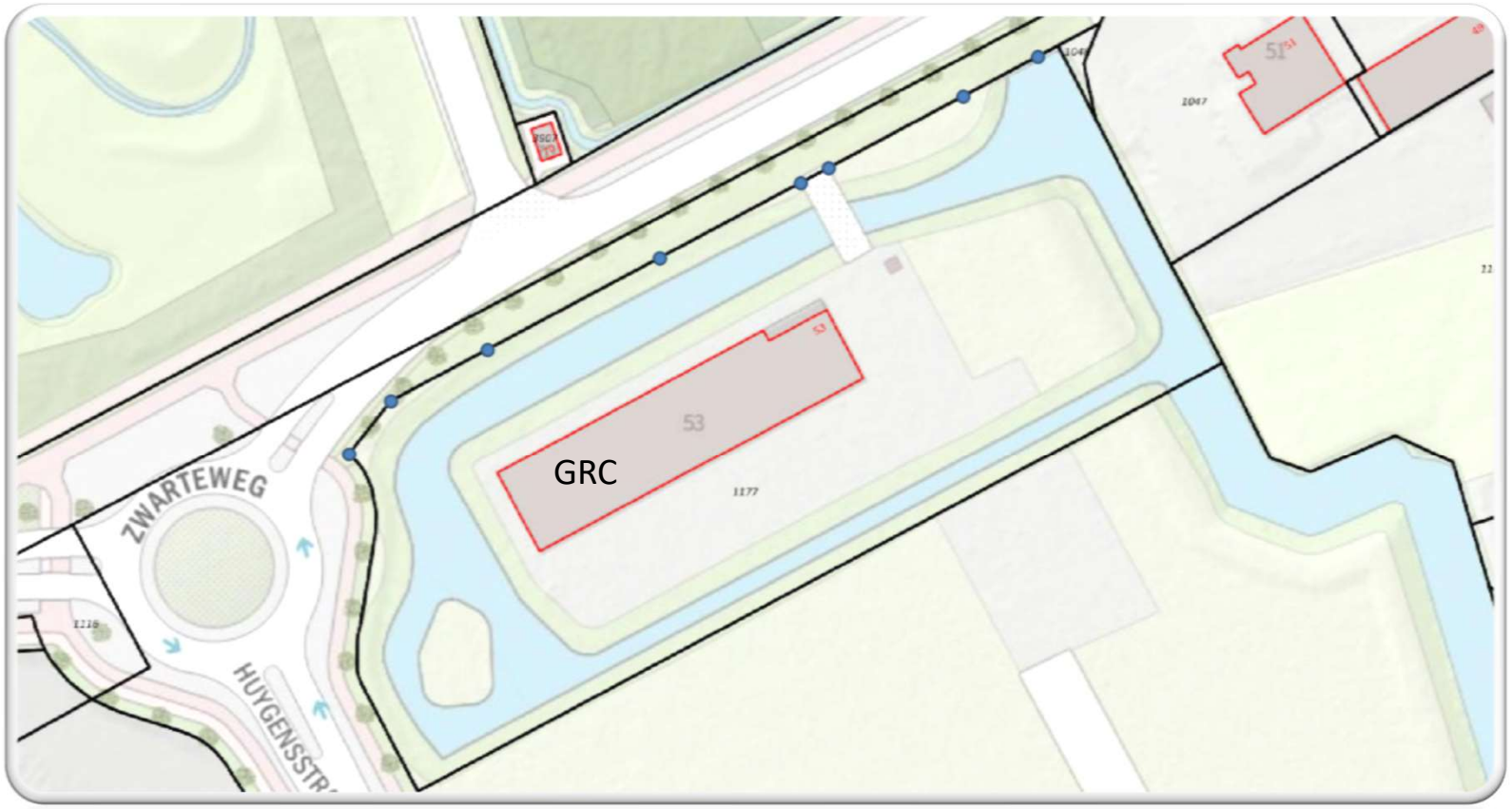




Boundary reconstruction result (1/2)

- Between 5 and 8 satellites available between 10:00 and 11:30 local time.
- After finalizing the boundary reconstruction all staked out points were measured again in network RTK mode, using GPS and GLONASS augmentation data from NETPOS, to verify the results.
- Next slide shows an overview of the boundary and its surroundings and the 2D differences between the measured coordinated using Galileo-only RTK and NETPOS RTK.
- The differences are at centimetre level which can be expected considering the RTK precision of 1 centimetre and the idealisation precision of about 1 cm of the stake out points.

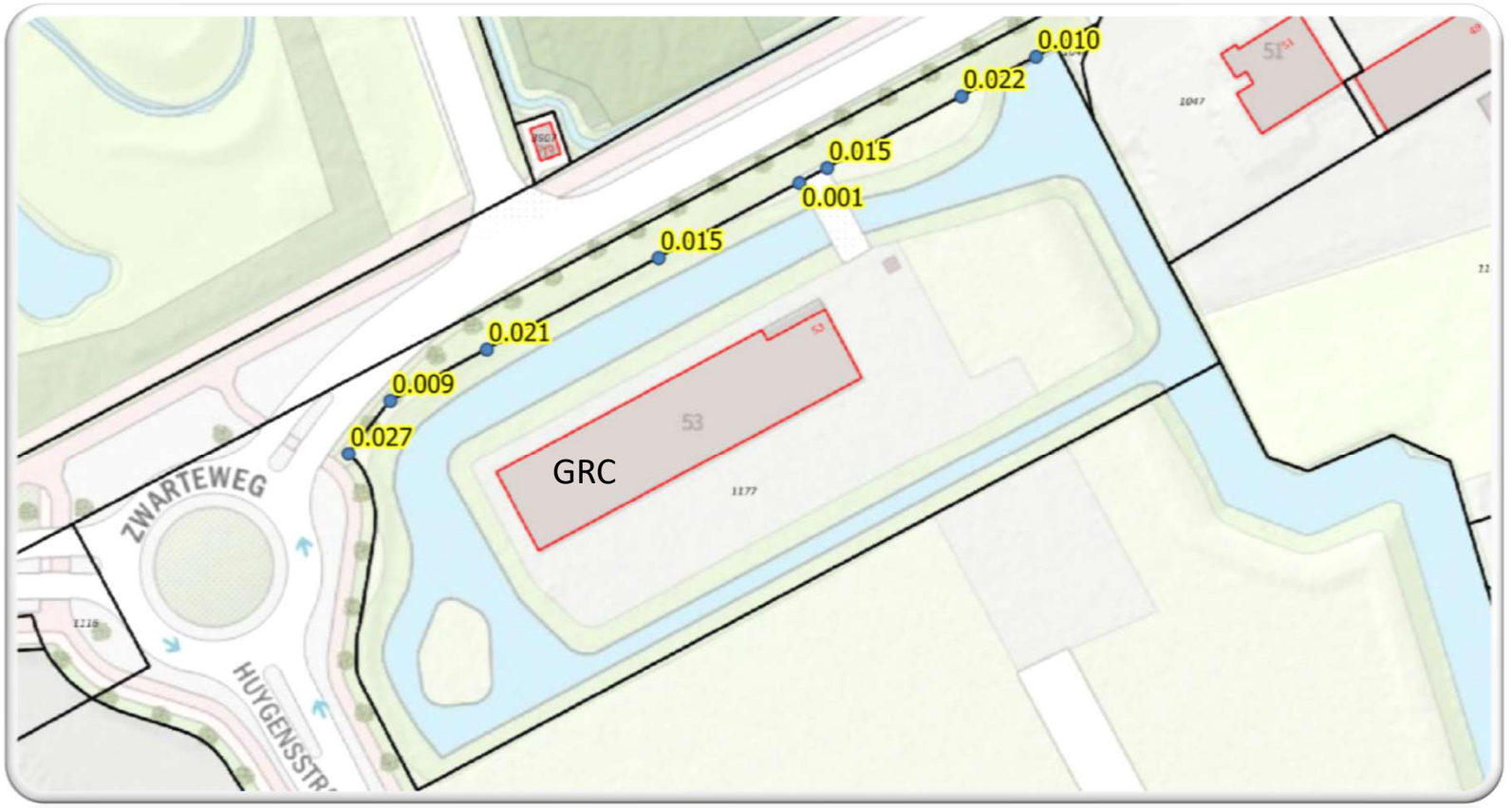
Boundary reconstruction result (2/2)



- Black line shows cadastral boundary.
- Blue points were staked out October 7th with Galileo only

Map source: www.opentopo.nl

Boundary reconstruction result (2/2)



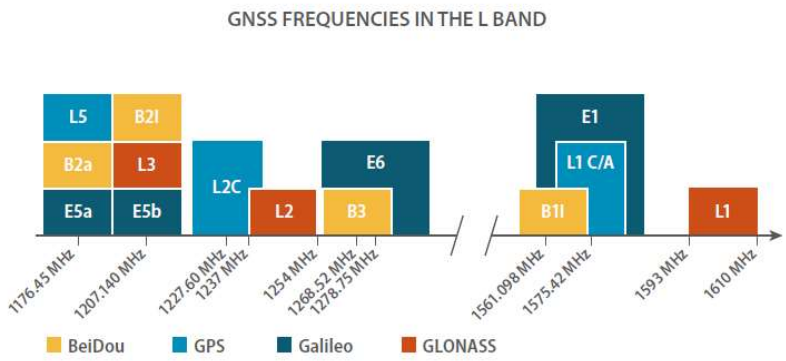
- Black line shows cadastral boundary.
- Blue points were staked out October 7th with Galileo only

- Values show difference in [m] between coordinates obtained with Galileo only RTK and NETPOS RTK service (GPS+GLONASS)

Map source: Kadaster www.opentopo.nl

Outlook: Galileo services for 3D-Surveys

Multi-frequency:
E5 as a 2nd frequency
E6 as a 3rd frequency



Better results in harsh environment (urban canyons, tree canopy, etc.) enabled by:

- Easier mitigation of multipath errors by E5 AltBOC modulation
- Higher SNR (signal-to-noise ratio)
- Additional satellites (Galileo + existing constellations)

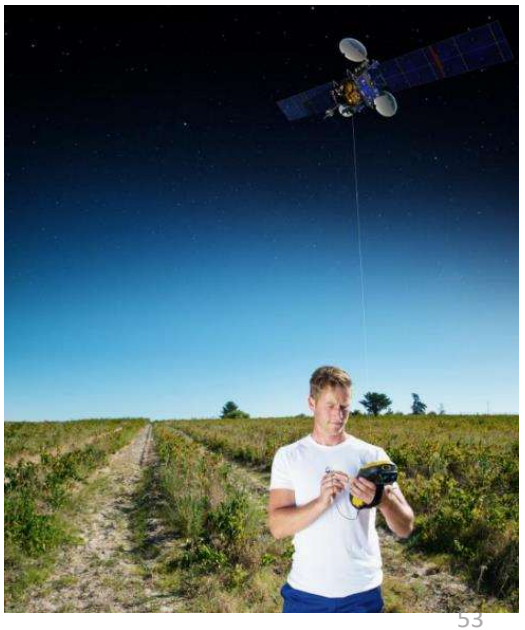
Increased availability, continuity and reliability of measurements enabled by:

- Additional satellites (Galileo + existing constellations)
- Improved geometry

Improved convergence time when integrated in PPP solutions

Outlook Galileo services for 3D-Surveys: High Accuracy Services

- FREE of charge
- Galileo will be the first constellation able to provide such High Accuracy service globally



- Allow innovation in consolidated and emerging markets.
- Enabling GLOBAL Positioning with Accuracies < 20 cm (H) / 40 cm (V)
- Improved Convergence for the Regional Service
- No need at user level for additional infrastructure (reference stations) nor network/internet connection
    - But corrections also provided over internet

GISCAD-OV Project

- Innovative GNSS High Accuracy Services for Cadastral Surveying
  - funded from the European GNSS Agency under the EU Horizon 2020 research and innovation programme grant agreement No 870231
- Objective: design, development and validation of reduced cost GNSS High Accuracy Services for Cadastral Surveying and Infrastructural Monitoring applications through Galileo HAS services, PPP and PPP-RTK
- Expected impacts:
  - Service Providers: reduced infrastructure and maintenance costs
  - Cadastral Professional users: reduced HA service costs
  - Receivers manufacturers: market uptake due to lower barrier to entry
  - National Mapping and Cadastre Administrations (NMCAs): Harmonized GNSS service levels over a wide area, improved efficiency

GISCAD-OV Project

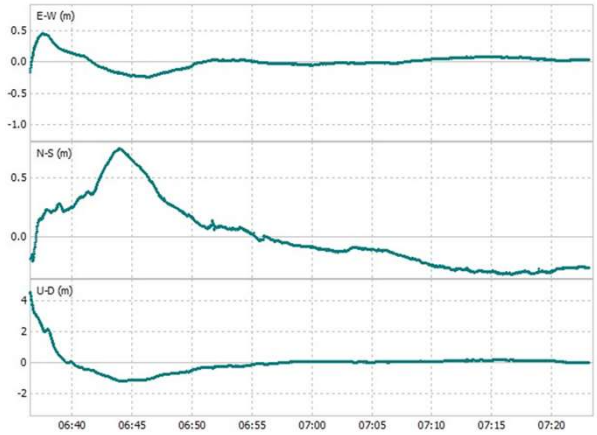
- Project Members:
  - International Organisation of Surveyors
  - Local and PPP Service Providers
  - Service Providers
  - PPP and NRTK Software Company
  - NMCAs
  - Surveyors Service Providers
  - Receiver Manufacturers
  - Universities
  - RTCM and ISO Standardisation Chairmen
  - Advisory Board, including NMCAs

Organization	Type
GEOWEB SpA	Industry
EXAGONE	Industry
IGN-CNIG	Public Body
SOGEI SpA	Industry
UNIPD	University
GEO++ MbH	Industry
NOVATEL Inc	Industry
YORK University	University
GEOFLEX	Industry
TU Delft	University
TELESPAZIO	Industry
VUGTK	Public Body
CLGE	Public Body
UNIROMATRE	University

GISCAD-OV: preliminary results

- Pilot project activities: Cadastral surveys in Italy and France
- Tested Services:
  - PPP-RTK
  - Galileo HAS

Surveying Method	Accuracy	Convergence Time
PPP-RTK (Local atmospheric correction)	2-3 cm	instantaneous
Galileo HAS: testing phase (No Reference Stations)	20 cm	15 min



Outlook Galileo services for 3D Surveys: Authentication

- Spoofing, the emerging threat across all market segments
- The authentication features of Galileo's new services may prove to fill a gap in surveying; currently no generally accepted technology exists to authenticate the position of the surveyor

OS Navigation Message Authentication (OS-NMA)

- Special encryption capability for Galileo messages to guarantee to the users that they are utilizing non-counterfeit navigation data that comes from the Galileo satellites and not from any other (potentially malicious) source
- Transmitted through E1 frequency
- Contributes to mitigate a well-known GNSS vulnerability (spoofing)
- Encryption based in a public-private key concept, transmitted to the users in a secure way
- Long-term cryptographically secure

FREE SERVICE

Commercial Authentication Service (CAS)

- Based on the E6-C Spreading Code Encryption to protect against more sophisticated attacks
- Increase the robustness of professional applications

Conclusions (1/2)

- Galileo services for Survey
  - Increased availability, continuity and reliability of measurements enabled by:
    - Additional satellites (Galileo + existing constellations)
    - Improved geometry
  - Increased availability of the Galileo supported RTK solutions, benefitting from the high accuracy of its observables, and multiple frequencies
  - PPP solutions benefit, as well, in terms of convergence time, accuracy and robustness
- Surveying hardware is Galileo capable.
- Galileo only Cadastral boundary reconstruction of the Galileo Reference Centre premises by Kadaster on 2019-10-07.
  - Centimeter level accuracy

Conclusions (2/2)

- Galileo will be offering ‘’Free’’ global high accuracy service (<20cm) directly from satellites without dependency of Internet or additional communication channels
  – without the need at user level for additional infrastructure
- Galileo will also offer increased robustness to spoofing thanks to its the OS Navigation Message Authentication (OS-NMA) and Commercial Authentication Service (CAS)
  – may prove to fill a gap in surveying; currently no generally accepted technology exists to authenticate the position of the surveyor

More information

- Galileo Programme documents and performance reports
  - https://www.gsc-europa.eu/electronic-library/
- *Galileo Only Cadastral Survey* (10573), Huisman, L., Vet, A., Hoentjen, K. and Buist, P., FIG Working Week 2020, Smart surveyors for land and water management, Amsterdam, the Netherlands, 10–14 May 2020
- H2020 Project Galileo Improved Services for Cadastral Augmentation Development On-field Validation
  - https://giscad-ov.eu/
- *Overview of the Galileo Reference Centre: Mission, Architecture and Operational Concept*, Buist, P., Mozo, A., Tork. H. (2017), Proceedings of the 30thInternational Technical Meeting of The Satellite Division of the Institute of Navigation (ION GNSS+2017), Portland, Oregon, United States, September 2017, pp. 1485-1495.
- *The Galileo Reference Centre and Its Role in the Galileo Service Provision*, Buist, P., Porretta, M., Mozo, A., and Tork, H.(2018), 69th International Astronautical Congress (IAC), Bremen, Germany, 1-5 October 2018.
- *Galileo Performance Workshop 2021: All you need to know about the performance of Europe's GNSS*
  - https://www.euspa.europa.eu/newsroom/european-space-expo/webinar-%e2%80%9call-you-need-know-about-performance-europe%e2%80%99s-global-navigation

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