# GNSMART2 and SSR

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# GNSMART2 and SSR

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# About Geo++

## Technology Leader in GNSS Correction Services

**Geo++ is a specialized software company focused on high-precision GNSS solutions.**

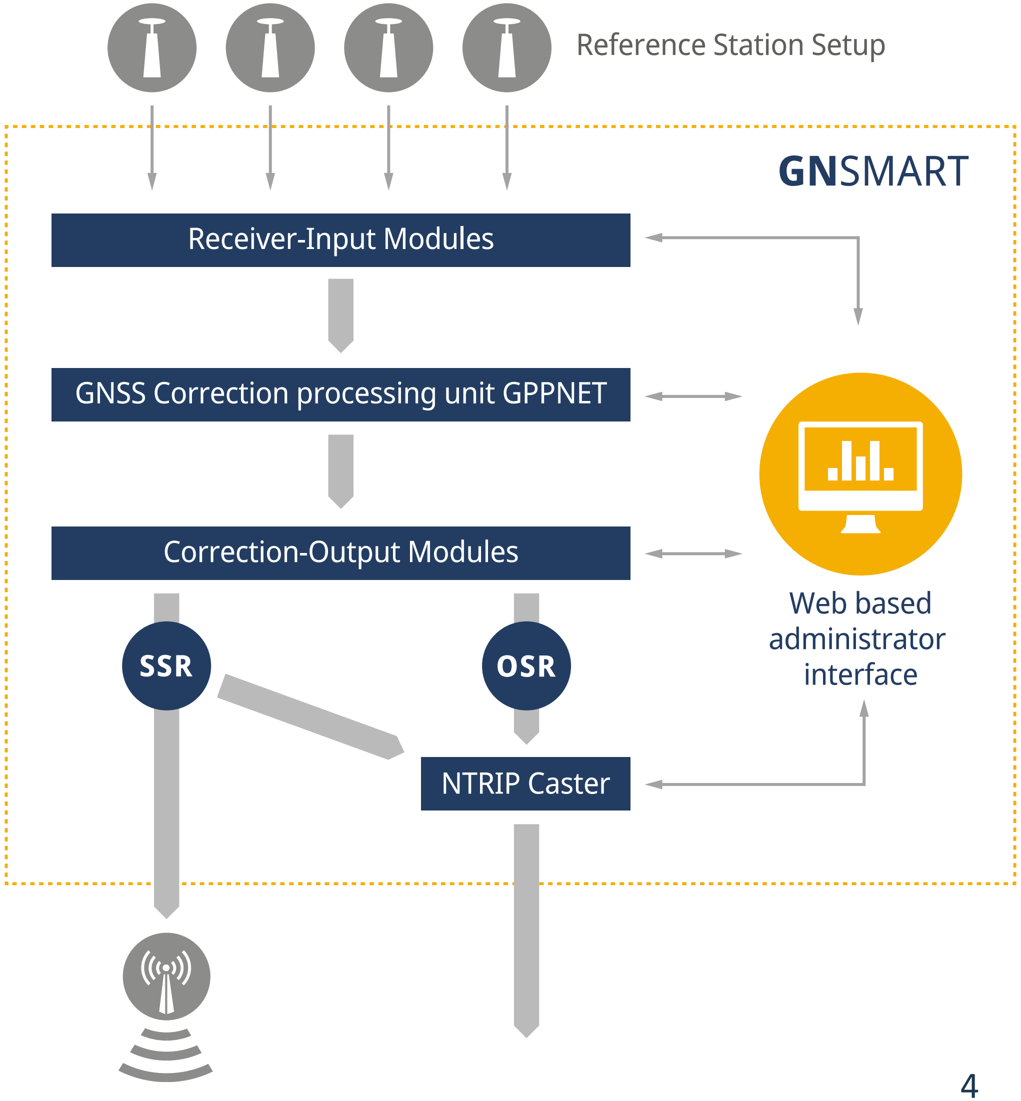
- Founded in 1990 with a focus on innovative satellite-based positioning technologies
- Serving industries such as:
    - Agricultural equipment manufacturers
    - National surveying and mapping authorities
    - Major transportation stakeholders
- Based in Germany, collaborations with international partners and universities

**Geo++ continues to lead in GNSS correction technology, delivering precise, scalable, and future-proof solutions to meet the evolving demands of various industries.**

Geo++ Customers

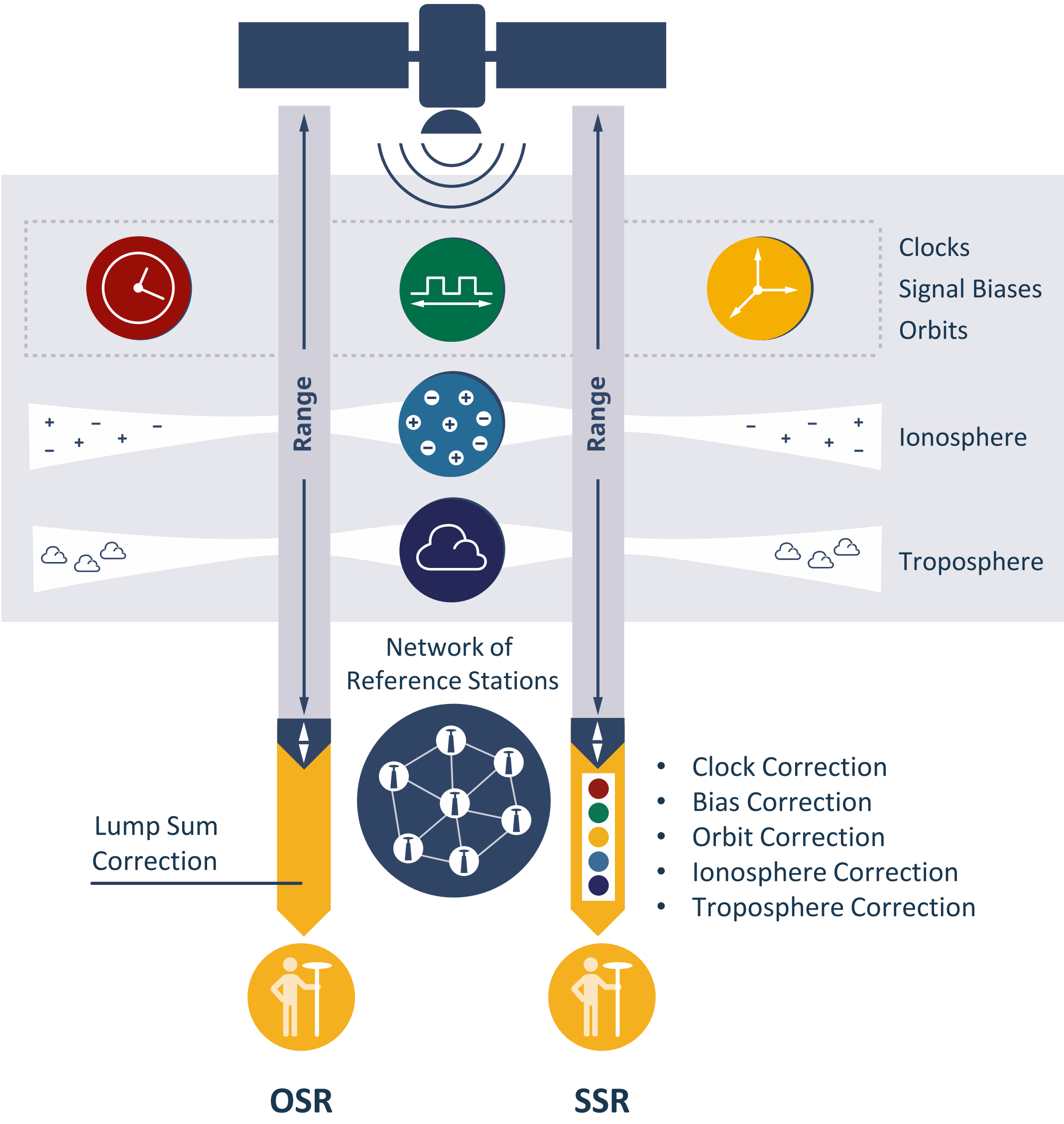
# GNSMART2
## Key Features

- **Geo++ GNSMART** (**GN**SS **S**tate **M**onitoring **A**nd **R**epresentation **T**echnique)
- **Modular and scalable Network RTK and PPP-RTK software suite**
- **Supports all GNSS constellations and signals**
- **Brand-neutral:** supports standard data formats and proprietary formats of all major manufacturers
- **OSR & SSR:** supports both Observation Space Representation (OSR) and State Space Representation (SSR)
- **Flexible positioning methods:** single-base RTK, VRS/PRS, FKP, MAC, SSR
- **Multiple correction distribution channels:** Ntrip, satellite, digital radio
- **GNSMART licence price includes an unlimited number of users**
- **GNSMART licence price is independent of reference station receiver type**



# OSR vs. SSR
## Concepts

- **OSR** (RTK / Network RTK)**:**
  - Combined impact of the errors is observed by the reference stations and transmitted to the rovers
  - OSR corrections contain lump sum of errors
- **SSR** (PPP / PPP-RTK)**:**
  - All error sources are precisely modelled and monitored separately
  - SSR consists of state space parameters that consistently describe the complete GNSS error budget
  - The individual error components are transmitted to the rovers as state parameters
  - SSR parameters have temporal and/or spatial variations
  - Multi-stage atmospheric corrections: can be divided into functional and stochastic (residual) parts



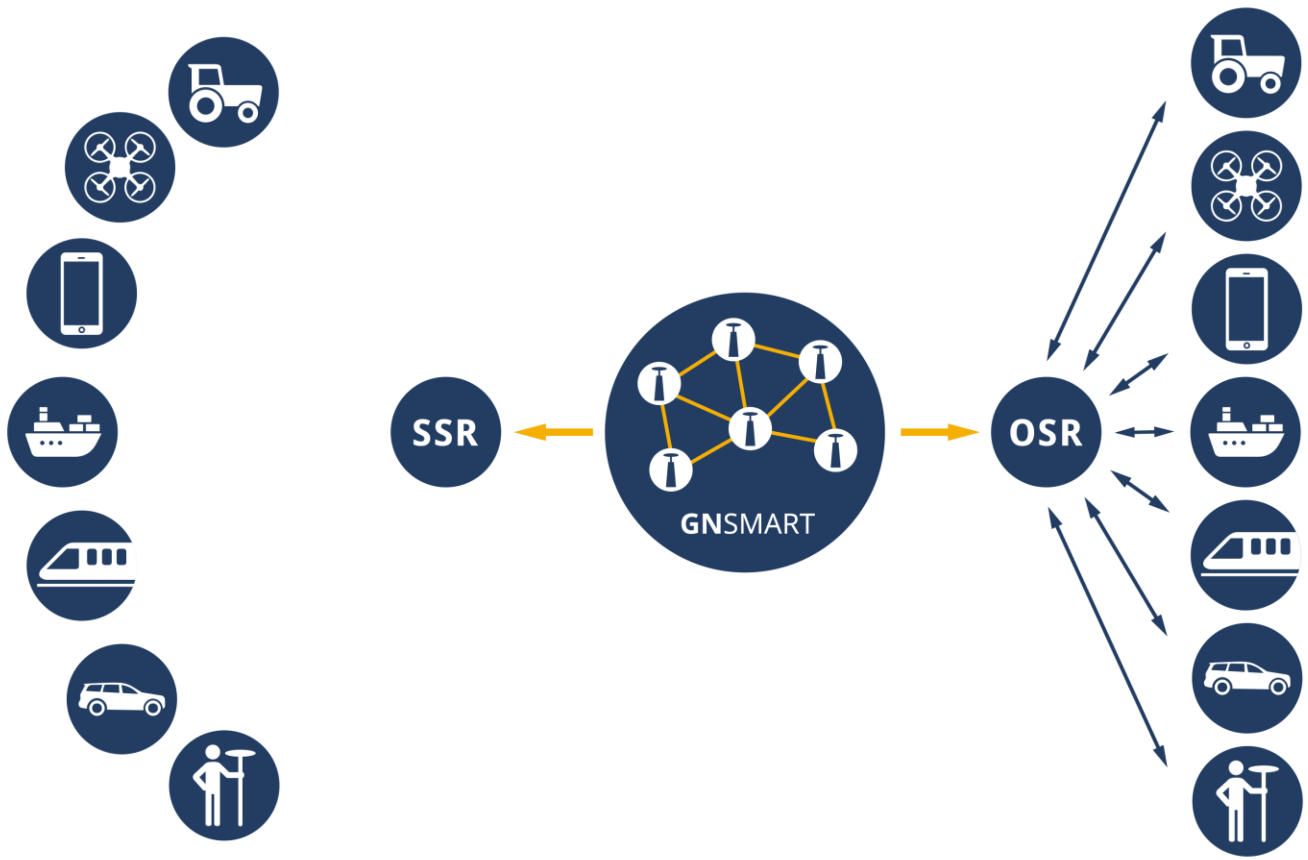
# OSR vs. SSR

## Pros & Cons

- **OSR advantages:**
  - Widely used as it requires no advanced computational techniques
- **OSR disadvantages:**
  - Cannot make use of the different stochastic properties of the underlying physical effects
  - Requires higher bandwidth: the fastest changing error source (satellite clock) defines the output interval – typically 1 Hz
  - Typically requires bi-directional (duplex) data connection between the user and the provider
  - Number of simultaneously connected users is limited

- **SSR advantages:**
  - Increased inter-station distances due to improved modelling of the spatial behaviour of physical effects
    → lower initial investment and maintenance costs
  - Scalable services: inhomogeneous reference station density
  - Not all stations in the network must to track all GNSS signals
  - Minimised bandwidth: different SSR components can be updated at different rates
  - No need for individualised correction generation: users over a large area receive the same corrections
    → reduces system complexity
  - One-way (simplex) data connection is sufficient
    → ideal for broadcast services e.g. satellite-based delivery
  - Unlimited number of users
- **SSR disadvantages:**
  - Requires higher standardisation effort from the manufacturers

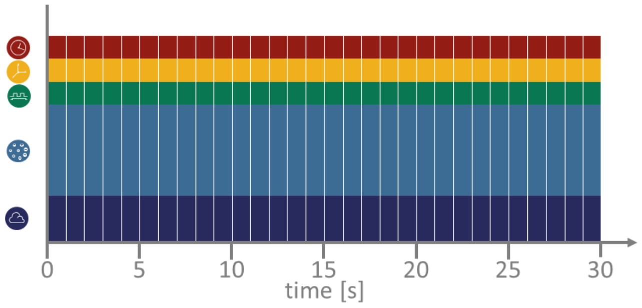
# OSR vs. SSR
## Output data



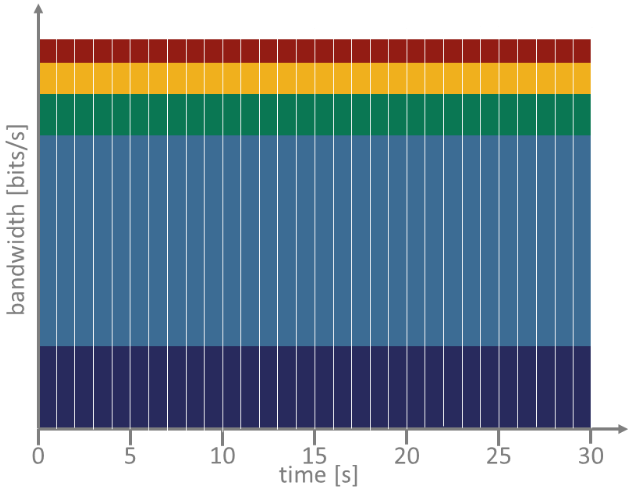
# SSR Distribution in Time
## SSR Consistency

**Geo++ SSRZ supports**

- **full set** of SSR corrections **every epoch**
  → very high bandwidth consumption

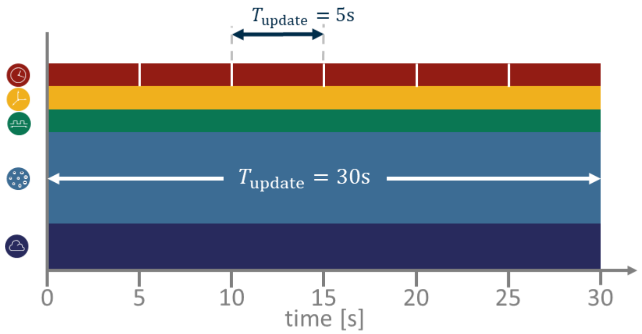


SSR Consistency Timeline

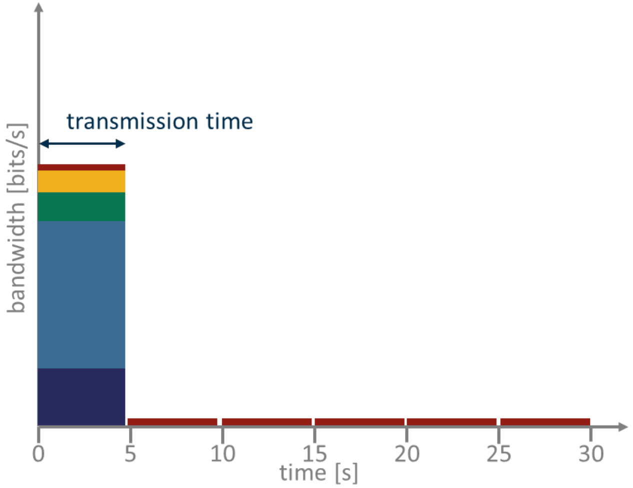


Bandwidth Diagram

- **burst mode**
  i.e. low-rate and high-rate corrections



SSR Consistency Timeline



Bandwidth Diagram

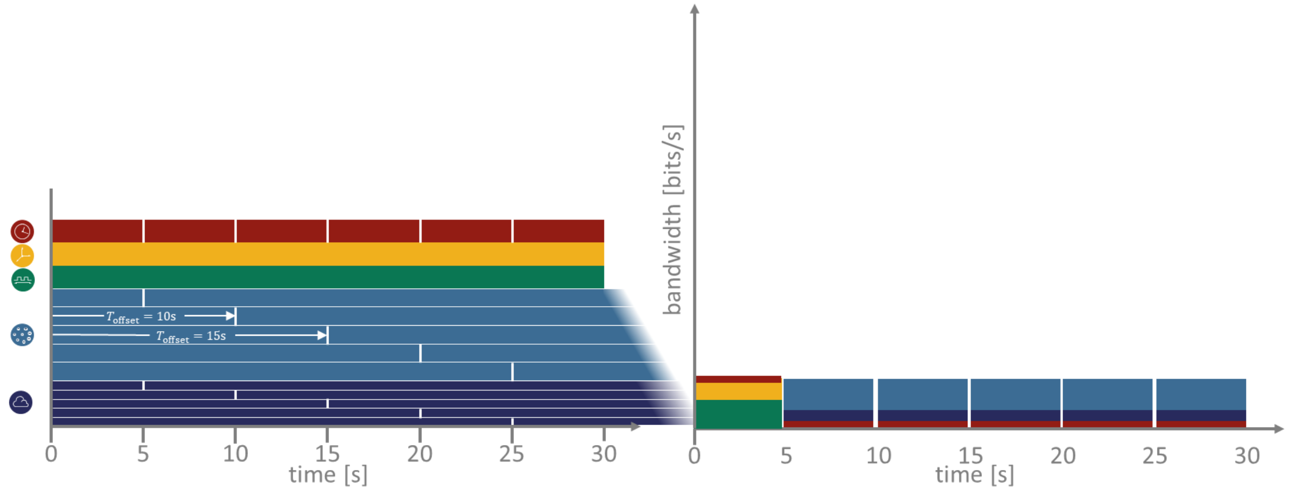
# SSR Distribution in Time

## SSR Consistency

**Geo++ SSRZ supports**

- Transmission with **temporal offsets**
- Service area separated into e.g. 5 sub-grids
- Each grid is updated with $T$_offset=5, 10, 15, 20, 25s

→ balanced bandwidth



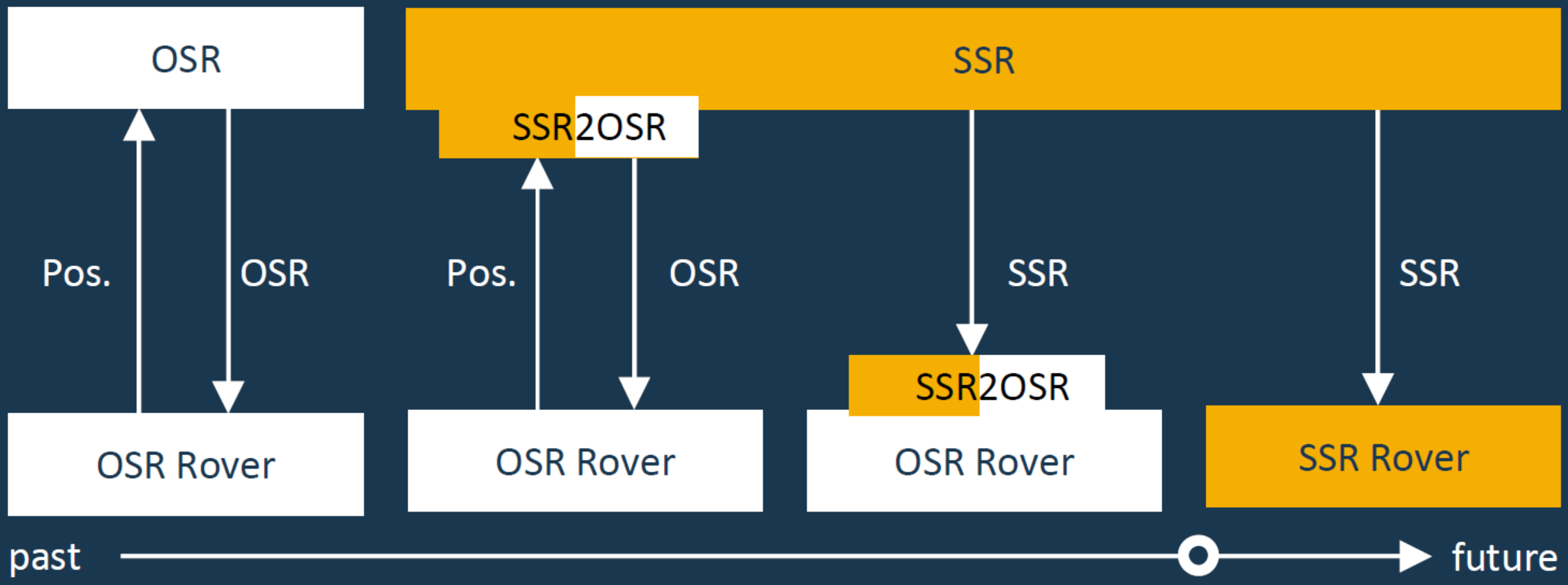

SSR Consistency Timeline

Bandwidth Diagram

# Open SSR Formats Supported by GNSMART2
## SSR Corrections

| SSR Basic Parameters | Multi-stage/ Scalability | | RTCM-SSR | IGS SSR (1.0) 4076 | SSRG Geo++ 4090.2 | 3GPP-LPP (Release 16) | SPARTN (2.0) u-blox | SSRZ (1.1) RTCM Geo++ 4090.7 |
|---|---|---|---|---|---|---|---|---|
| Supported GNSS | | | G,R | G,R,E,C,J | G,R,E,C,J,S,I | G,R,E,C,J,S,I | G,R,E,C,J | G,R,E,C,J,S,I |
| SV **clock** | high-rate clock | | available | available | available | available | available | available |
| | low-rate clock | | available | available | | | | available |
| SV **orbit** | | | available | available | available | available | available | available |
| SV code **bias** | | | available | available | available | available | available | available |
| SV phase **bias** | | | available | available | available | available | available | available |
| **ionosphere** | global | VTEC | | available | | | available | available |
| | global | STEC | | in preparation | | | | available |
| | regional | STEC | interop-testing | | | available | available | available |
| | residual | gridded | interop-testing | | available | available | available | available |
| **troposphere** | regional | | interop-testing | in preparation | | available | available | available |
| | residual | gridded | interop-testing | | available | available | available | available |
| complete SSR model | | | yes | no | yes | yes | yes | yes |

# From OSR to SSR
## Status

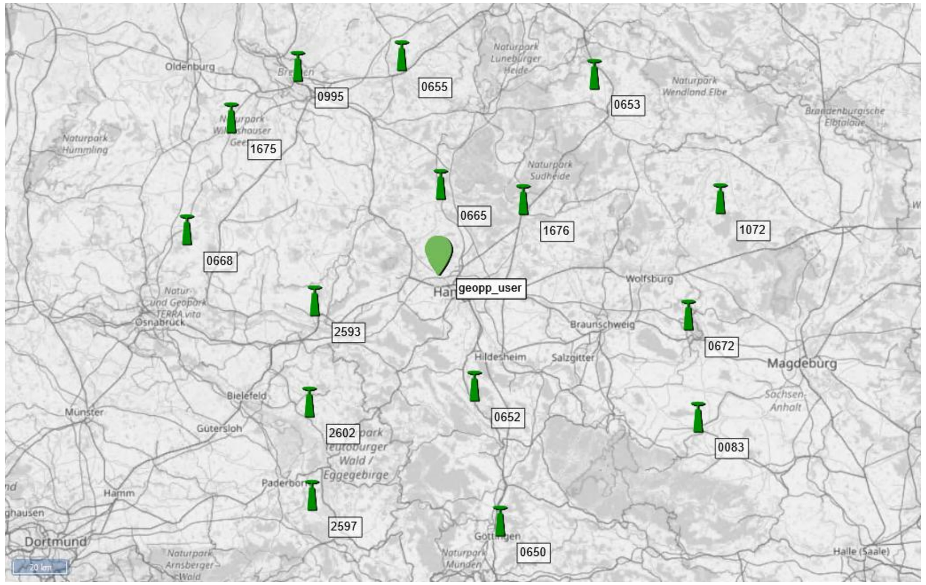


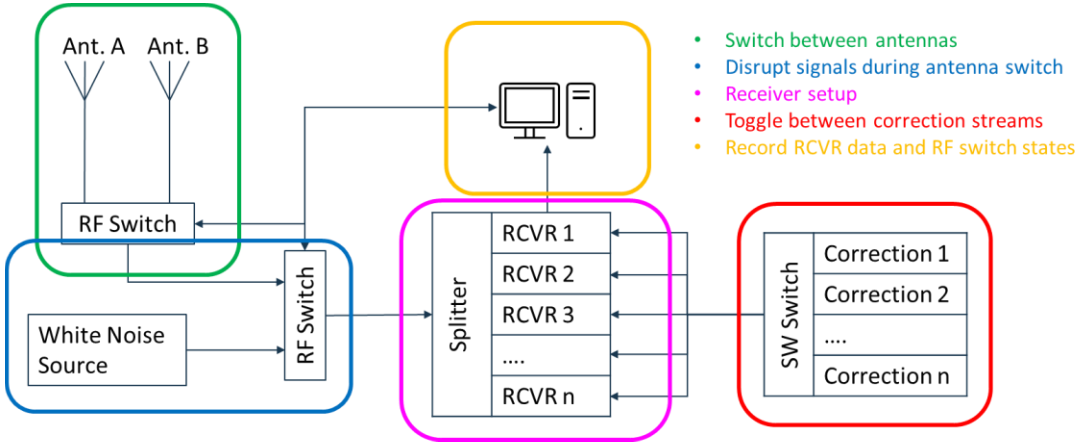
# Rover-side SSR to OSR Conversion
## Examples

- Geo++ SSR2OBS executable for Windows and Linux OS
- Geo++ SSR2OSR Android App
- CNH PCM modem
- Teltonika TRB142 modem
- Alberding A10-RTK GNSS receiver
- TERIA PYX GNSS receiver
- Hi-Target T800 GNSS receiver
- Hi-Target HT Farmstar F3
- CHCNAV PA-5 GNSS receiver


# SSRZ Rover Performance Tests
## Network RTK vs. PPP-RTK

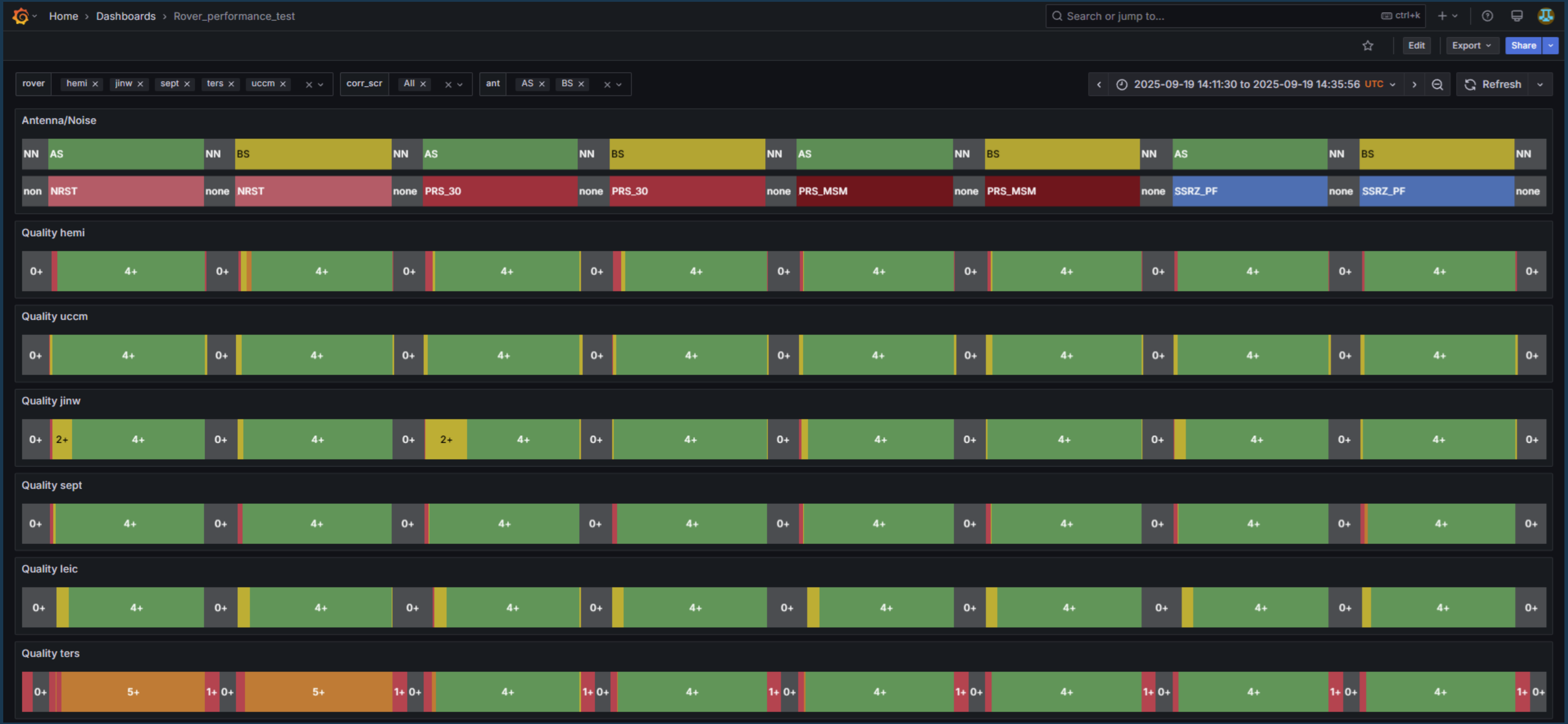
- **GNSMART test network**
  - 15 SAPOS stations around Hanover (~65 km interstation dist.)
- **RTK rover test bench at the Geo++ office in Garbsen** (near Hanover)
  - 30 km from the nearest station
- **GNSS antennas:**
  - Antenna A: choke-ring antenna
  - Antenna B: rover antenna
- **RTK rover receivers:**
  - Hemisphere Phantom 40
  - Unicorecomm UM980
  - Jinwei DM711
  - Septentrio AsteRx m2
  - Leica GS25
  - Tersus David30
- **Corrections:**
  - Nearest-base
  - PRS RTCM 3.0
  - PRS MSM
  - SSRZ
- **SSR2OBS running on PC**



# SSRZ Rover Performance Tests

## RTK Fixing Status Analysis

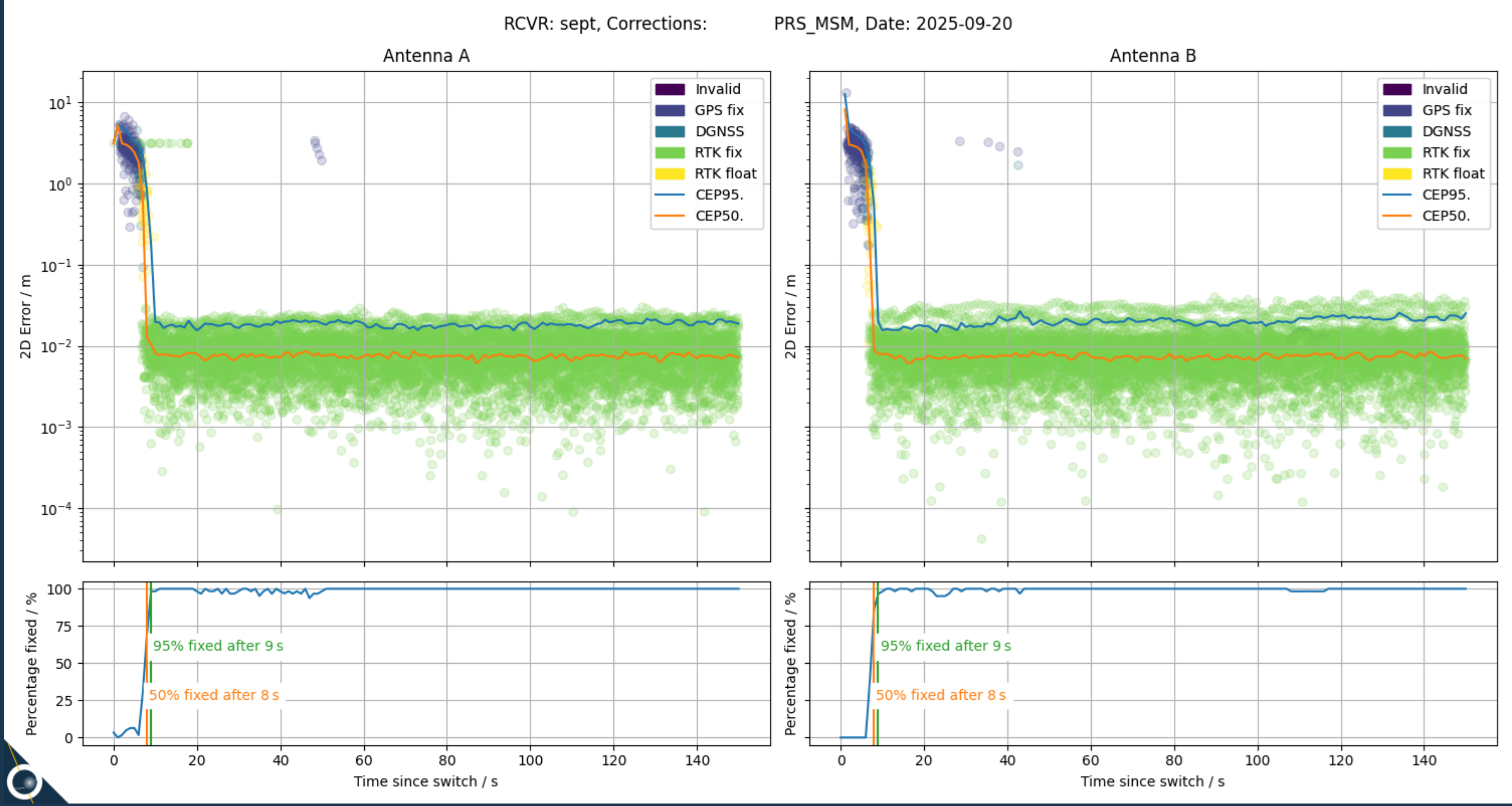


# SSRZ Rover Performance Tests

## RTK Fixing Status Analysis

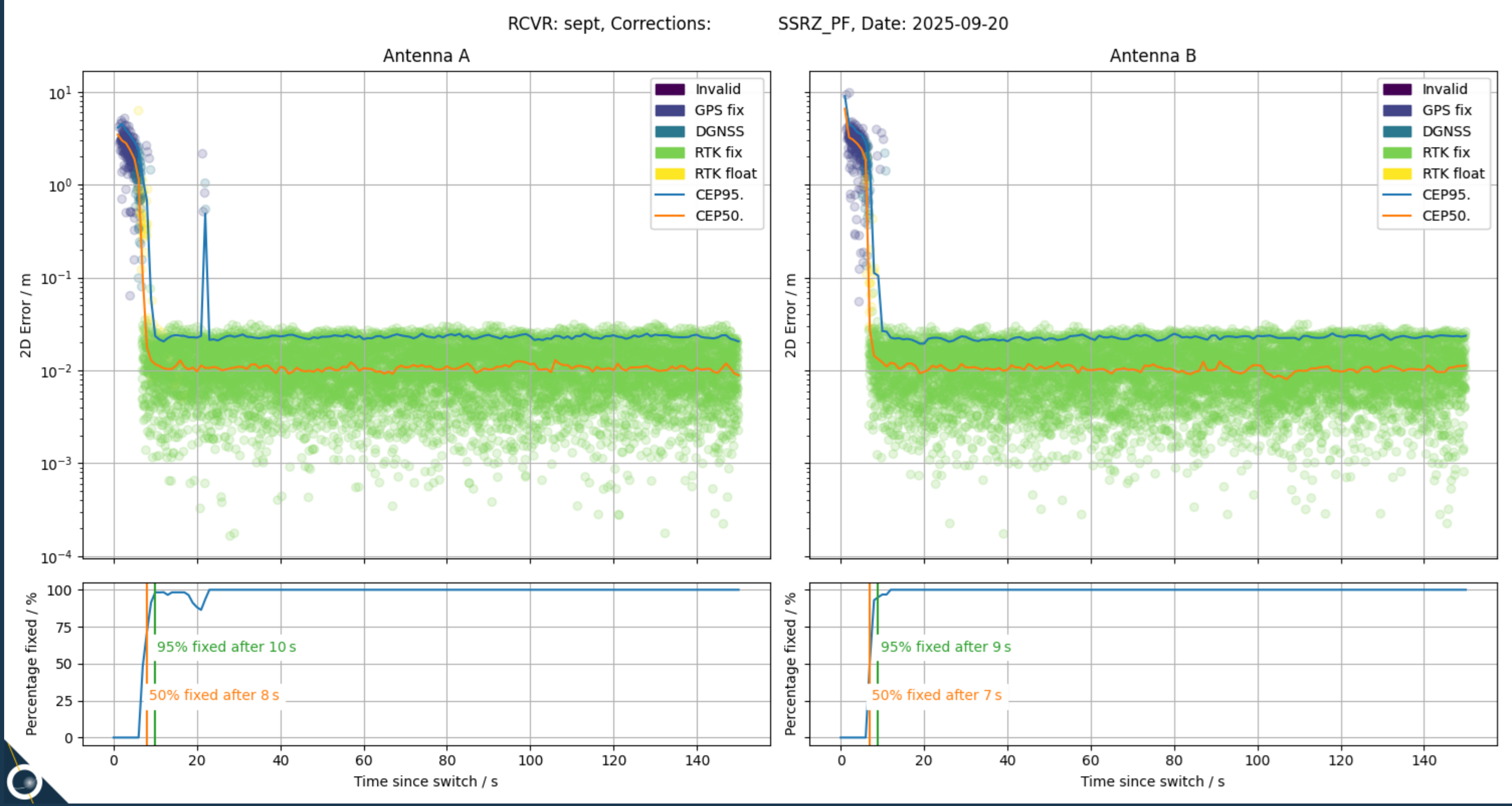
# SSRZ Rover Performance Tests

## Ambiguity Fixing Time and Hz Positioning Accuracy Analysis – PRS MSM

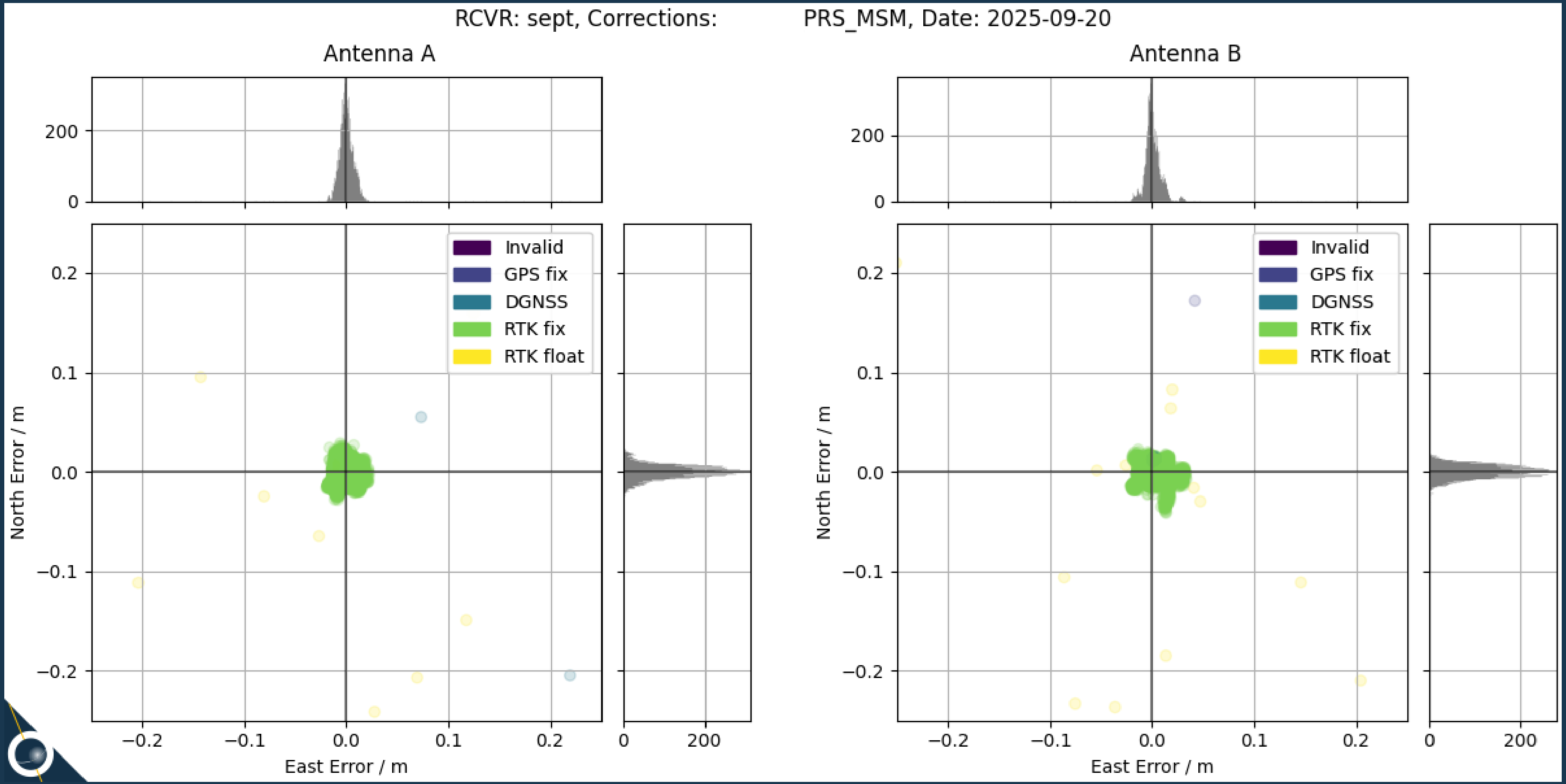


# SSRZ Rover Performance Tests

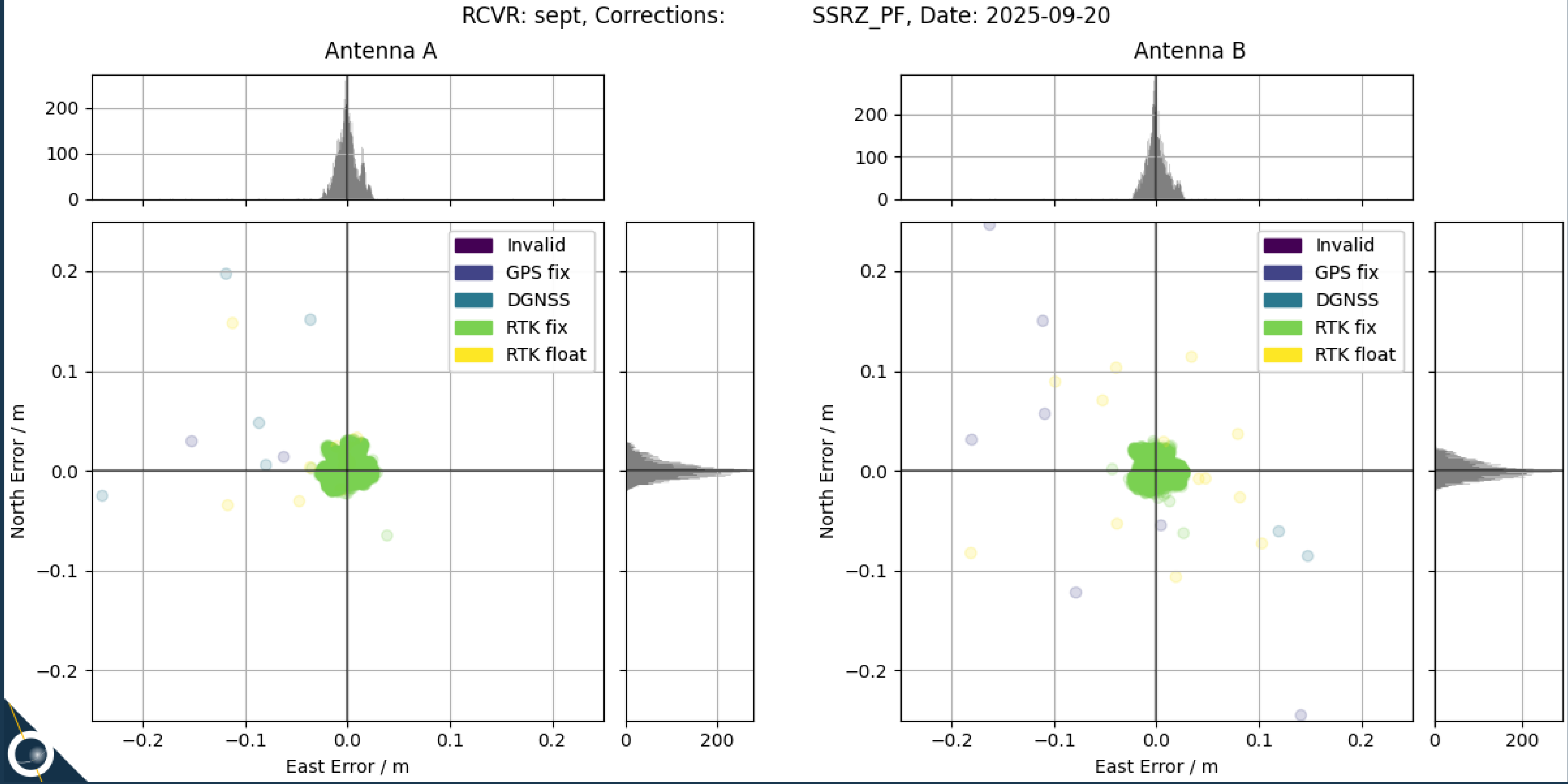
## Ambiguity Fixing Time and Hz Positioning Accuracy Analysis – SSRZ



# SSRZ Rover Performance Tests
## Hz Positioning Accuracy Analysis – PRS MSM



# SSRZ Rover Performance Tests
## Hz Positioning Accuracy Analysis – SSRZ



# Case Study:
## GNSS Correction Data in Japan – Implementation of GNSMART for QZSS L6 CLAS

**Challenge:**
- Japan needs efficient and precise GNSS corrections for nationwide high-accuracy positioning
- Requirement to seamlessly integrate multiple sub-networks into a consistent SSR
- Reception of GNSS correction in Urban Environment

**Geo++ Solution:**
- Geo++ implemented GNSMART with 300 reference stations
- Divided the system into 12 sub-networks, each running its own GNSMART instance
- Cascaded networks to form a unified, consistent SSR solution for Japan

**Results:**
✓ Achieved nationwide high-precision GNSS correction coverage
✓ 12 SSR datasets updated and merged every 5 seconds
✓ Optimized data transmission at 1700 bit/s for reliable performance

**Geo++ GNSMART is the backbone of Japan's GNSS CLAS service, enabling precise and advanced applications supporting geospatial and future mobility solutions**.


1. West Hokkaido
2. East Hokkaido
3. North Tohoku
4. South Tohoku
5. Kanto
6. Hokuriku
7. Chubu
8. Kansai
9. Chugoku
10. Shikoku
11. North Kyushu
12. South Kyushu

# Case Study:

## *SAPOS* | GEPOS - Joint Official PPP-RTK Positioning Service of the Federal and State Authorities

**Challenge:**

- The Federal Agency for Cartography and Geodesy (BKG) and the Working Committee of the Surveying Authorities of the Federal Republic of Germany (AdV) integrated Geo++ GNSMART into its surveying processes to receive precise, real-time GNSS corrections
- Enable a German wide broadcast GNSS correction service for the bandwidth restricted communication channel DAB+
- Coverage of the North Sea exclusive economic zone
- In addition, Internet-based GNSS correction services

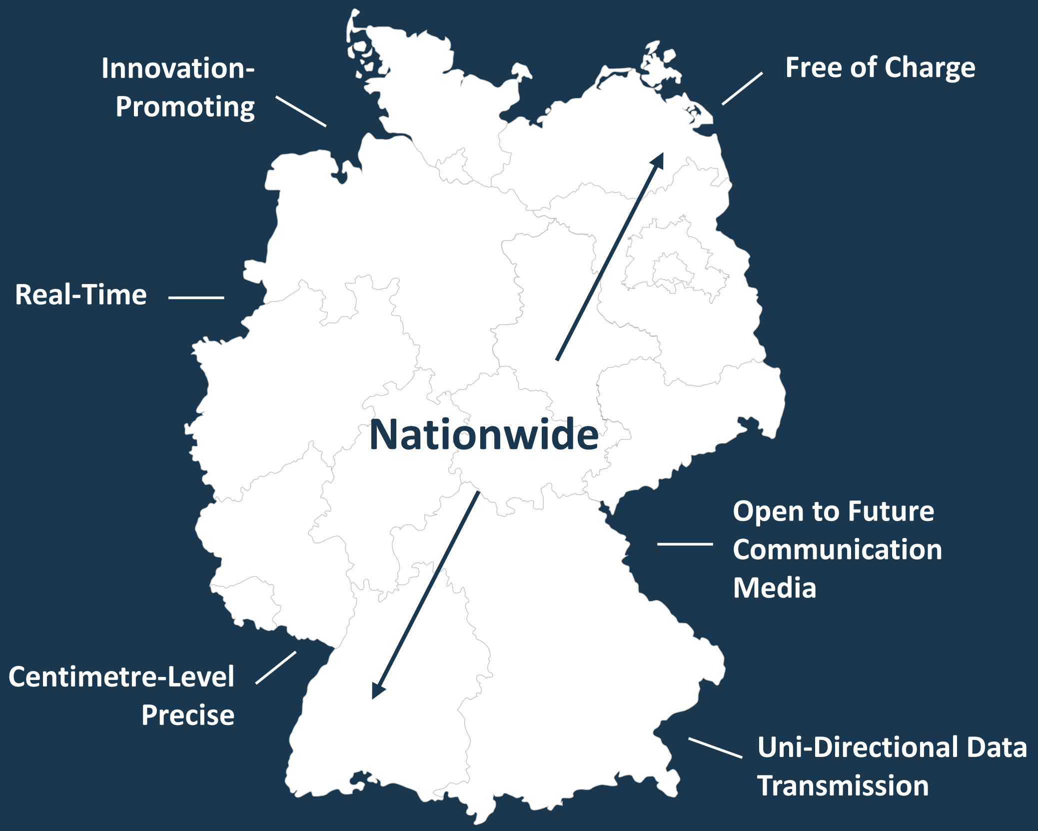
**Geo++ Solution:**

- Use of advanced SSR corrections
- Utilization of a large network of GNSS reference stations
- Real-time corrections to reduce positioning errors to 1–2 centimetres

**Results:**

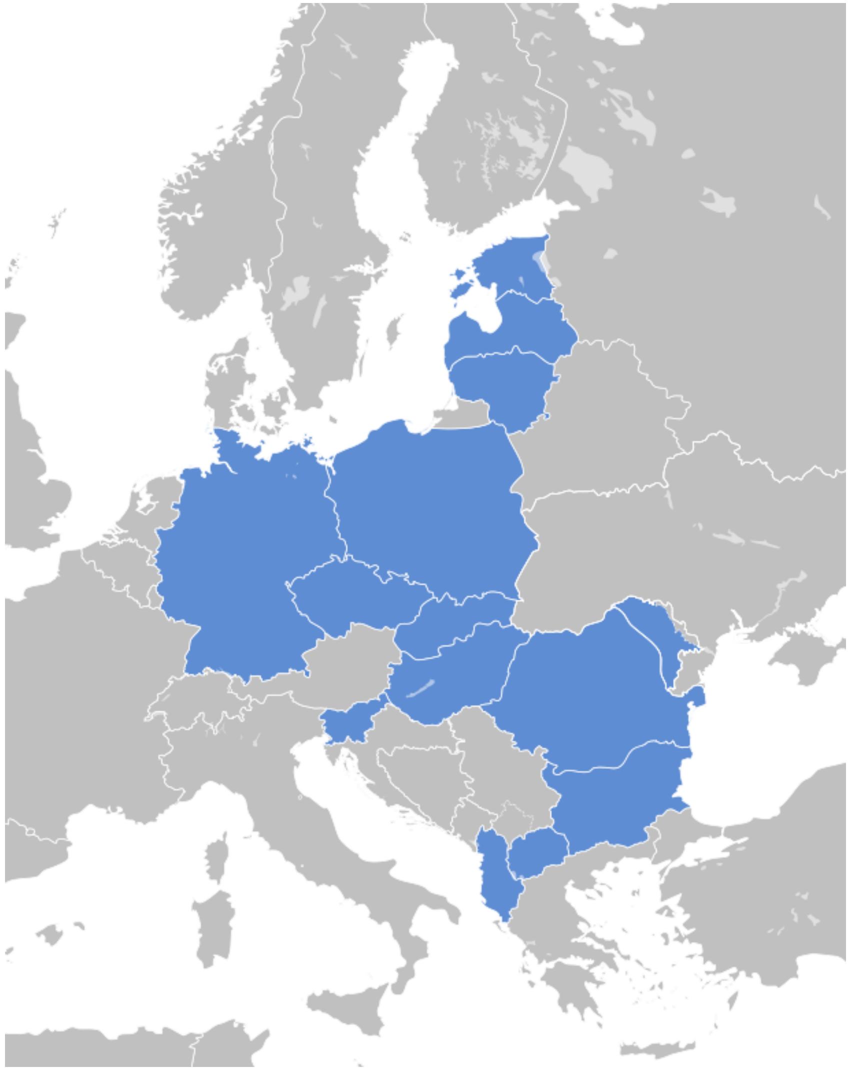
- RTK fix is achieved within seconds, resulting in minimal downtime.
- High Accuracy: 2D horizontal errors are consistently reduced to 1–2 centimetres.
- Increased coverage with DAB+ compared to mobile services

**Collaboration with BKG and ZSS (Central Office *SAPOS*) within AdV demonstrates how Geo++ GNSMART is revolutionizing national surveying processes with precise, scalable, and future-proof GNSS correction solutions.**



# *EUPOS®* SSR service
## Would you be interested?

- Local SSR service in any *EUPOS®* country
- Regional *EUPOS®* SSR service



# Antenna Calibration
## Geo++ Service

- **Individual absolute antenna calibration**
- **Type Mean calibration results (GNPCVDB)**
  - ~200 antenna types
  - Regularly updated
  - Multi-frequency PCV/GDV corrections
  - ATX and ATZ formats

- **GPPVC6050 VeraChoke®**
  - Rebranded Tallysman VeraChoke® VC6050
  - Geo++ GPP1 radome

# Further Information

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