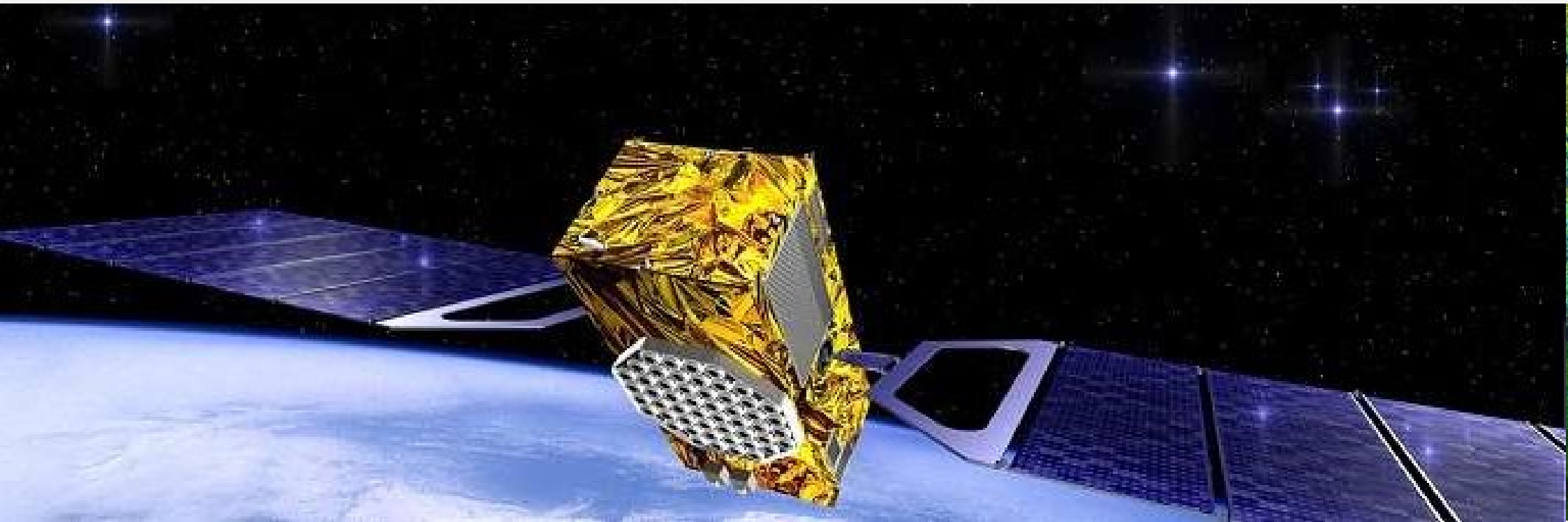


Galileo High Accuracy Service (HAS) performance

Michael Dähn

Reykjavik, 13.03.2024



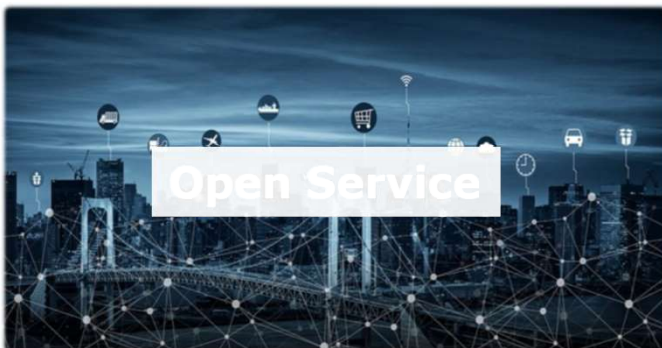
Part I

Background

Galileo services



Galileo services

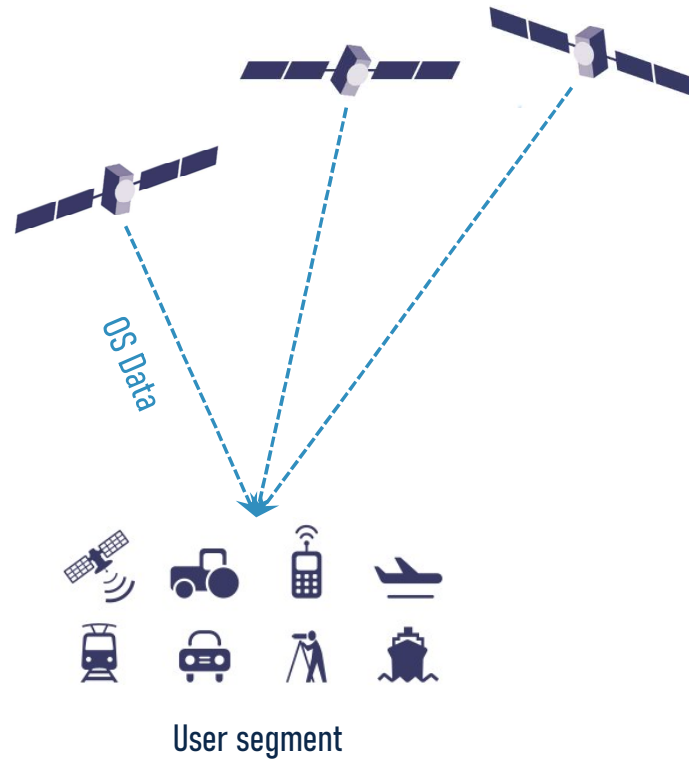


What is Galileo HAS?

- Galileo High Accuracy Service (HAS) is high-precision positioning service
- Established by European Commission
- Decimeter level positioning accuracy target (Horizontal: 20 cm, Vertical: 40 cm)
- Galileo HAS delivers correction data for Galileo Open Service (OS) and GPS Standard Positioning System (SPS)
- A real-time service, which is globally available, free of charge and its data delivery is based on open formats
- Available for an unlimited number of users

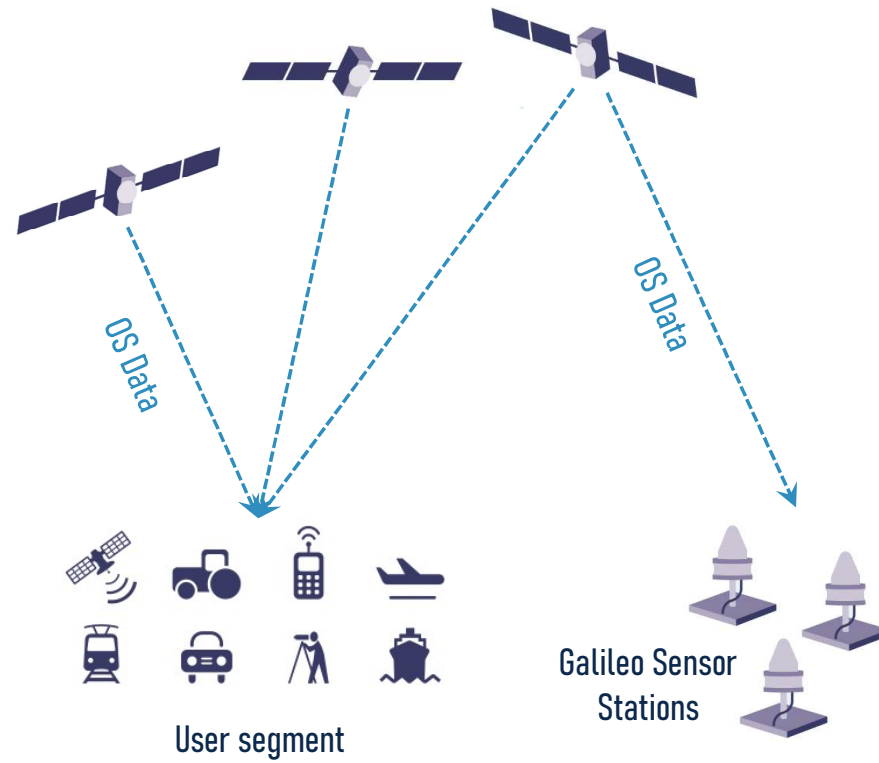


Galileo HAS architecture



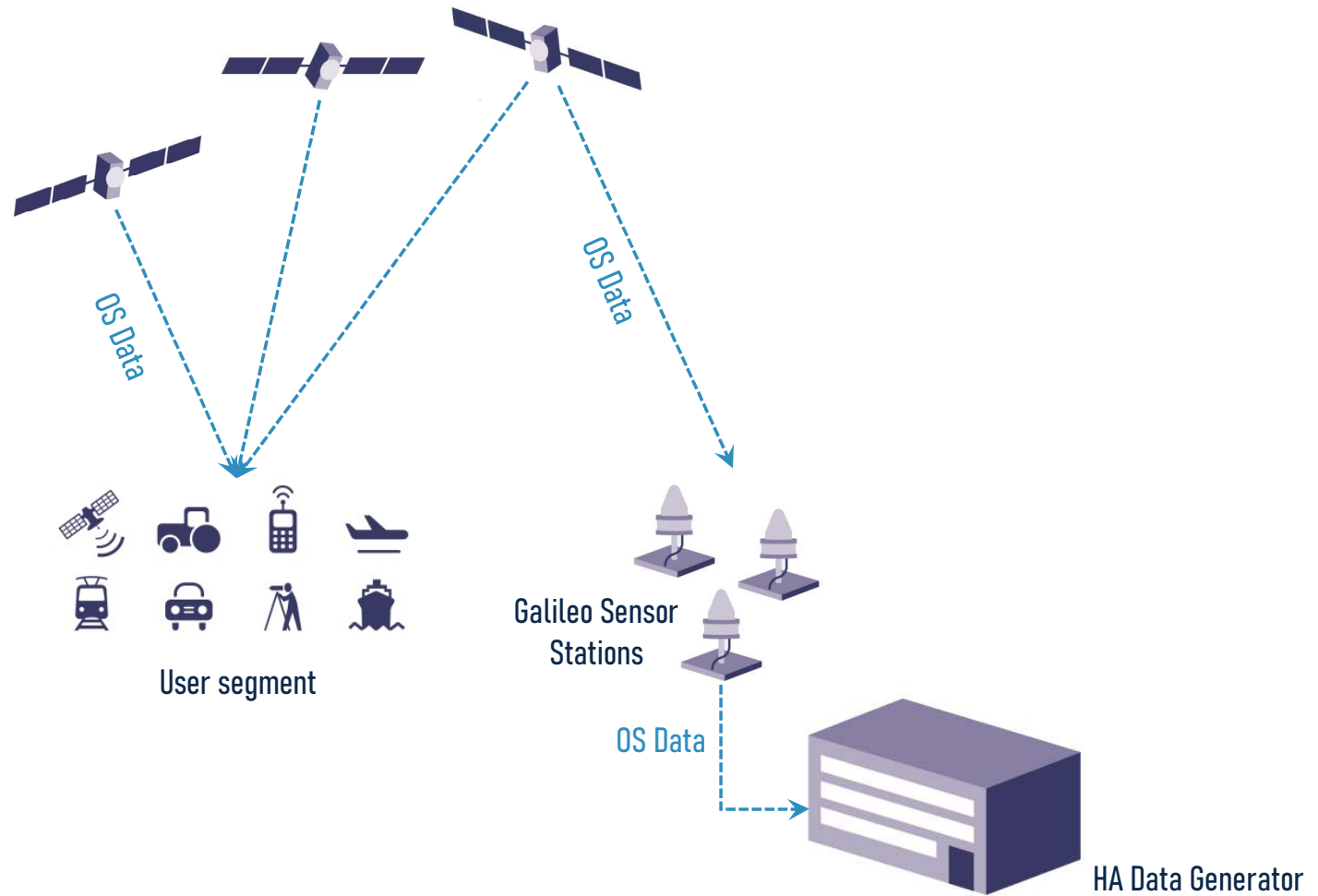
Source: Based on Galileo HAS Info note.

Galileo HAS architecture



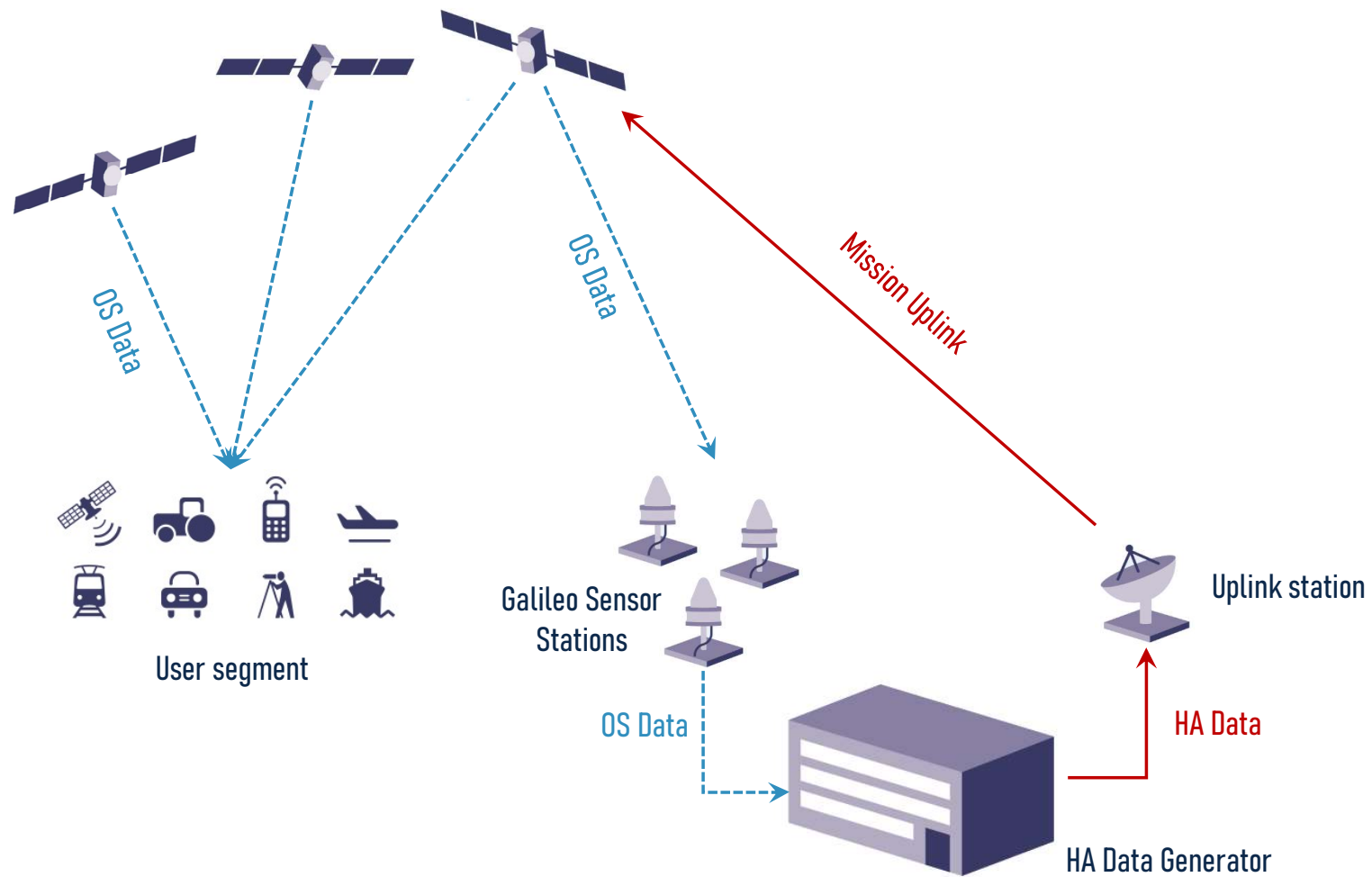
Source: Based on Galileo HAS Info note.

Galileo HAS architecture



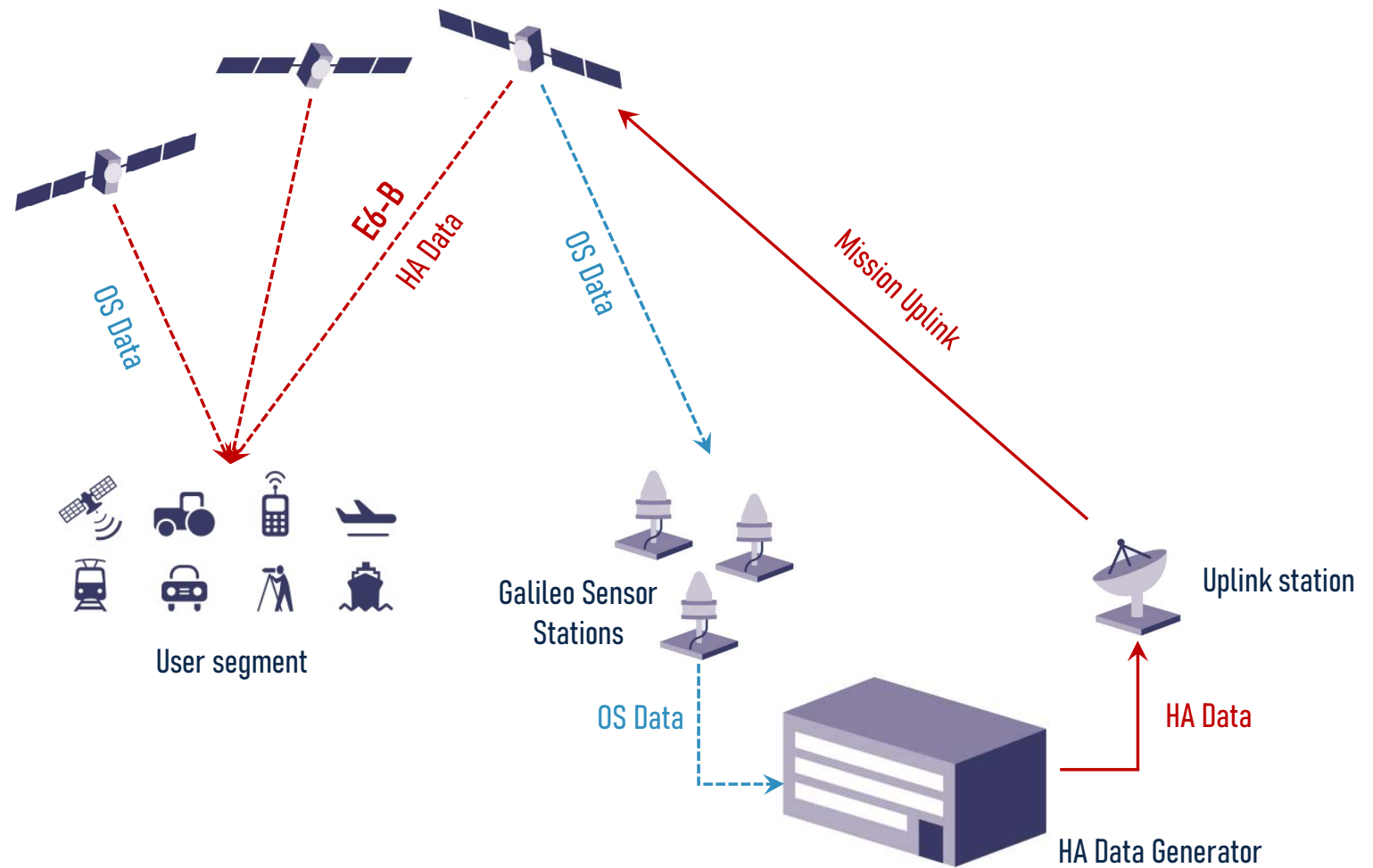
Source: Based on Galileo HAS Info note.

Galileo HAS architecture



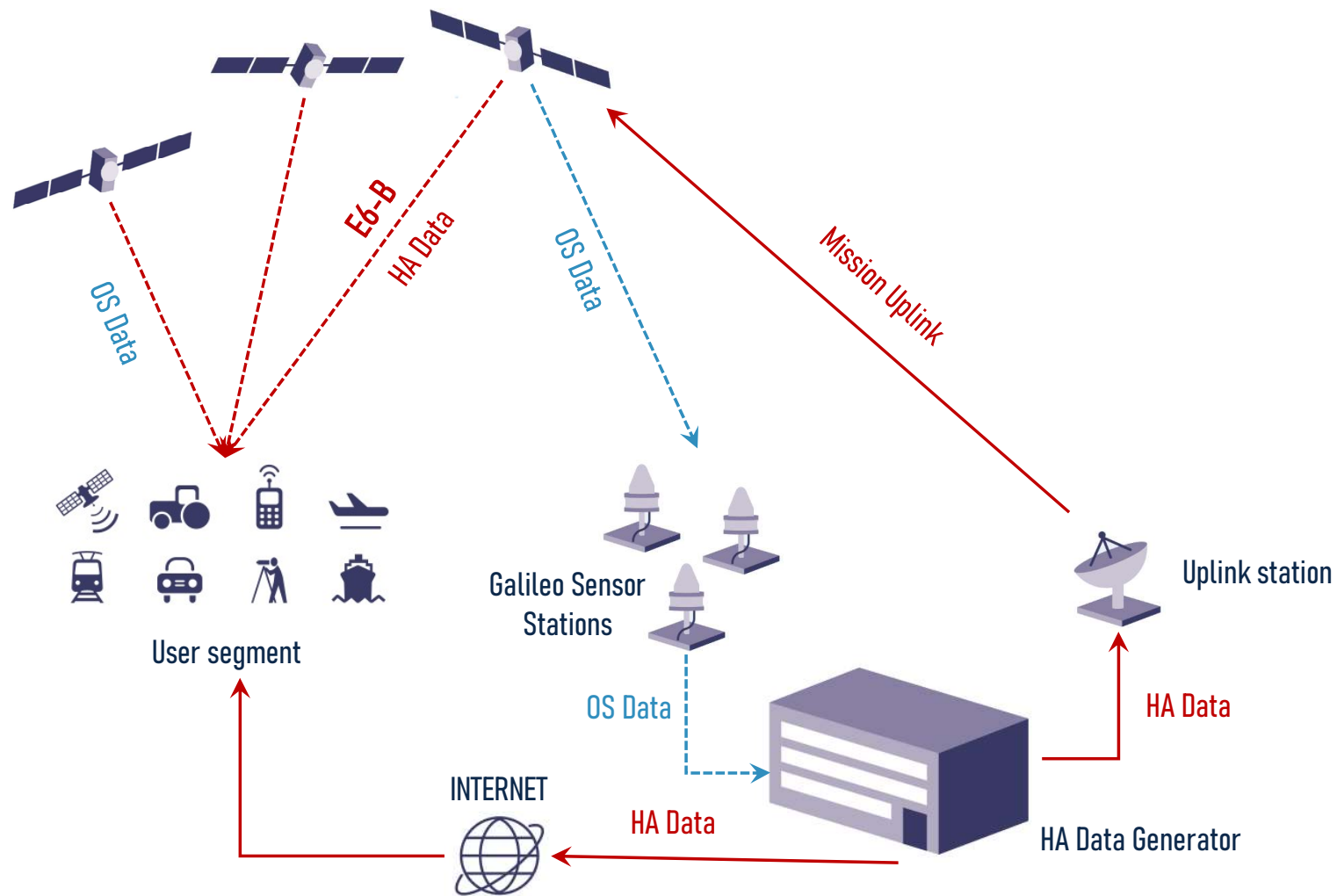
Source: Based on Galileo HAS Info note.

Galileo HAS architecture



Source: Based on Galileo HAS Info note.

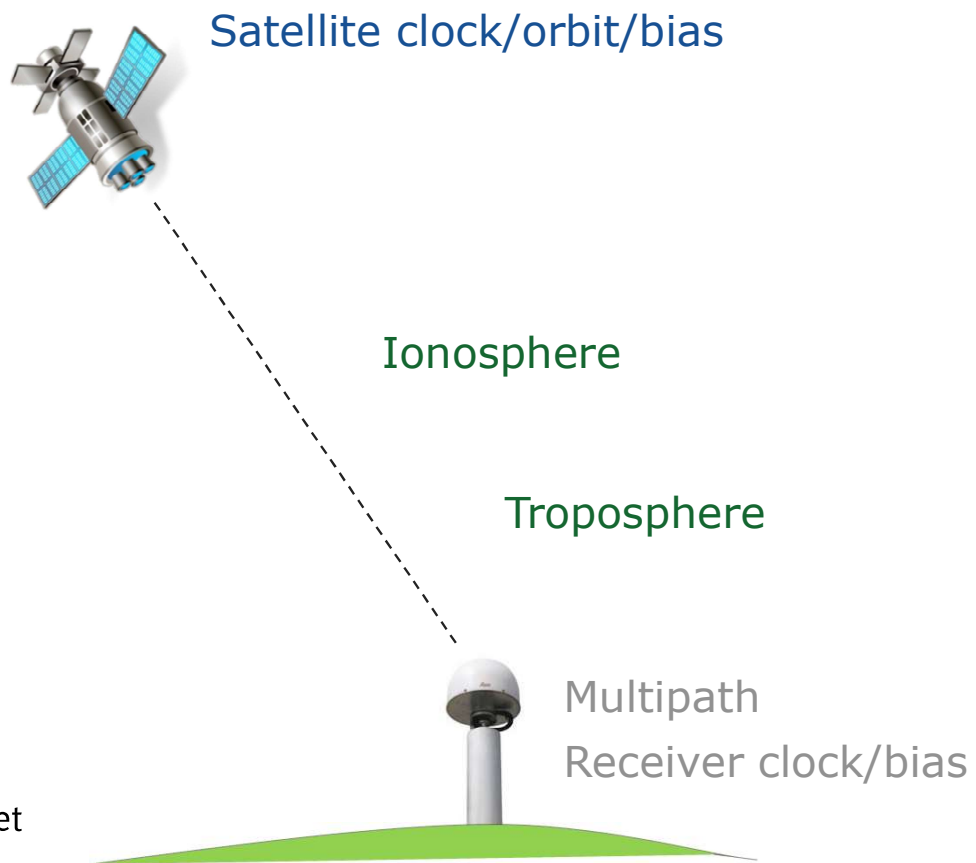
Galileo HAS architecture



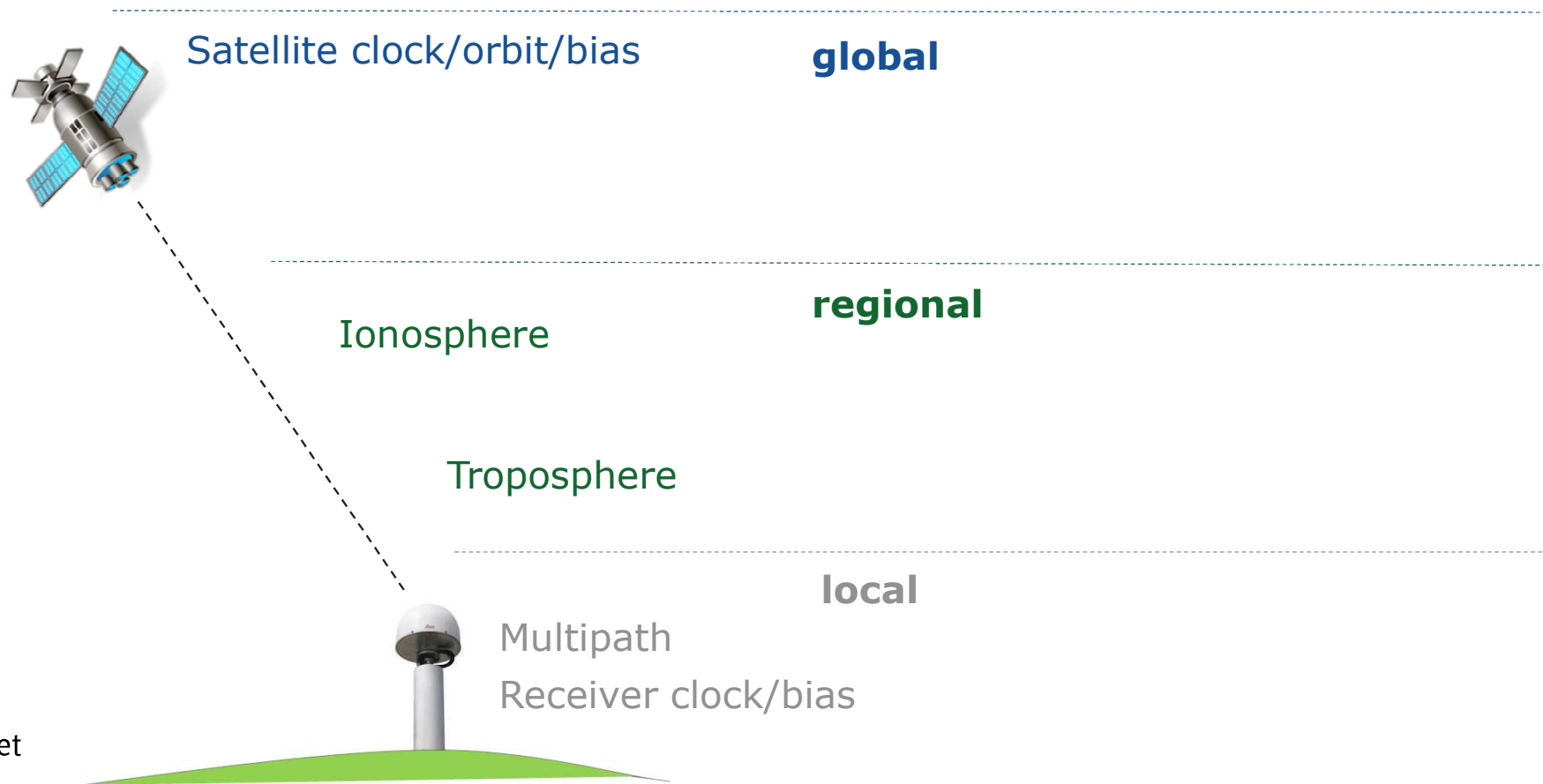
Source: Based on Galileo HAS Info note.

How works Galileo HAS?

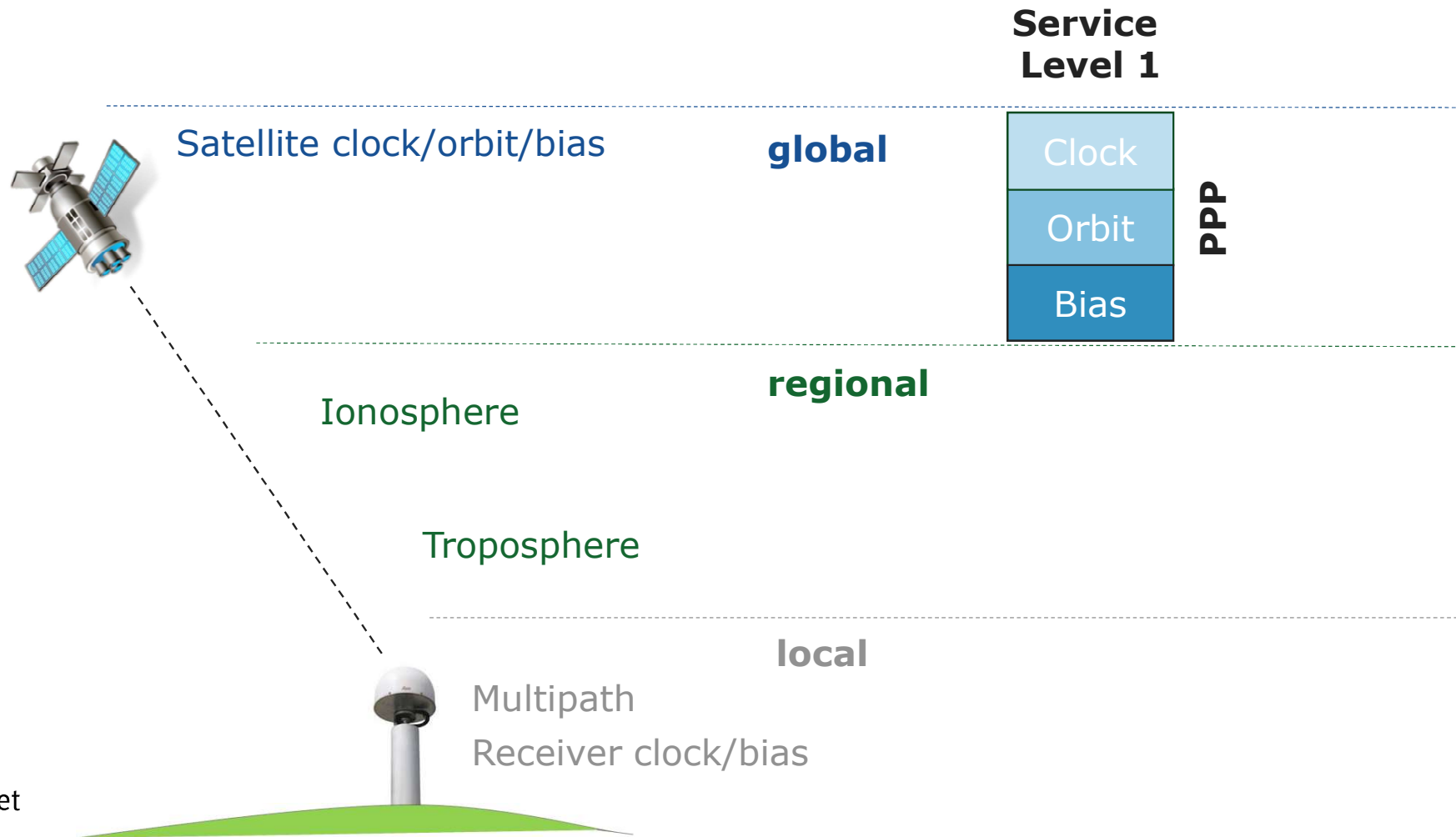
How works Galileo HAS?



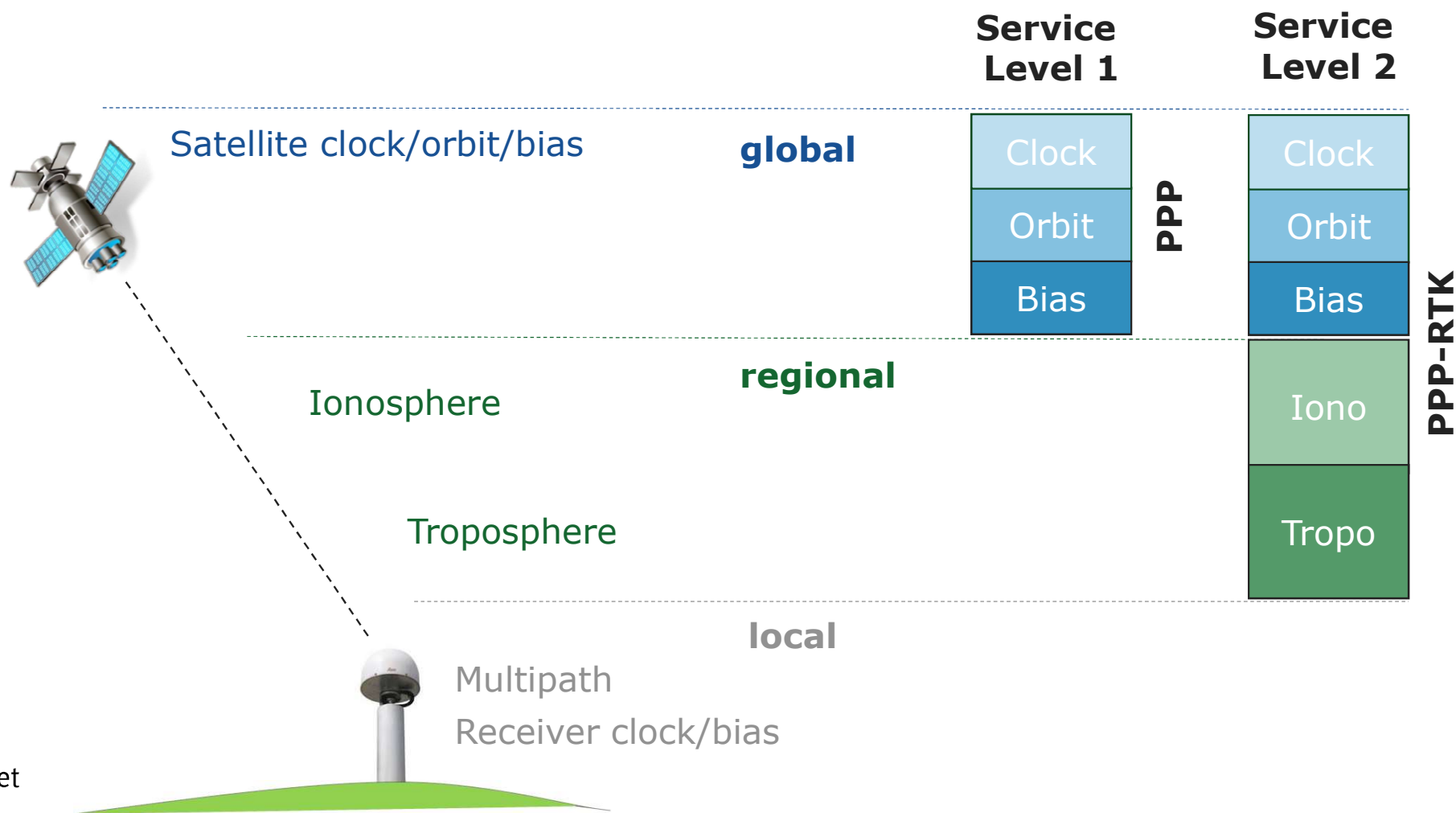
How works Galileo HAS?



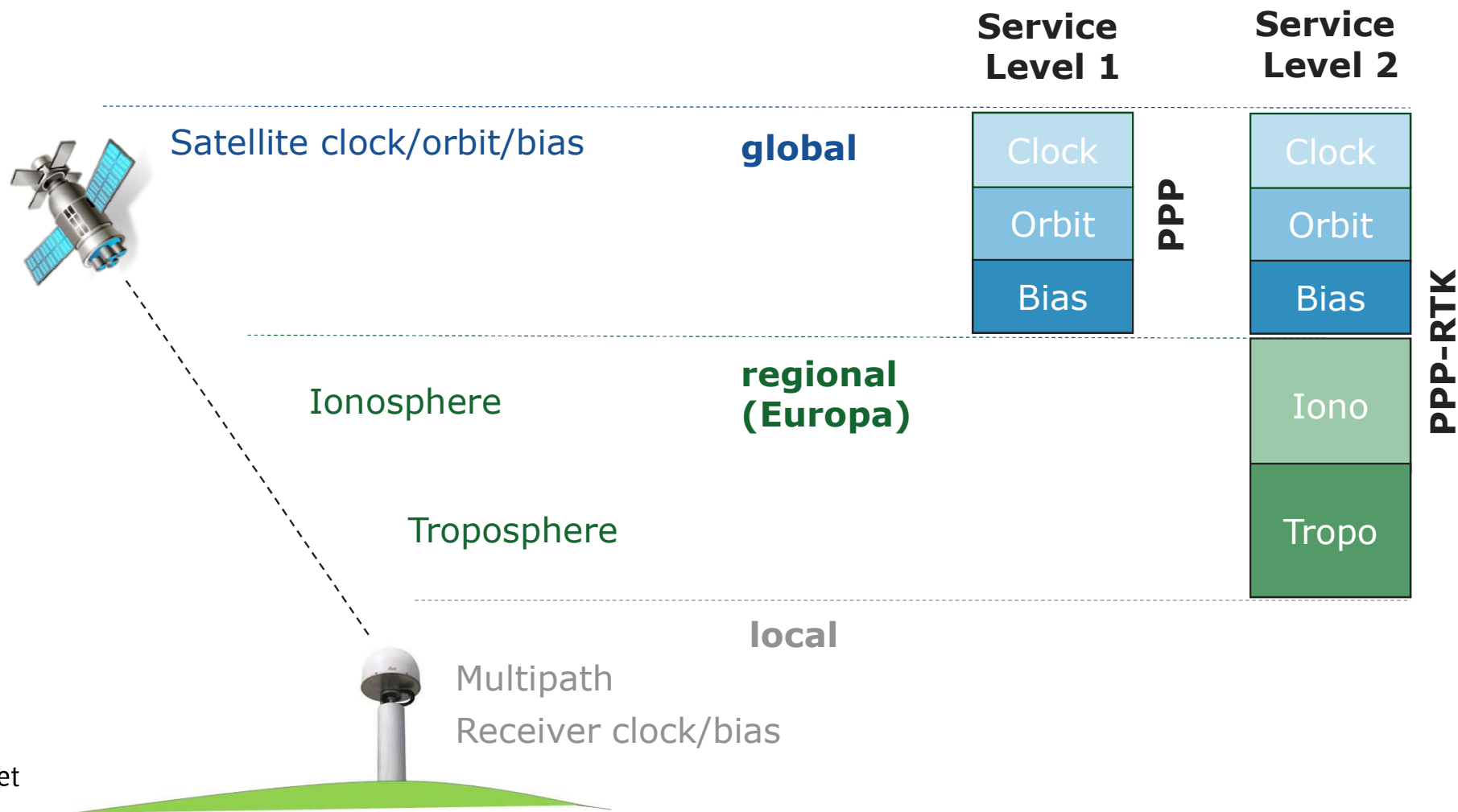
How works Galileo HAS?



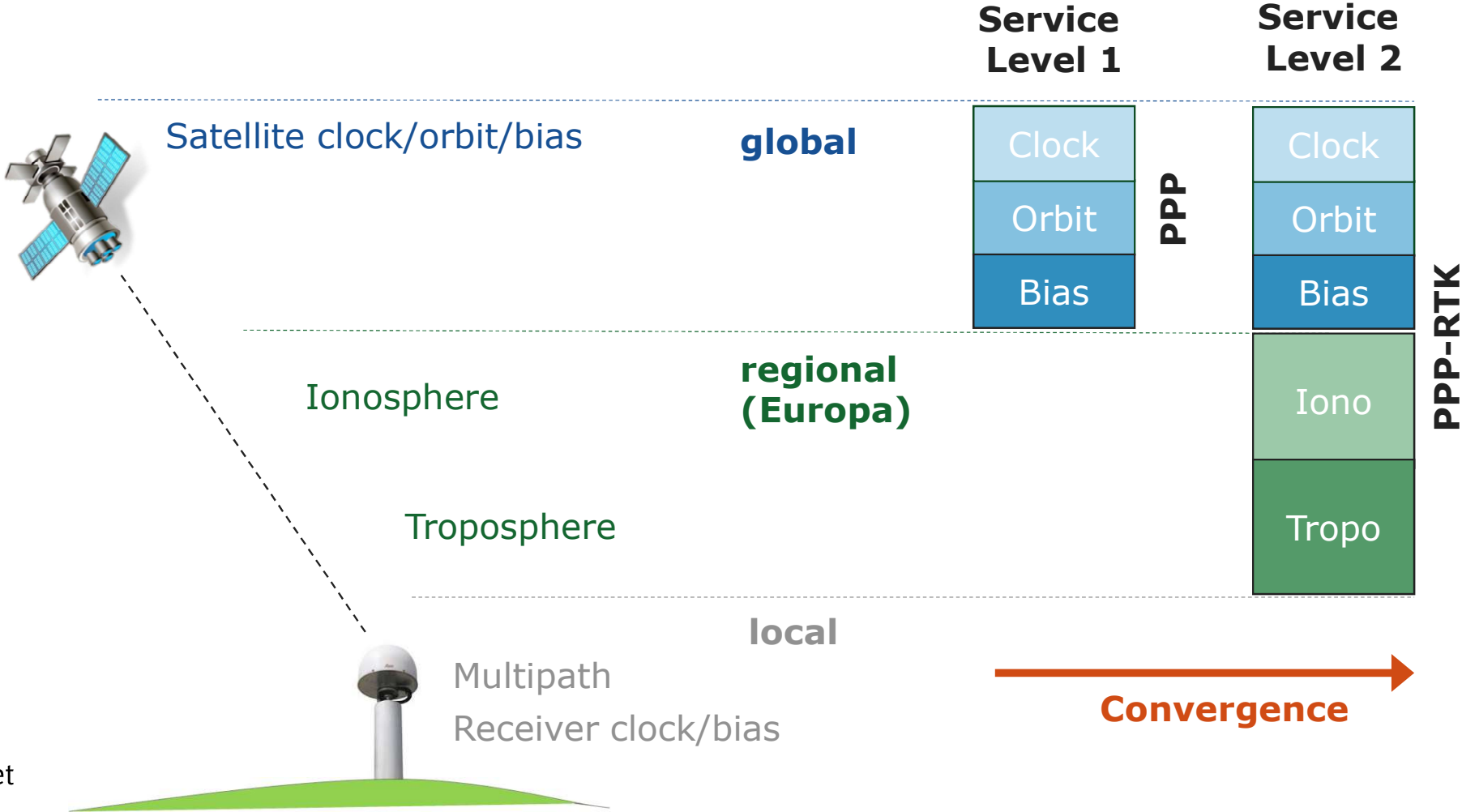
How works Galileo HAS?



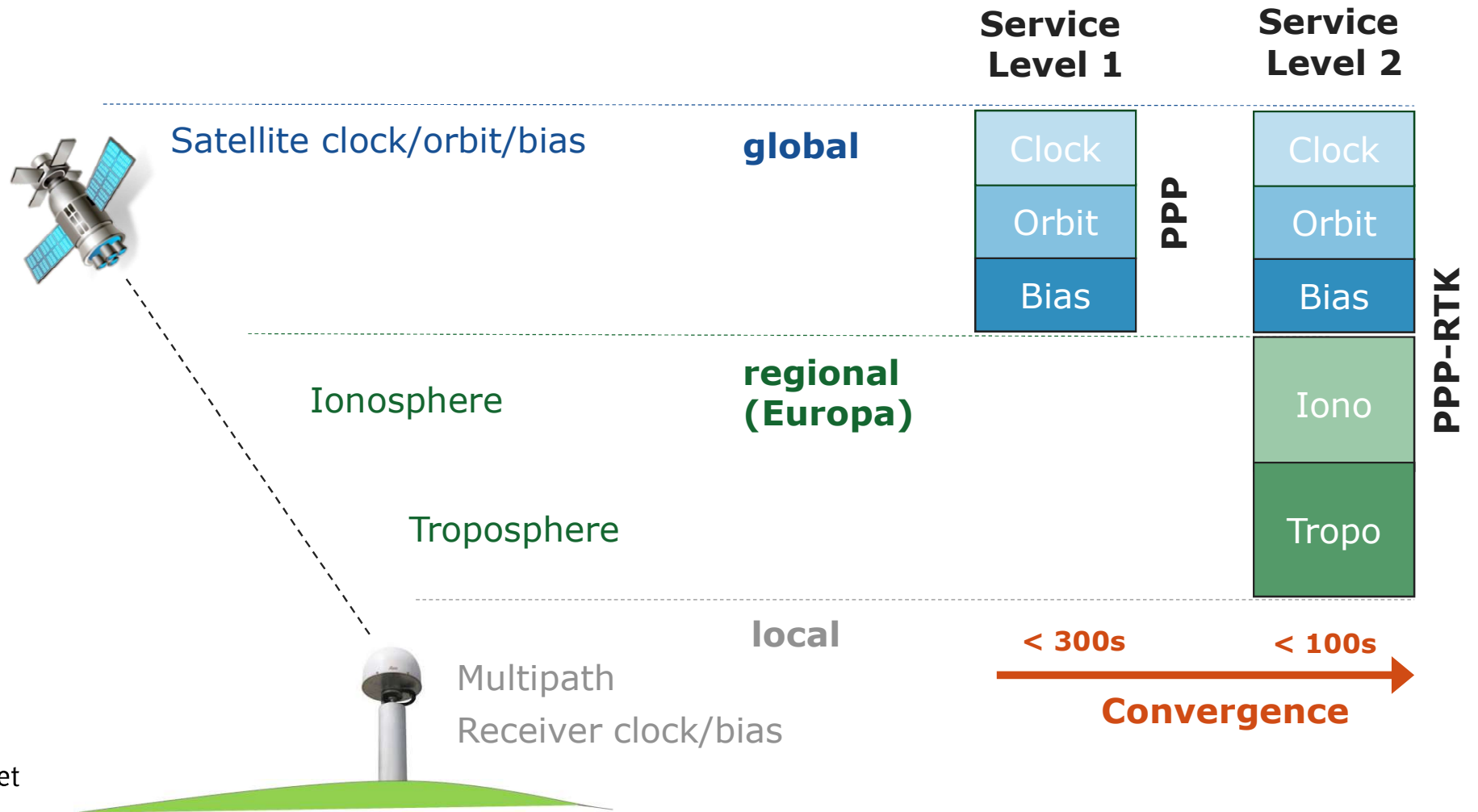
How works Galileo HAS?



How works Galileo HAS?



How works Galileo HAS?

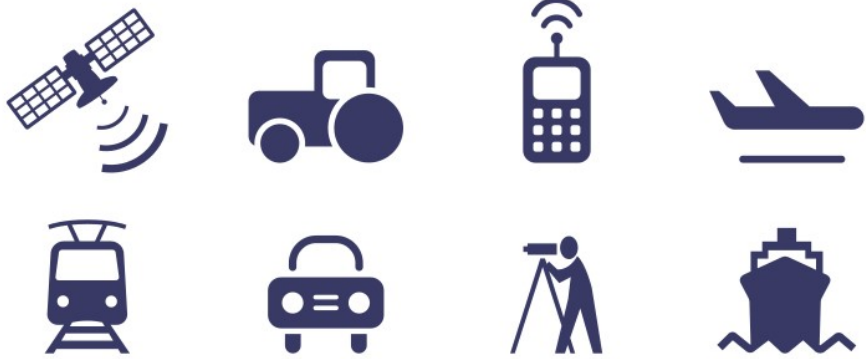


User of Galileo HAS



Source: Galileo HAS Info note.

User of Galileo HAS



Source: Galileo HAS Info note.

User of Galileo HAS



Source: Galileo HAS Info note.

User of Galileo HAS



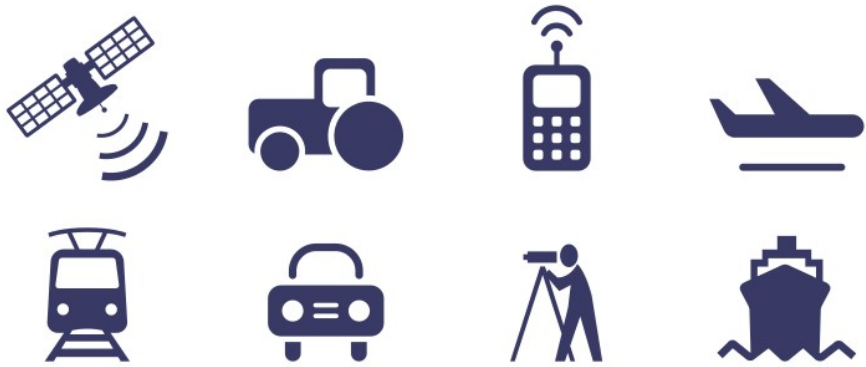
Source: Galileo HAS Info note.

User of Galileo HAS



Source: Galileo HAS Info note.

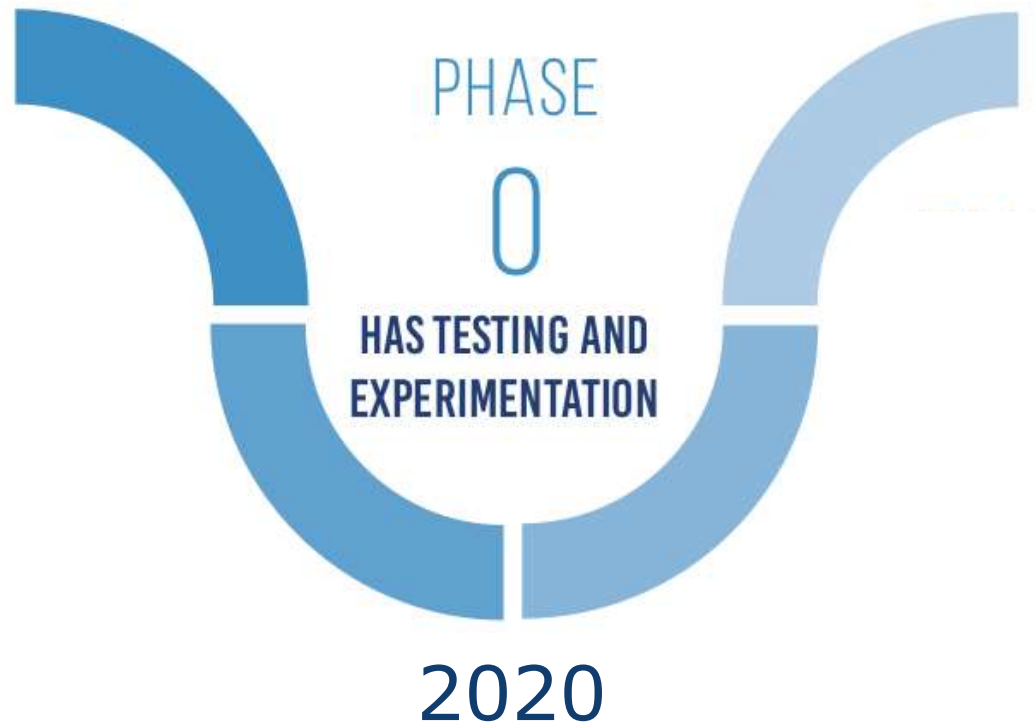
User of Galileo HAS



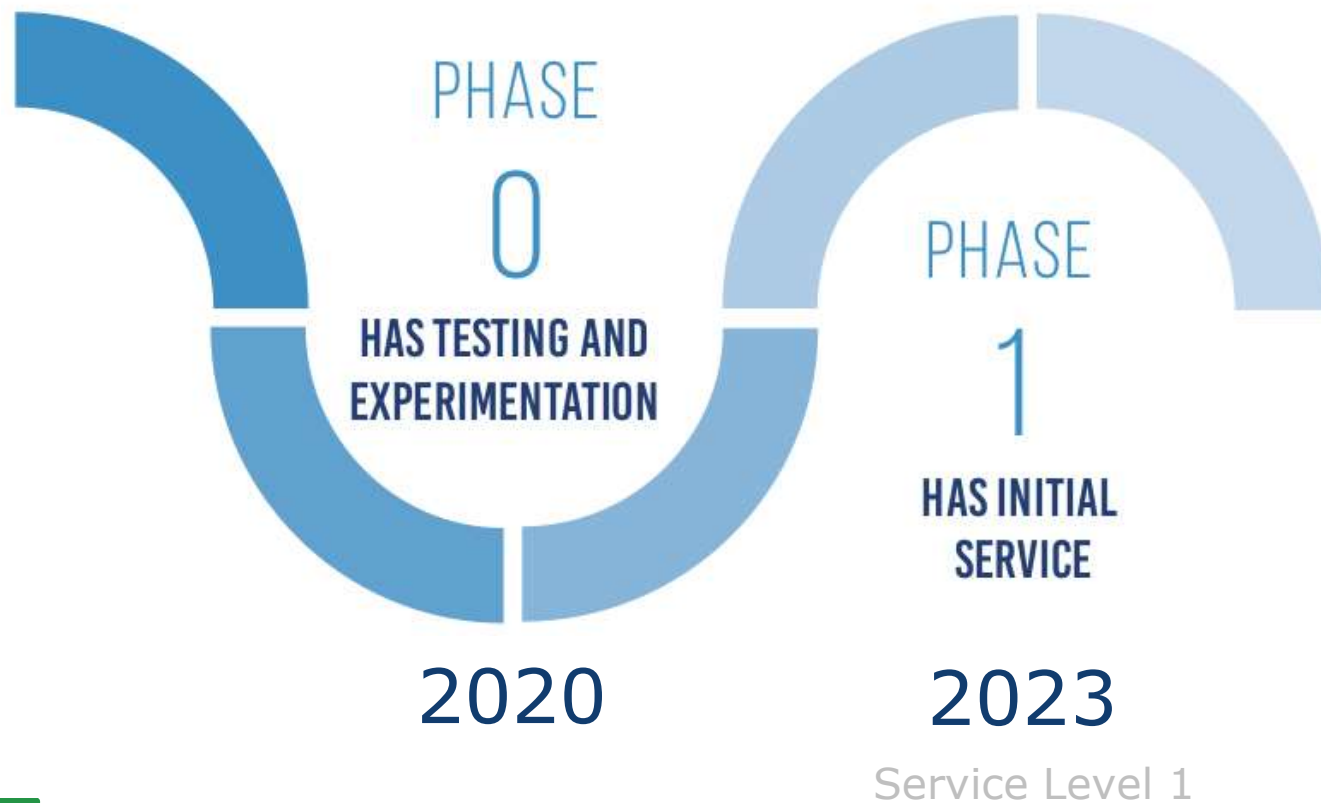
Source: Galileo HAS Info note.



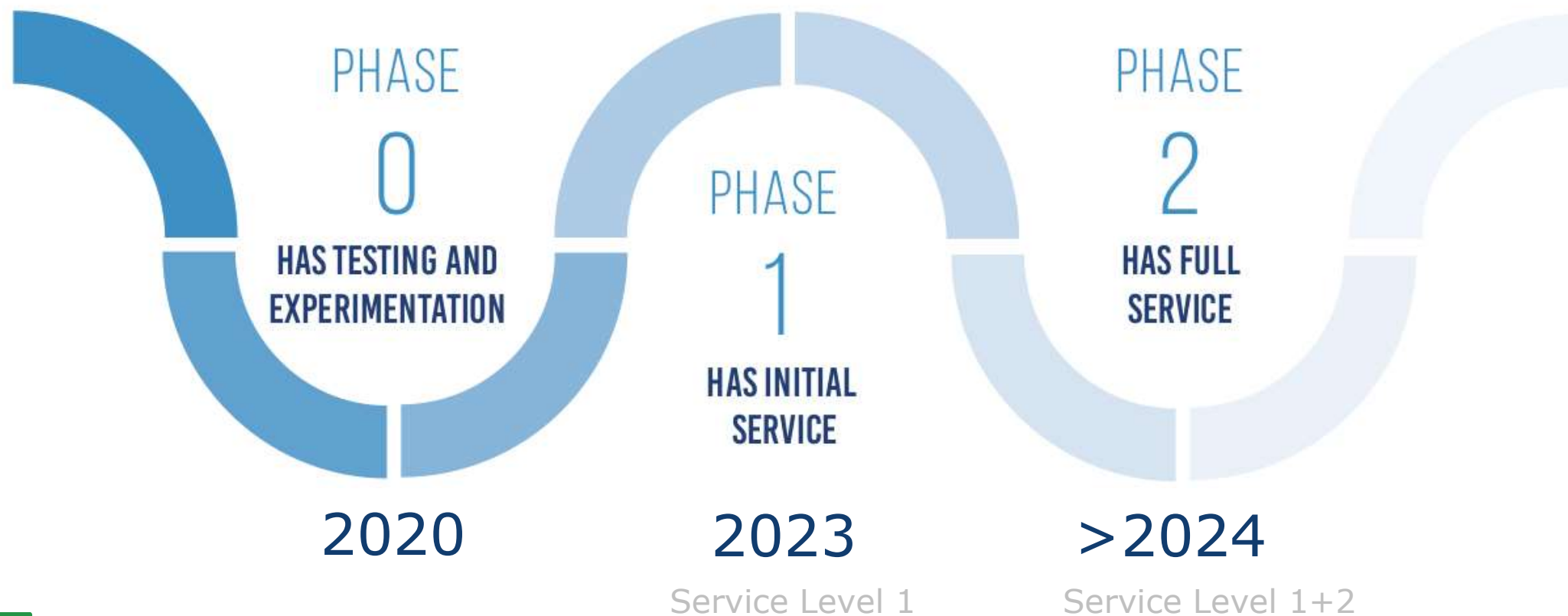
Galileo HAS roadmap



Galileo HAS roadmap



Galileo HAS roadmap



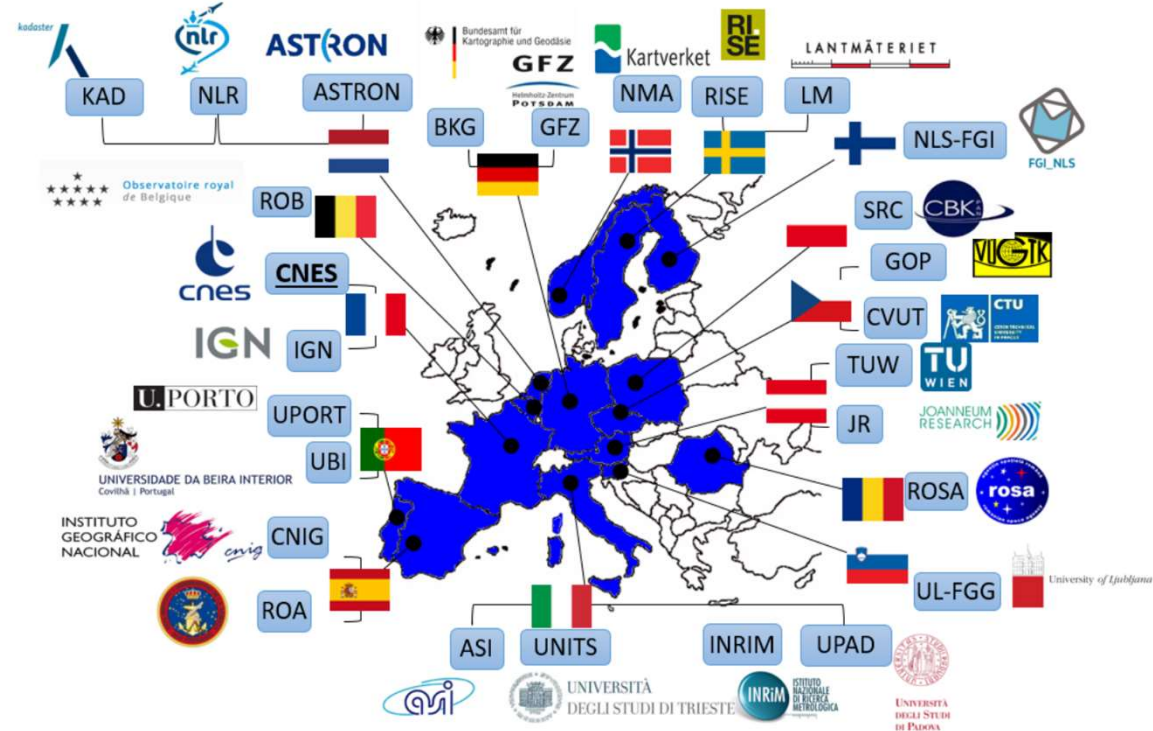
Part II

Monitoring of Galileo HAS

GEMOP project

Galileo and EGNOS Monitoring Of Performances by Member States

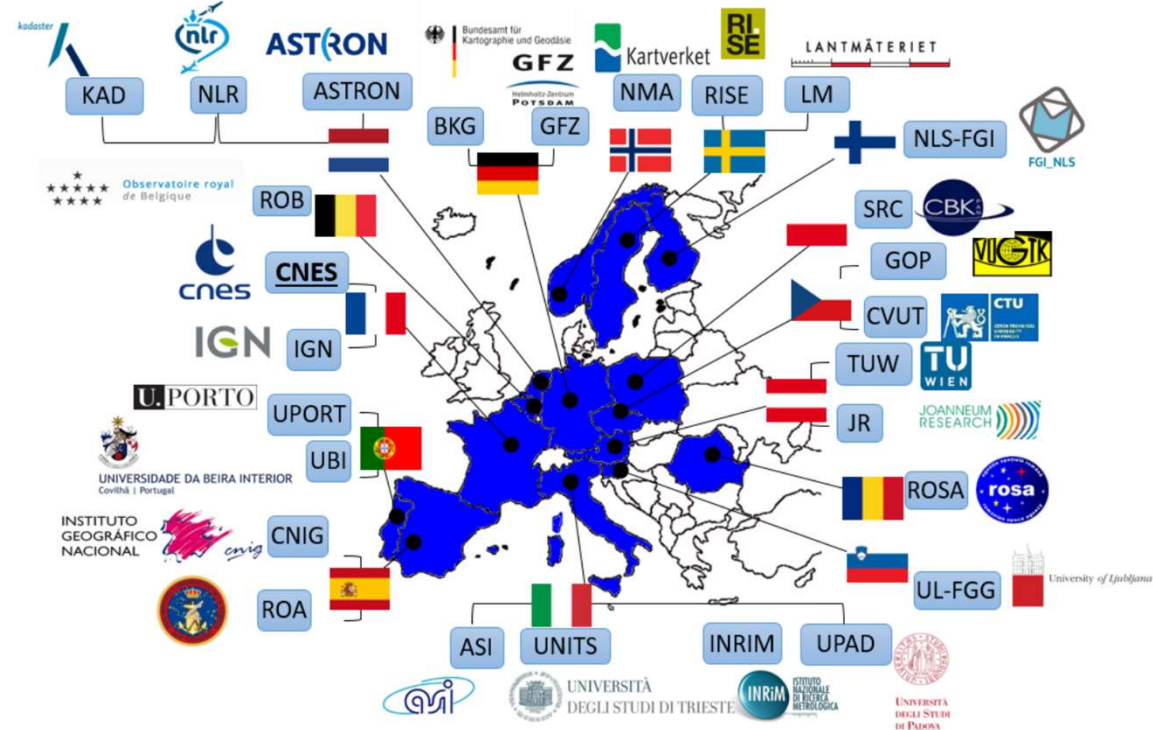
- Project participants: 27 organizations of 15 European countries
- Support for the Galileo Reference Centre (GRC) in Netherland
- Monitoring of Galileo and EGNOS service performance
- NMA is involved in several working package:
 - OS navigation performance (WPG3.1)
 - HAS performance (WPG3.2)
 - Nequick model performance (WPG3.4)
 - Galileo SLR evaluation (WPG5.2)
 - EGNOS OS & SoL performance (WPE3.1)



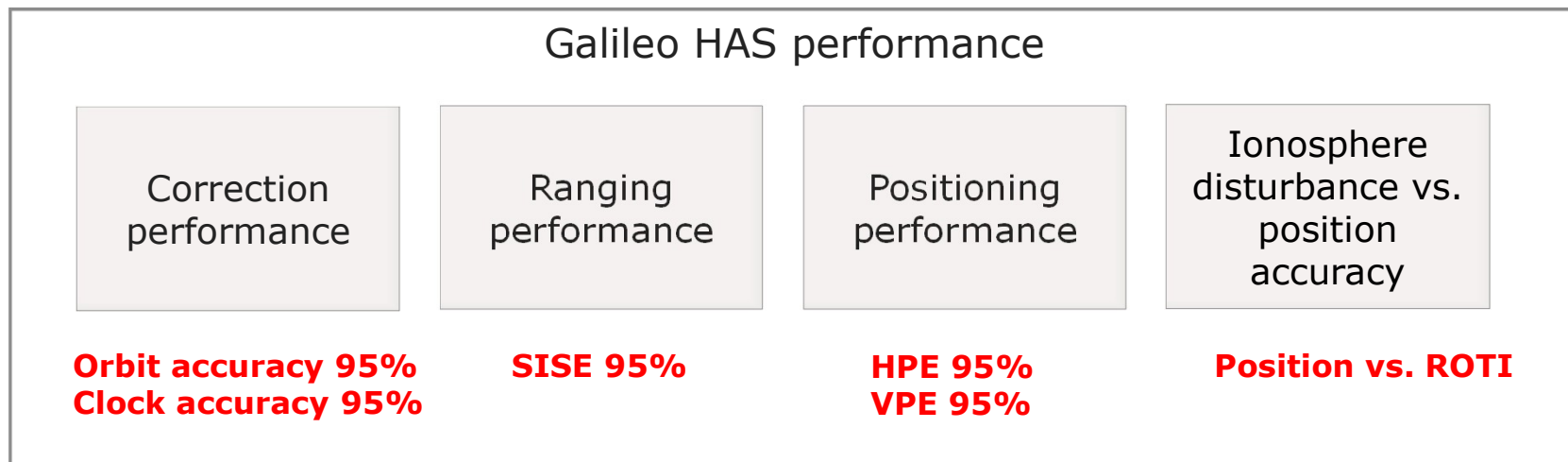
GEMOP project

Galileo and EGNOS Monitoring Of Performances by Member States

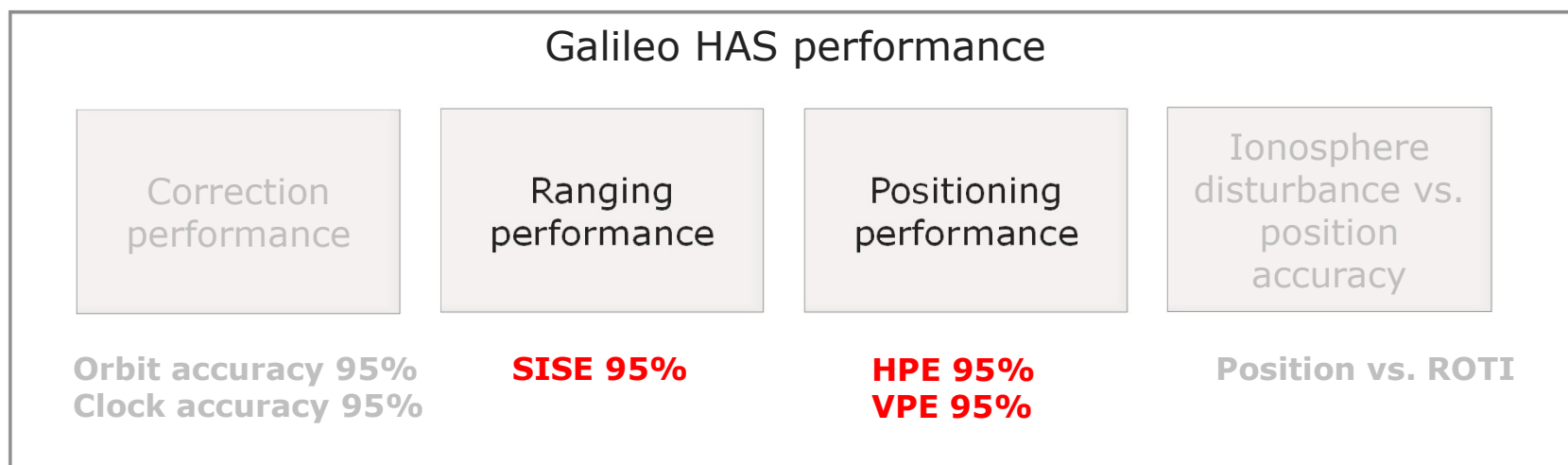
- Project participants: 27 organizations of 15 European countries
- Support for the Galileo Reference Centre (GRC) in Netherland
- Monitoring of Galileo and EGNOS service performance
- NMA is involved in several working package:
 - OS navigation performance (WPG3.1)
 - **HAS performance (WPG3.2)**
 - Nequick model performance (WPG3.4)
 - Galileo SLR evaluation (WPG5.2)
 - EGNOS OS & SoL performance (WPE3.1)



Monitoring of Galileo HAS



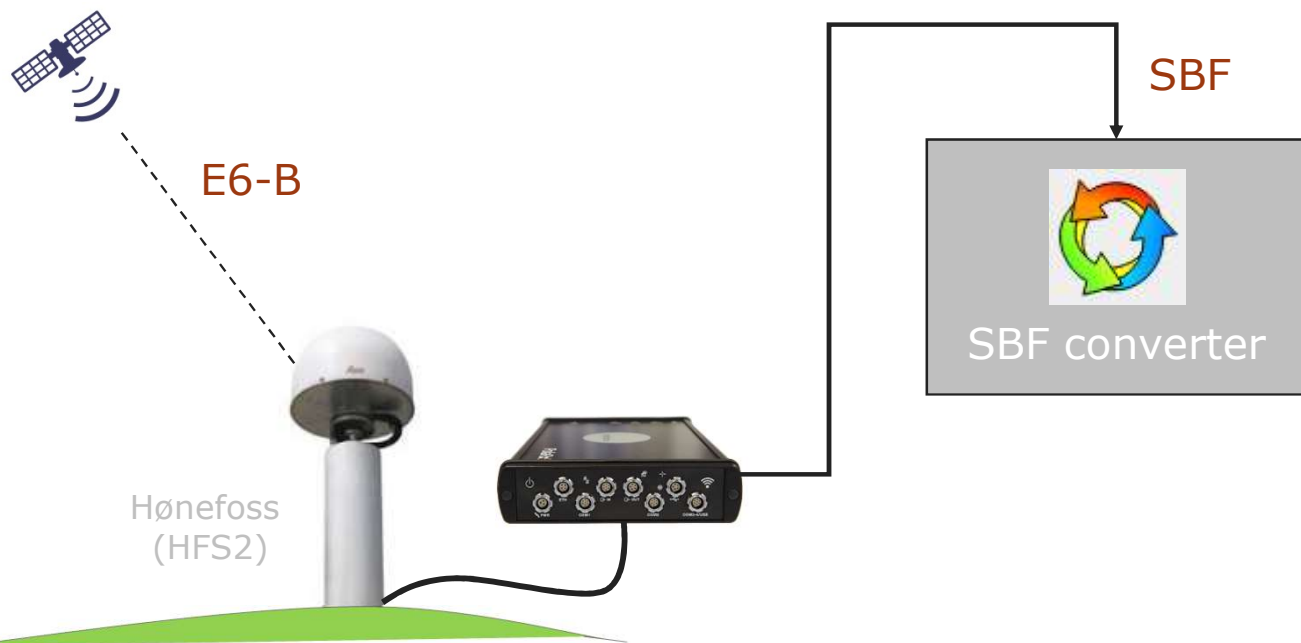
Monitoring of Galileo HAS



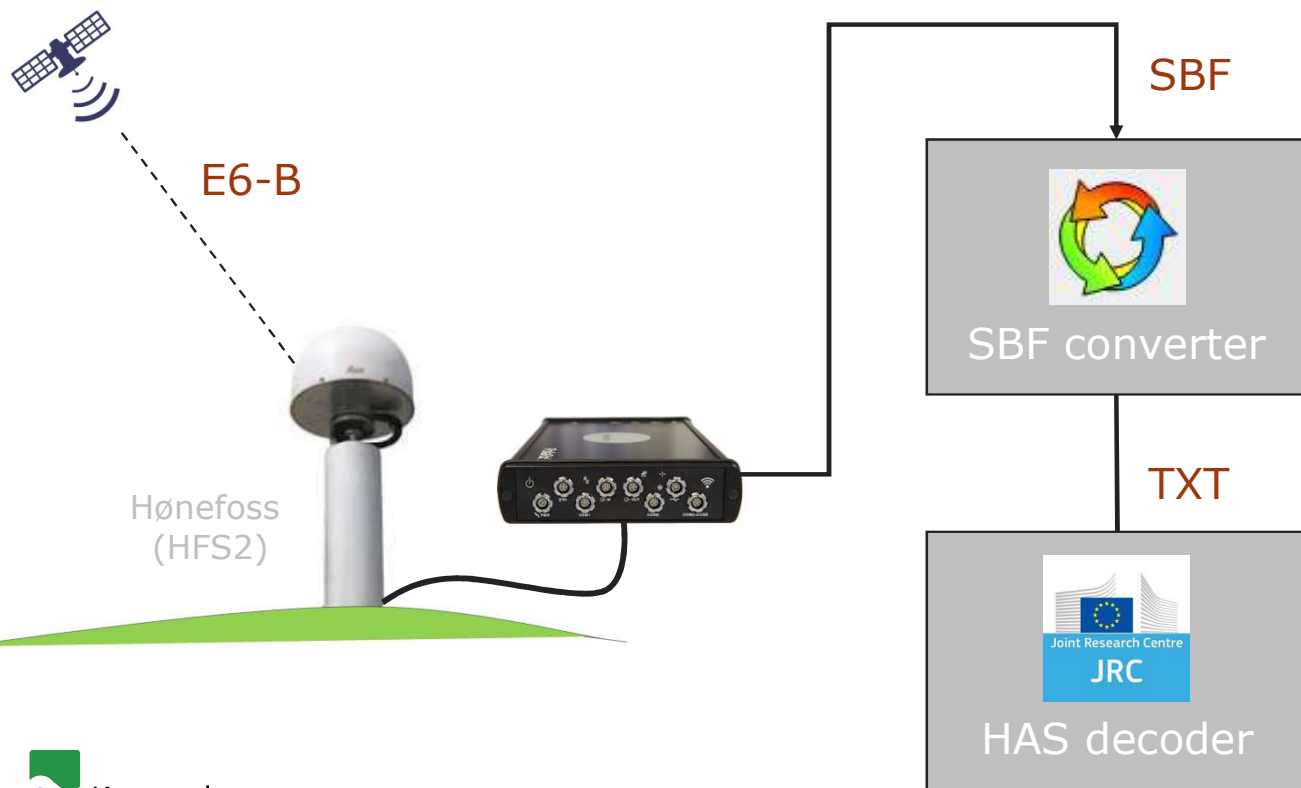
How do we get the HAS messages?



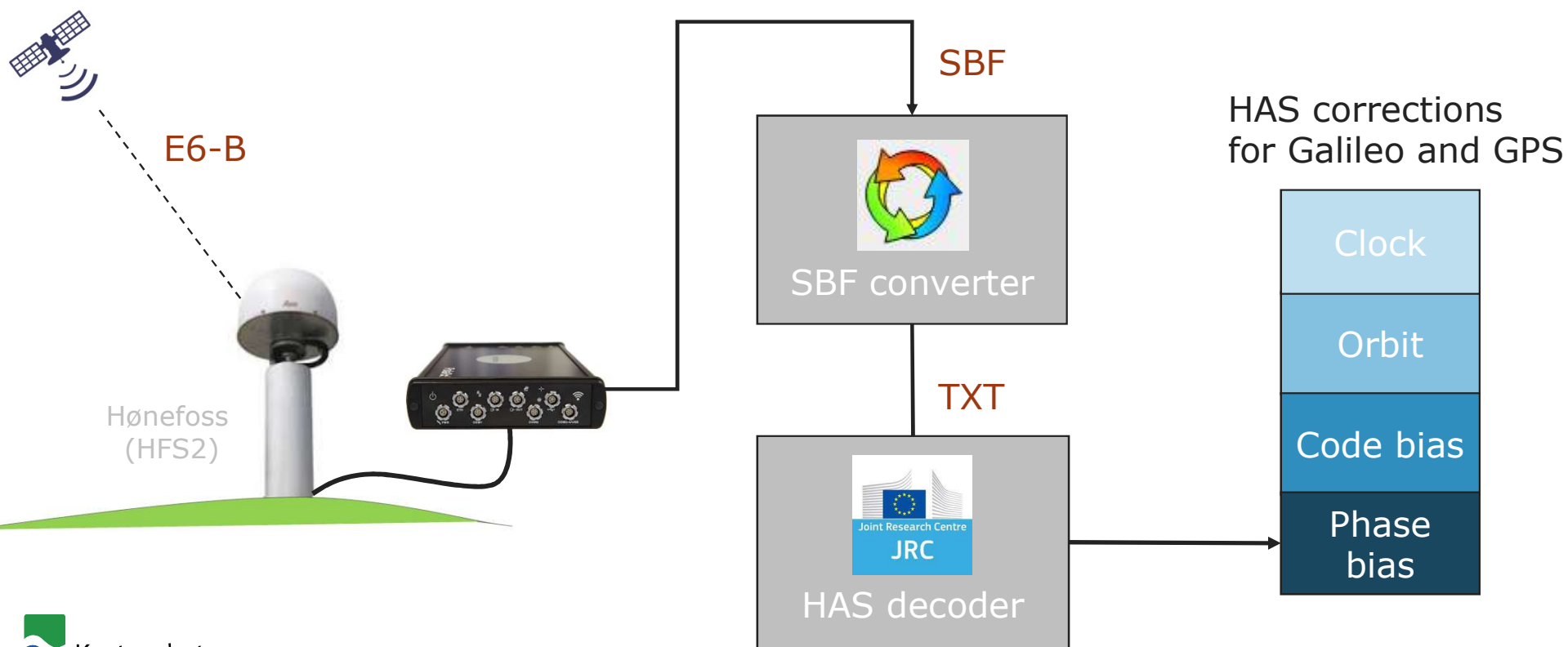
How do we get the HAS messages?



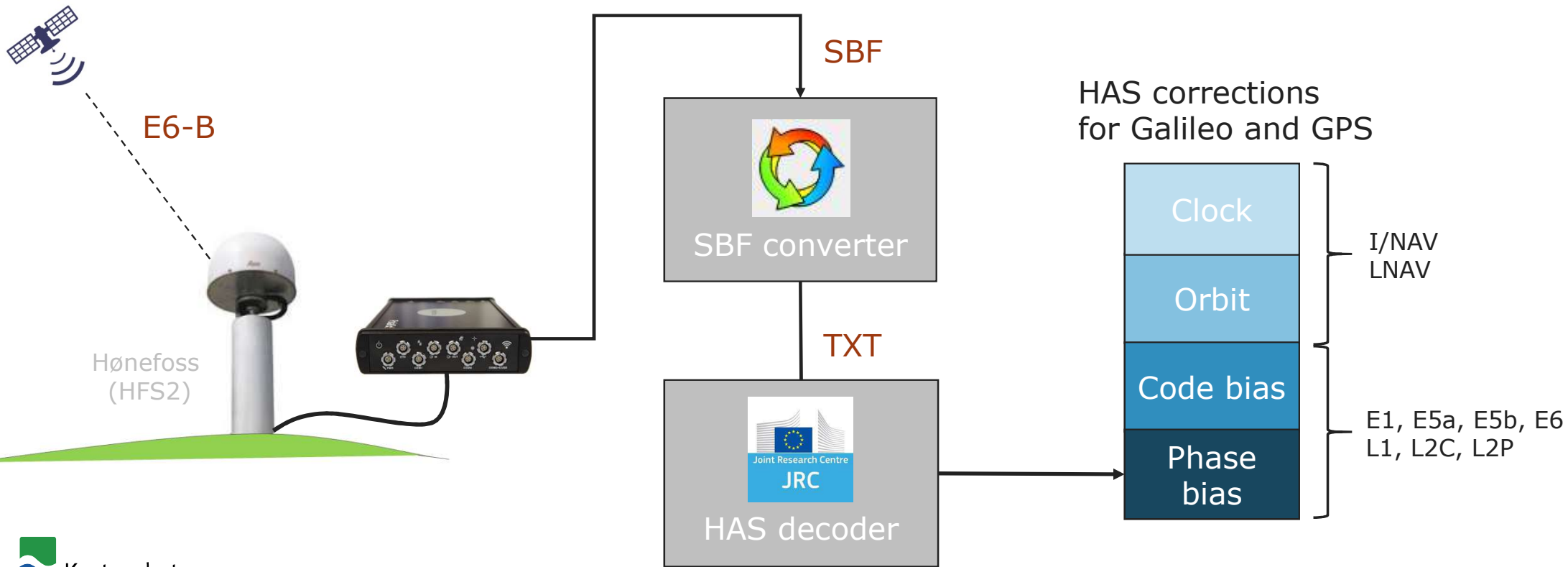
How do we get the HAS messages?



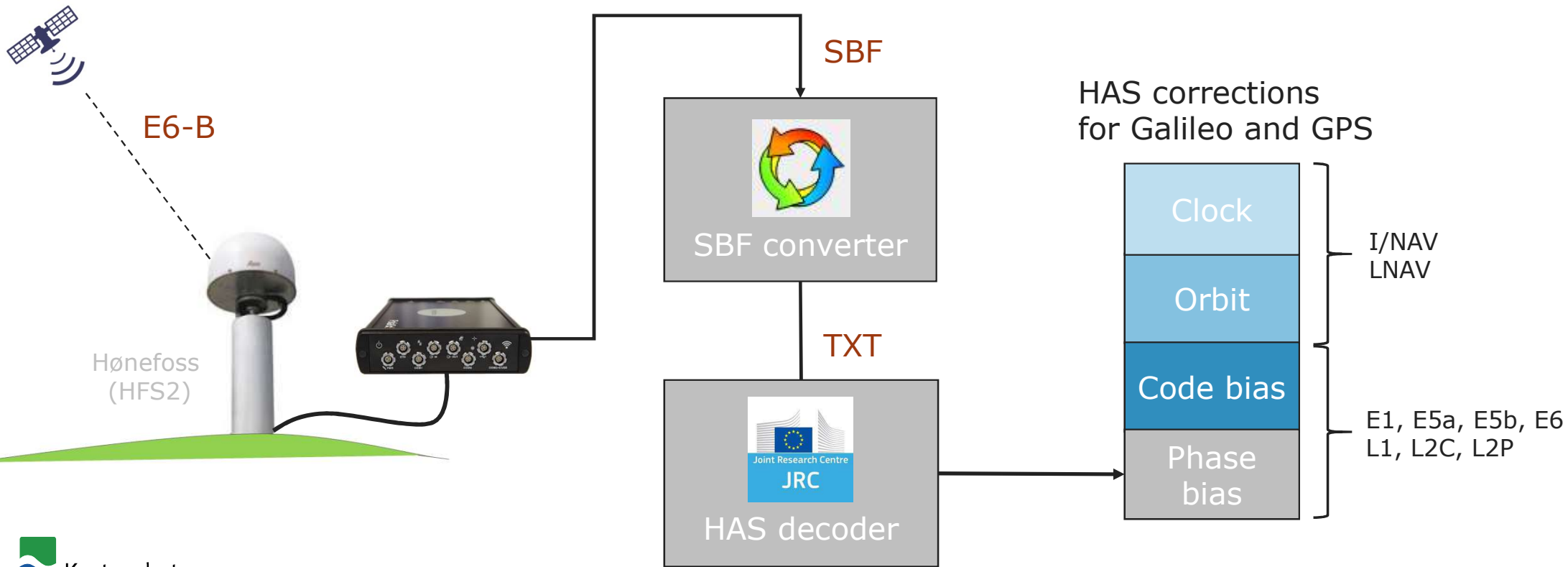
How do we get the HAS messages?



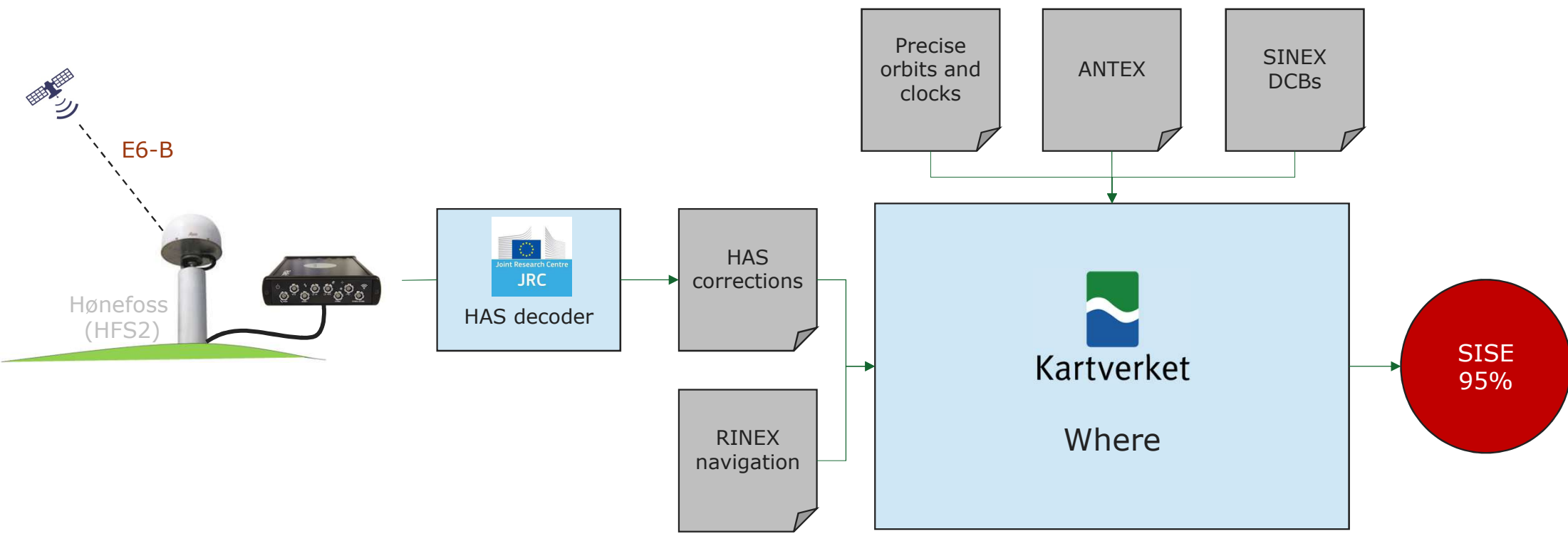
How do we get the HAS messages?



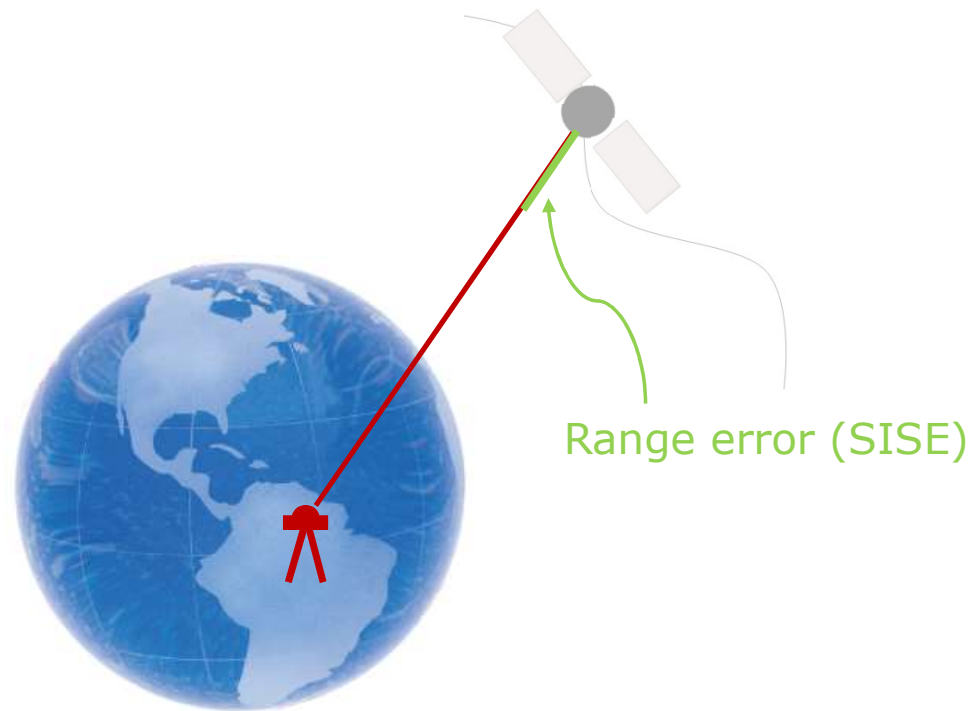
How do we get the HAS messages?



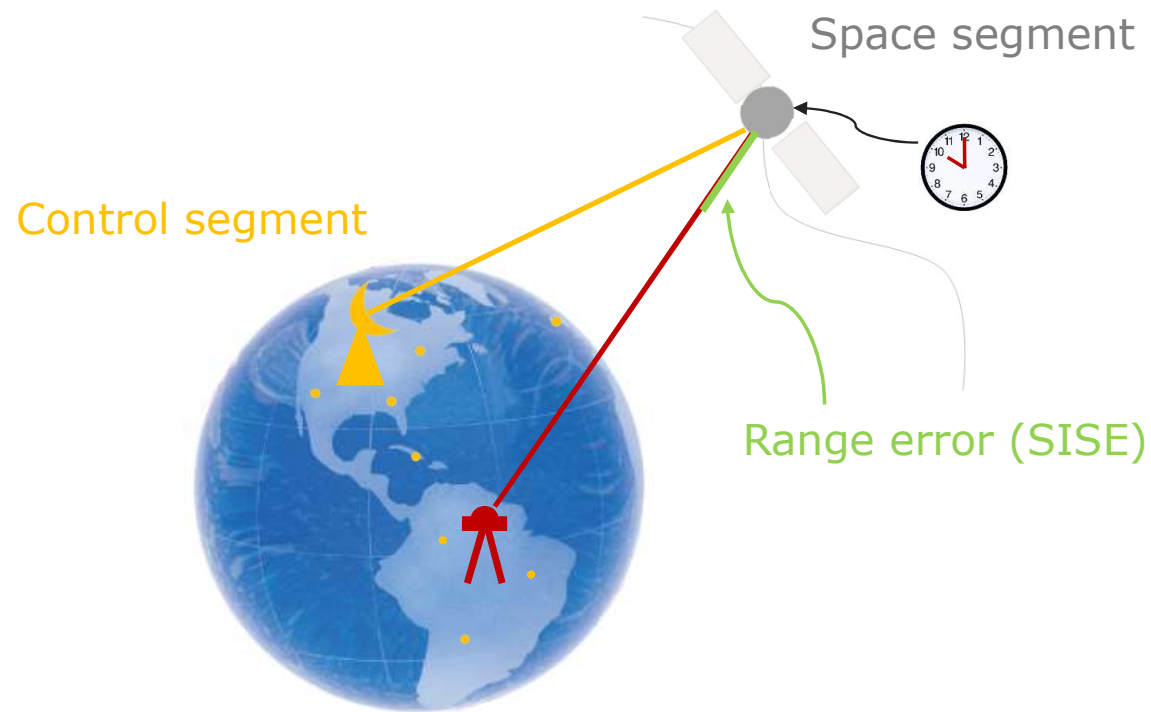
Galileo HAS ranging performance



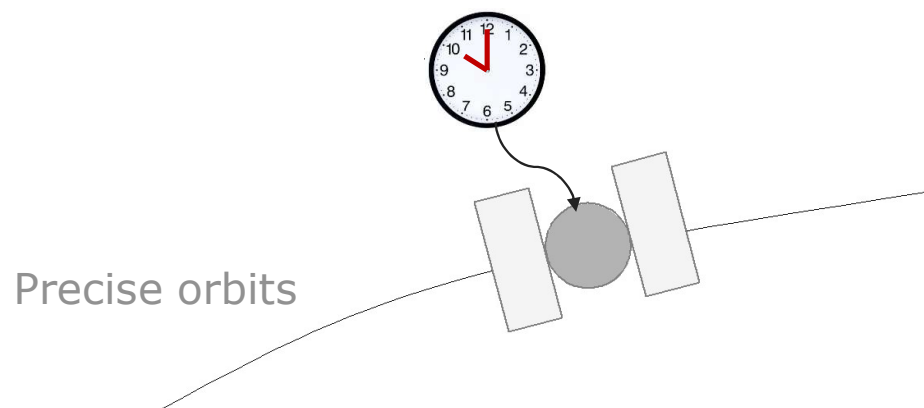
How can the Galileo HAS orbit- and clock performance be determined?



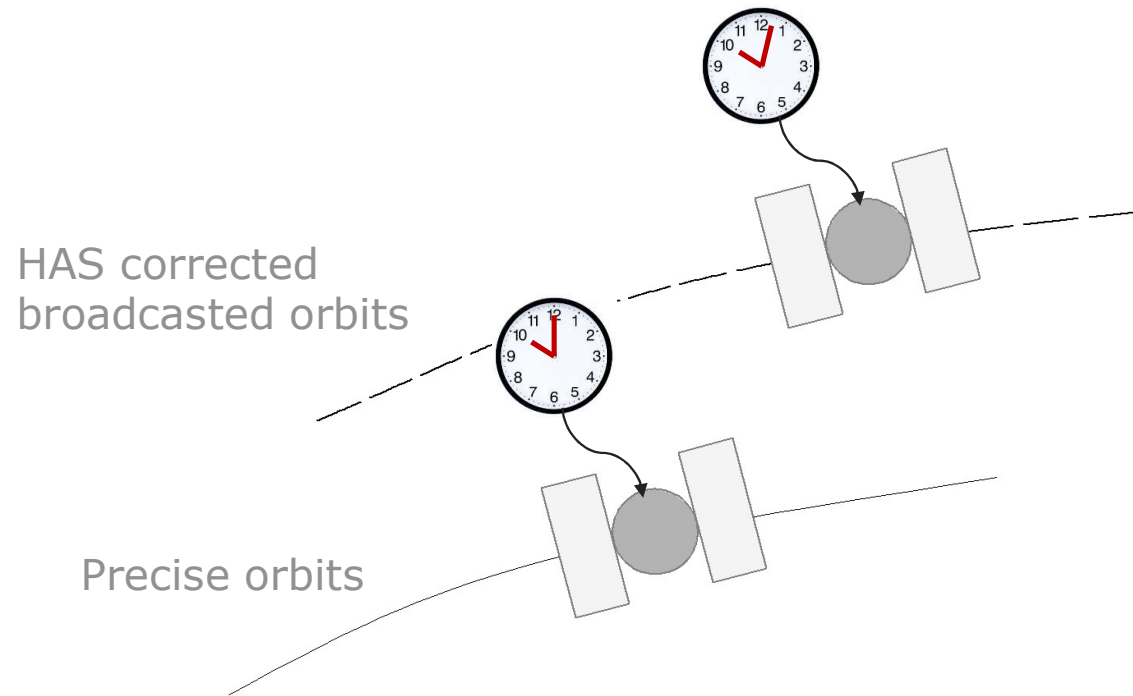
How can the Galileo HAS orbit- and clock performance be determined?



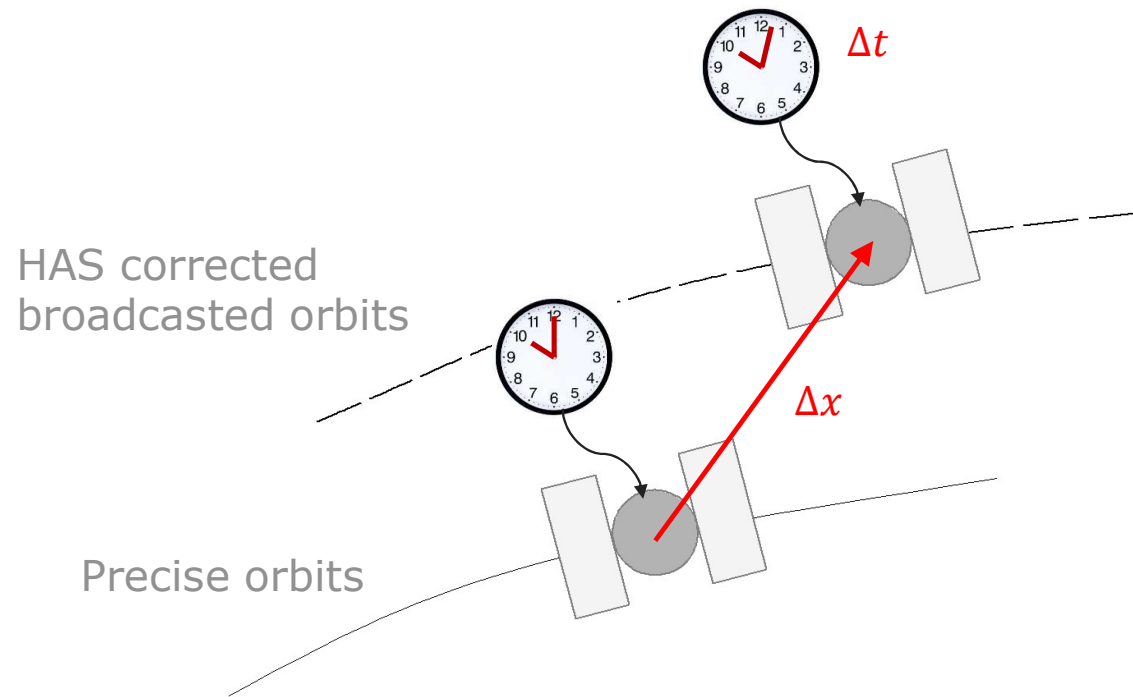
Signal-in-space ranging error (SISE)



Signal-in-space ranging error (SISE)



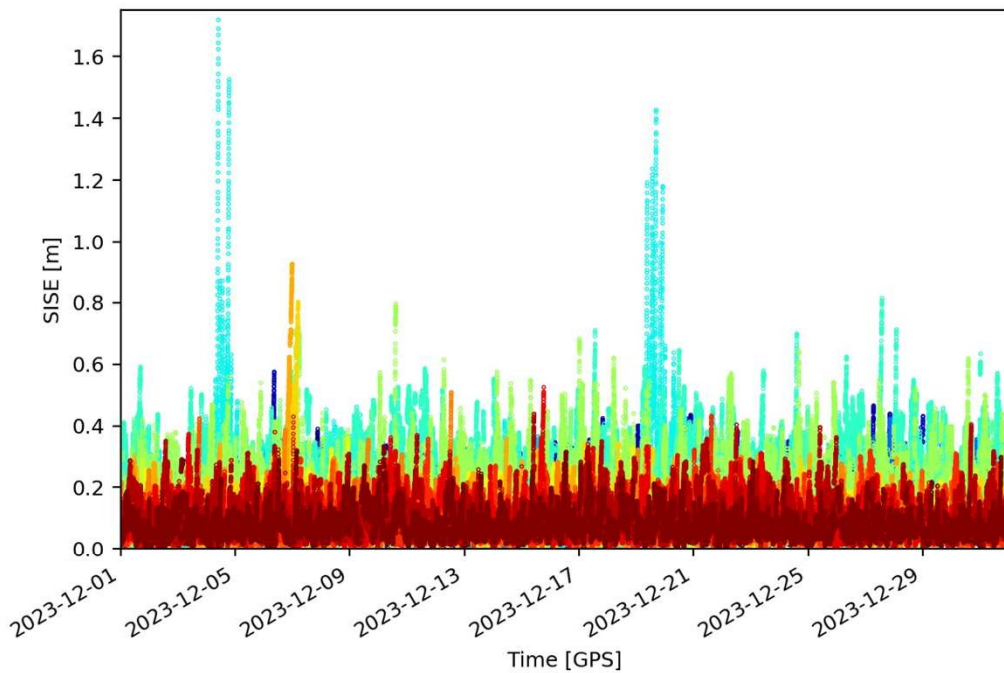
Signal-in-space ranging error (SISE)



What is the performance of Galileo HAS orbit and clock data?

Solution: **OS**-CNES-INAV-E1E5b, Step: 60 s

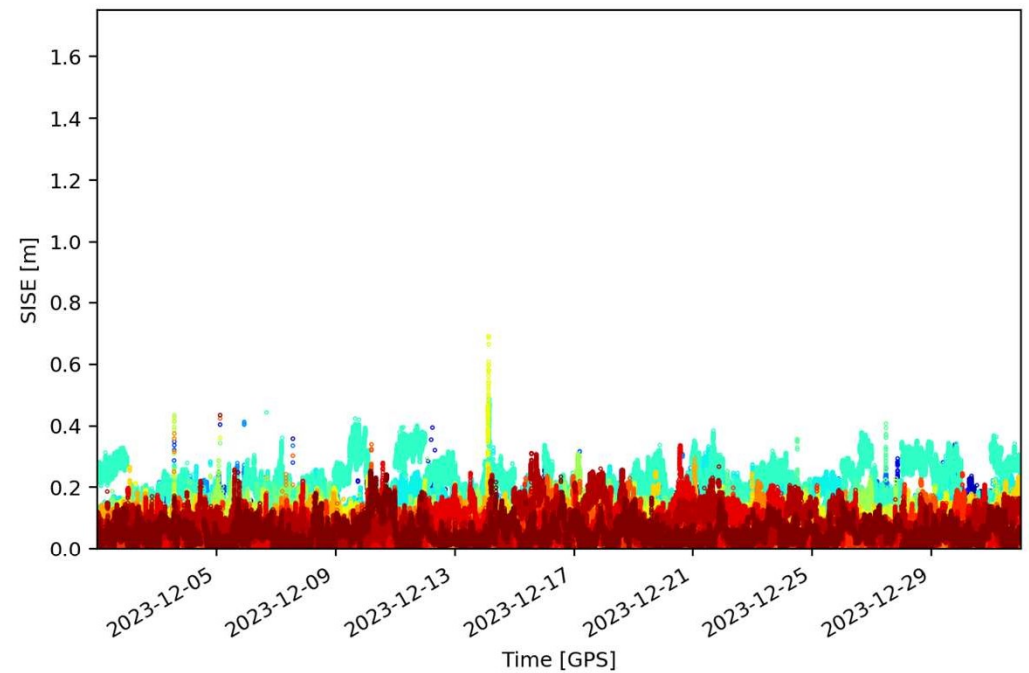
RMS: 0.13 m, Mean: 0.10 m, Std: 0.08 m, Min: 3e-04 m, Max: 1.72 m, 95th perc.: 0.25 m



- | | | | | | |
|-------|-------|-------|-------|-------|-------|
| • E02 | • E07 | • E11 | • E19 | • E26 | • E33 |
| • E03 | • E08 | • E12 | • E21 | • E27 | • E34 |
| • E04 | • E09 | • E13 | • E24 | • E30 | • E36 |
| • E05 | • E10 | • E15 | • E25 | • E31 | |

Solution: **HAS**-CNES-INAV-E1E5b, Step: 30 s

RMS: 0.08 m, Mean: 0.06 m, Std: 0.05 m, Min: 2e-04 m, Max: 2.53 m, 95th perc.: 0.17 m

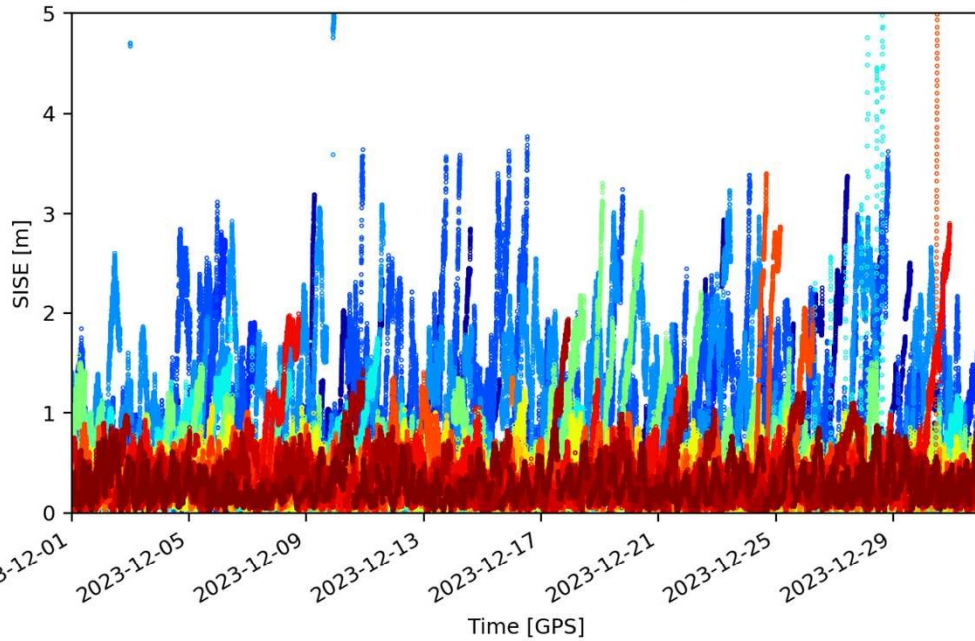


- | | | | | | |
|-------|-------|-------|-------|-------|-------|
| • E02 | • E07 | • E11 | • E19 | • E26 | • E33 |
| • E03 | • E08 | • E12 | • E21 | • E27 | • E34 |
| • E04 | • E09 | • E13 | • E24 | • E30 | • E36 |
| • E05 | • E10 | • E15 | • E25 | • E31 | |

What is the performance of Galileo HAS orbit and clock data?

Solution: **OS**-CNES-LNAV-L1L2, Step: 60 s

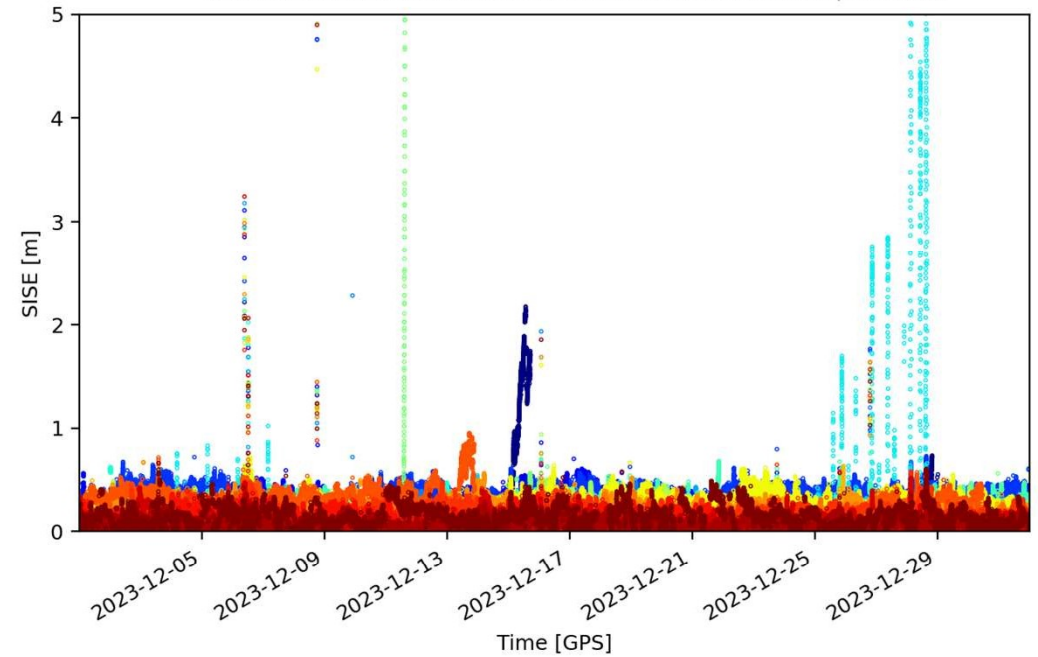
RMS: 290.25 m, Mean: 1.55 m, Std: 290.24 m, Min: 2e-03 m, Max: 1e+05 m, 95th perc.: 0.98 m



• G02	• G08	• G13	• G18	• G23	• G28
• G03	• G09	• G14	• G19	• G24	• G29
• G04	• G10	• G15	• G20	• G25	• G30
• G05	• G11	• G16	• G21	• G26	• G31
• G06	• G12	• G17	• G22	• G27	• G32
• G07					

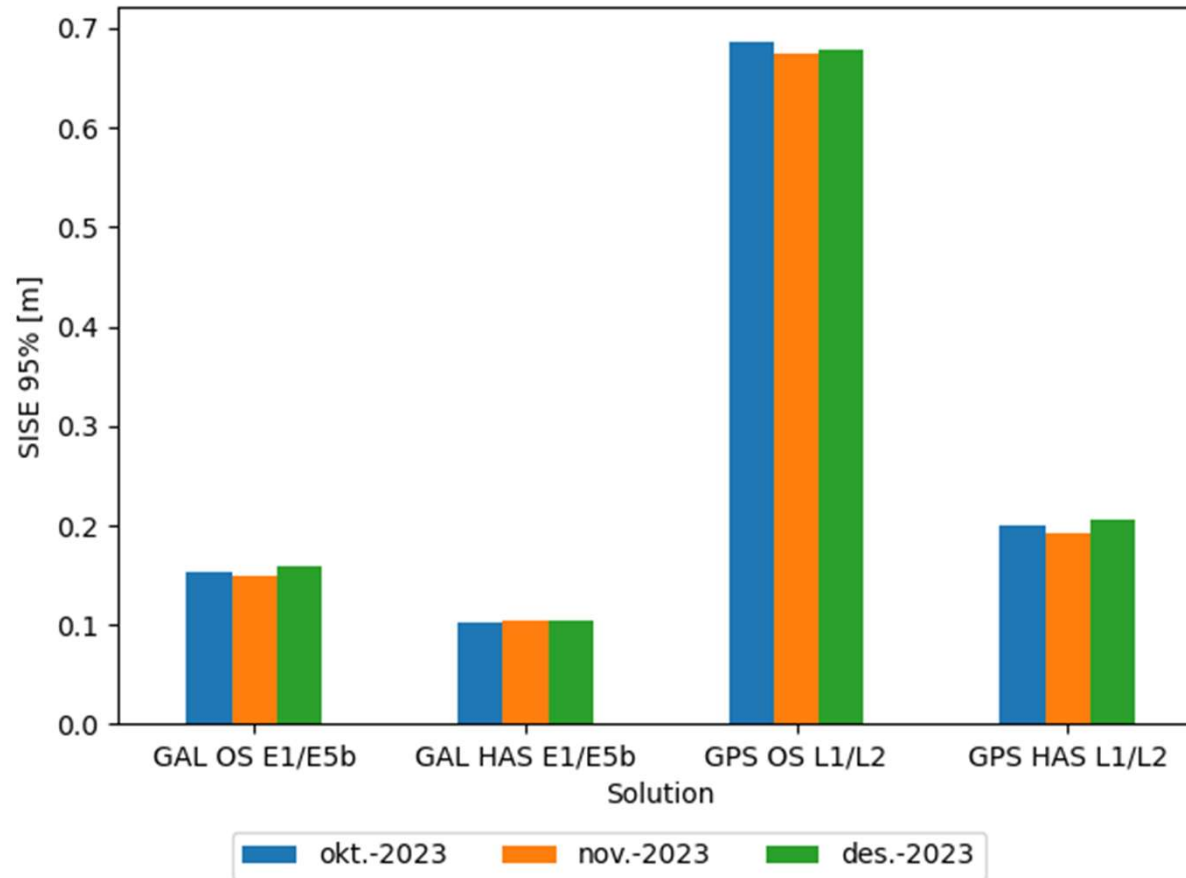
Solution: **HAS**-CNES-LNAV-L1L2, Step: 30 s

RMS: 0.42 m, Mean: 0.14 m, Std: 0.39 m, Min: 3e-04 m, Max: 174.11 m, 95th perc.: 0.34 m

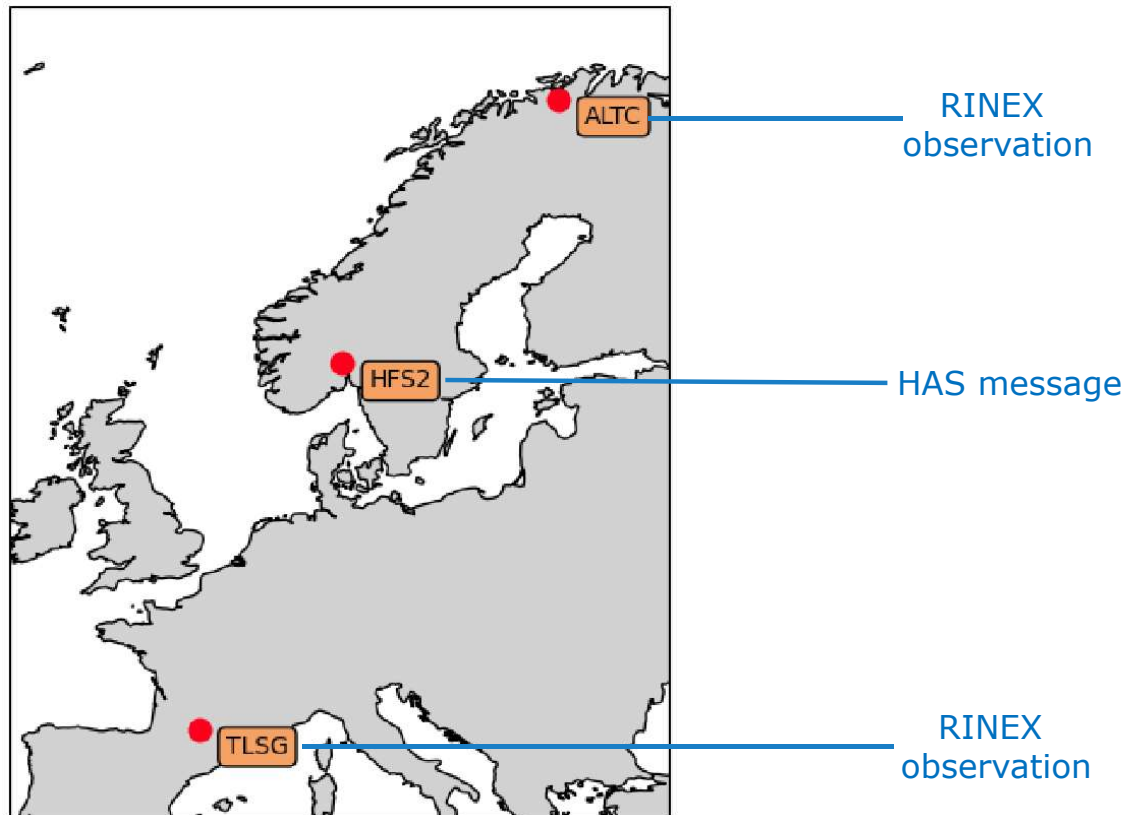


• G03	• G08	• G13	• G18	• G24	• G29
• G04	• G09	• G14	• G19	• G25	• G30
• G05	• G10	• G15	• G20	• G26	• G31
• G06	• G11	• G16	• G21	• G27	• G32
• G07	• G12	• G17	• G23	• G28	

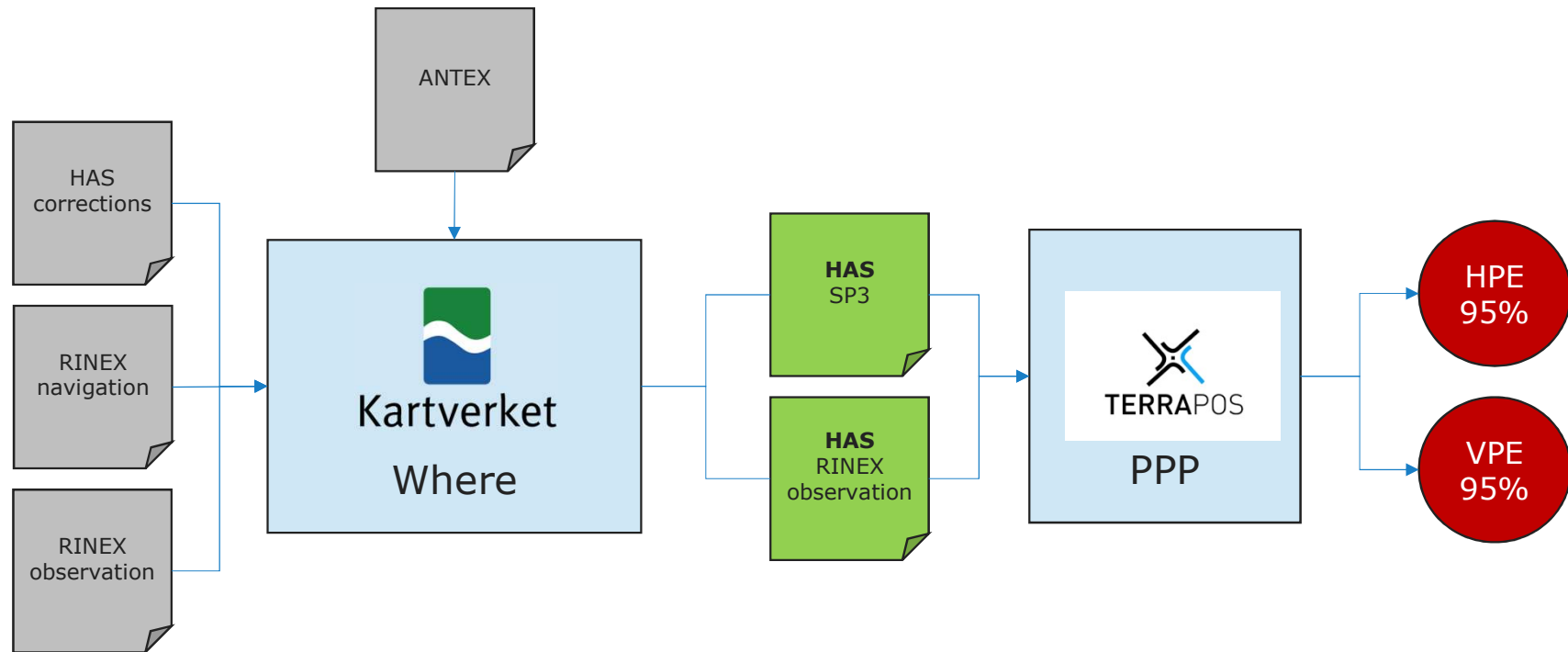
What is the performance of Galileo HAS orbit and clock data?



Galileo HAS positioning performance

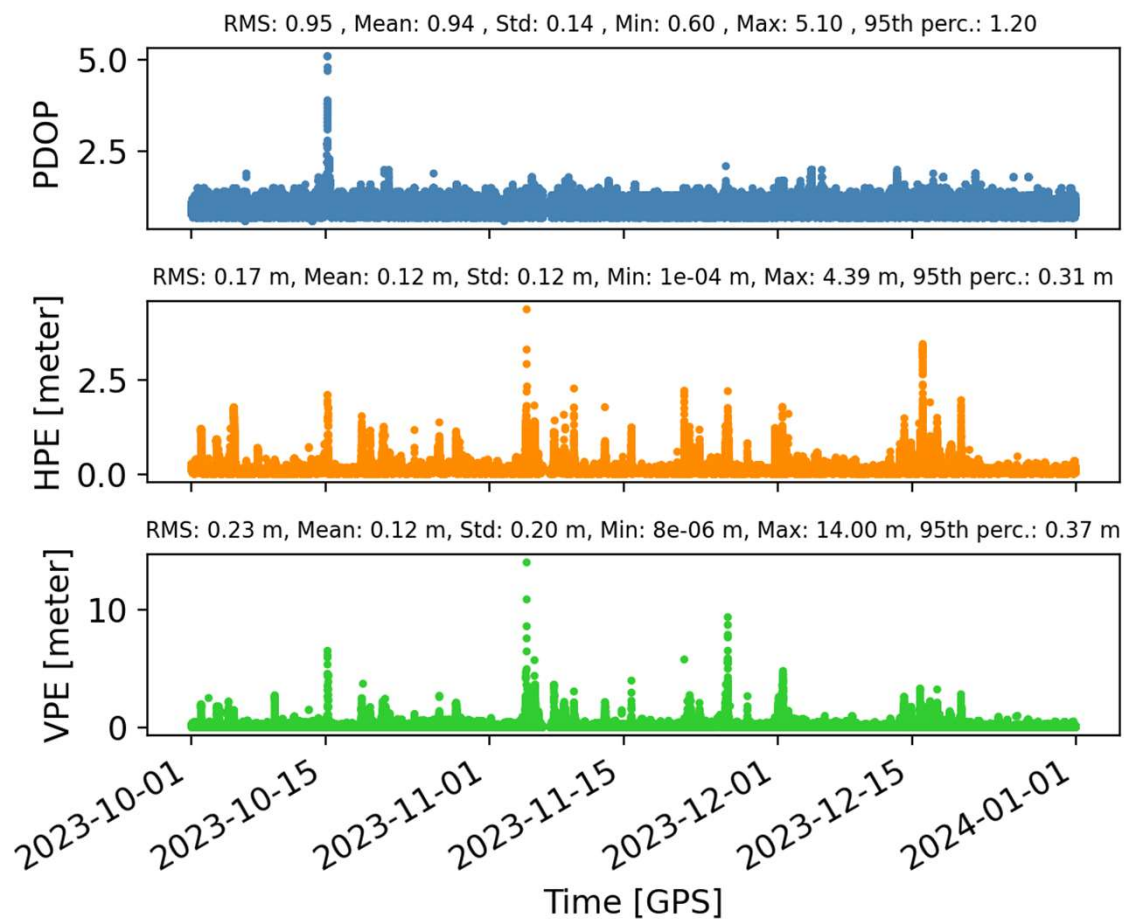


Galileo HAS positioning performance



Galileo HAS positioning performance

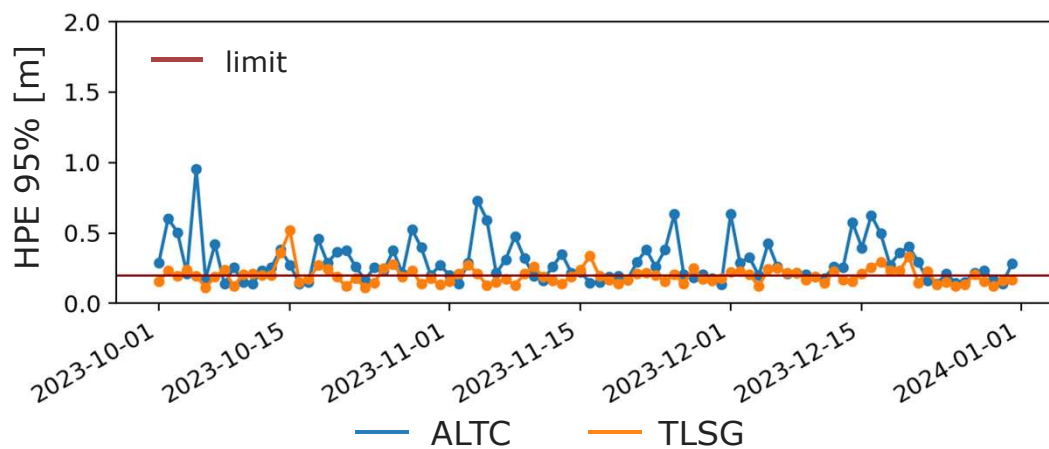
ALTC: HAS GAL+GPS (quarter 4 2023)



Galileo HAS positioning performance

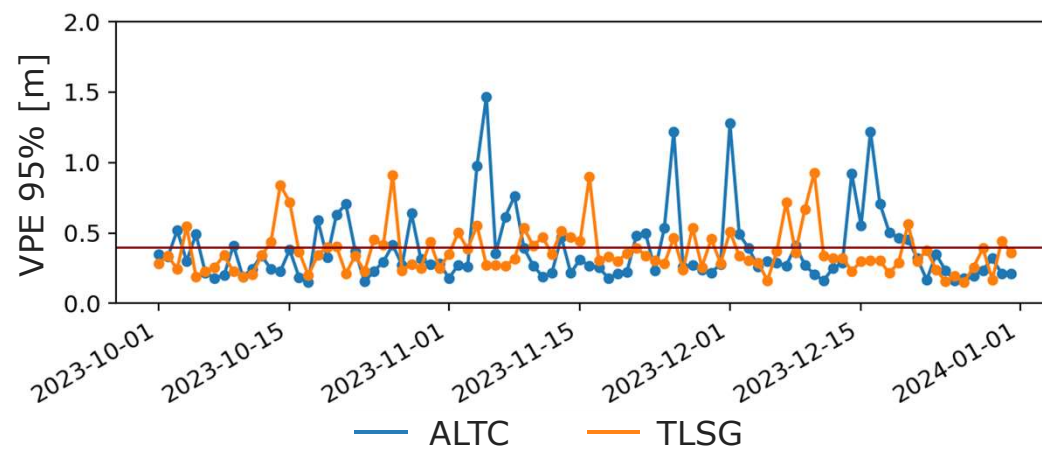
HAS GAL+GPS (quarter 4 2023)

ALTC: 65 (71%) days > 0.2 m, mean: 0.29 m, max: 0.96 m, min: 0.14 m
TLSG: 42 (46%) days > 0.2 m, mean: 0.20 m, max: 0.52 m, min: 0.11 m



HAS GAL+GPS (quarter 4 2023)

ALTC: 27 (29%) days > 0.4 m, mean: 0.38 m, max: 1.47 m, min: 0.15 m
TLSG: 27 (29%) days > 0.4 m, mean: 0.37 m, max: 0.93 m, min: 0.15 m



Summary

- Galileo High Accuracy Service (HAS) is a global and free of charge positioning service with decimeter accuracy
- Galileo HAS Initial Service is available since 24th January 2023
- Galileo HAS Full Operational Service is expected > 2024
- HAS performance for quarter 4 2023:
 - SISE 95%: < 11 cm (GAL), < 20 cm (GPS)
 - Mean HPE 95% (GAL+GPS): 25 cm
 - Mean VPE 95% (GAL+GPS): 38 cm



Outlook

- NMA will proceed with Galileo HAS performance monitoring via GEMOP project
- One of the NMA geodesy division strategy targets is the “Accurate and reliable positioning for all people”, which means:
 - Inhabitants should have easy access to accurate and reliable positioning
 - Through Research & Development cooperations will we find solutions which make a user-based data collection possible with 10 cm position accuracy



Outlook

- NMA has established a team working with “Accurate and reliable positioning for all people”
 - Purchase a Galileo HAS “**ready-to-use**” receiver and look at the positioning performance
 - Following receivers provides/or will provide Galileo HAS solutions:
 - EOS Arrow Gold+
 - **ANavS Arox or MS-RTK**
 - Leica GS07 DS
 - Trimble R580 (expected with a later firmware update)





Questions?

Contact information

→ Michael Dähnn

→ michael.daehnn@kartverket.no



Kartverket