Integrity of an RTK-INS positioning system using SSR corrections for safety-critical automotive applications

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SSR corrections in Septentrio’s RTK-INS engine

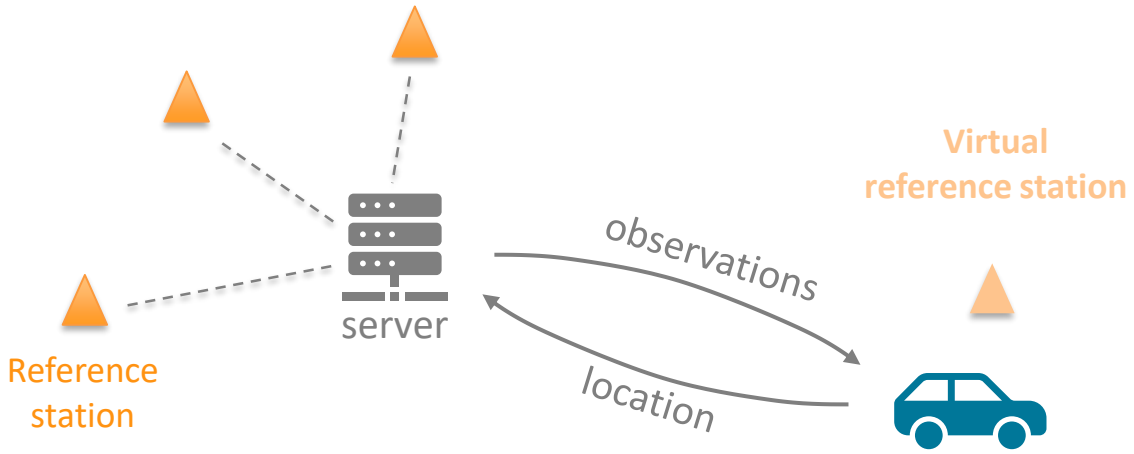
Proven reliability in automotive applications

SSR corrections in Septentrio’s RTK-INS engine

State Space Representation corrections

Observation **S**pace **R**epresentation

Traditional RTK



Message: observations (code, phase)

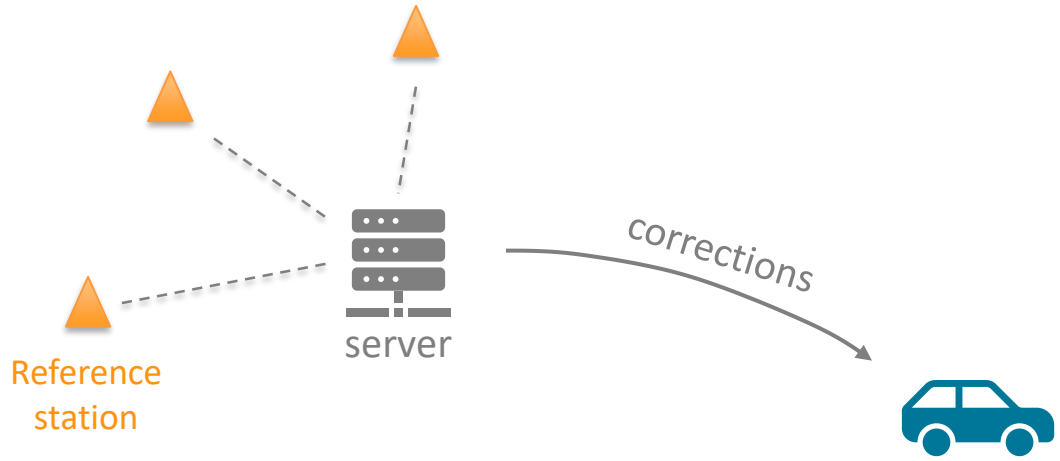
Valid at reference location

Local coverage

Two way communication

State **S**pace **R**epresentation

Future high precision GNSS



Message: corrections (orbit, clock, iono,...)

Valid in entire region

Regional coverage

One way communication

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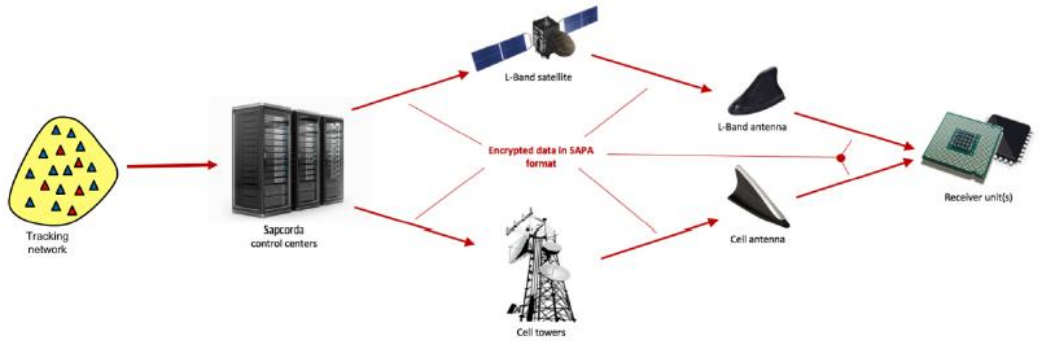
SSR in Septentrio's RTK-INS engine

- SAPCORDAafe **A**nd **P**recise **COR**rection **DA**ta services) is a leading SSR corrections provider
- SAPA message format is converted to OSR (RTCM MSM format) in the receiver

  → Enables use of Septentrio's **field proven multi-constellation RTK engine**
- RTK solution is fused with IMU measurements

Provider side



Raw GNSS Data collected by tracking network

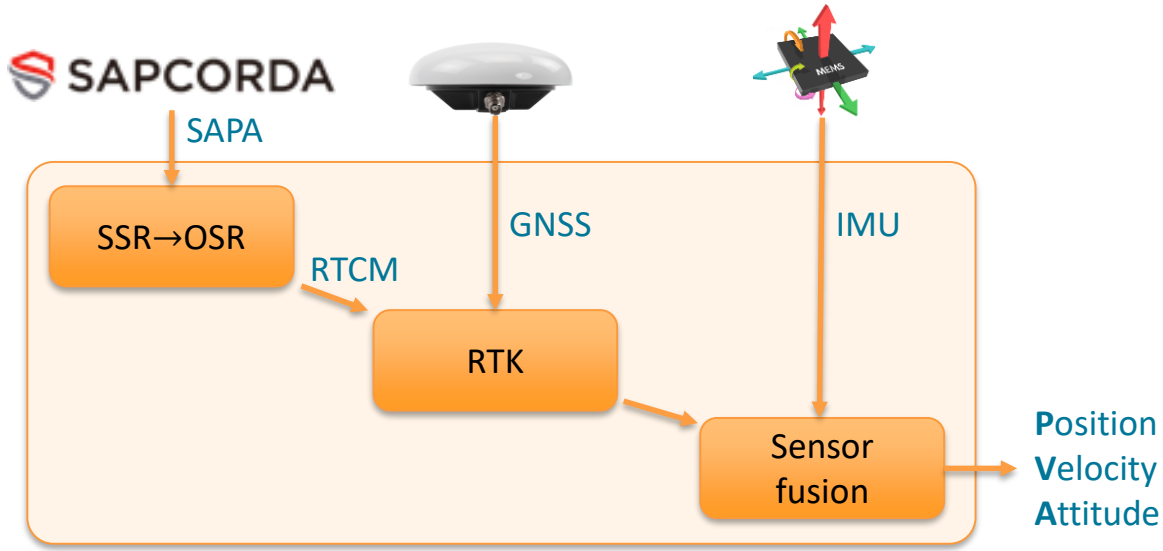
Processed by data centers to generate corrections

Broadcast by internet or L-Band

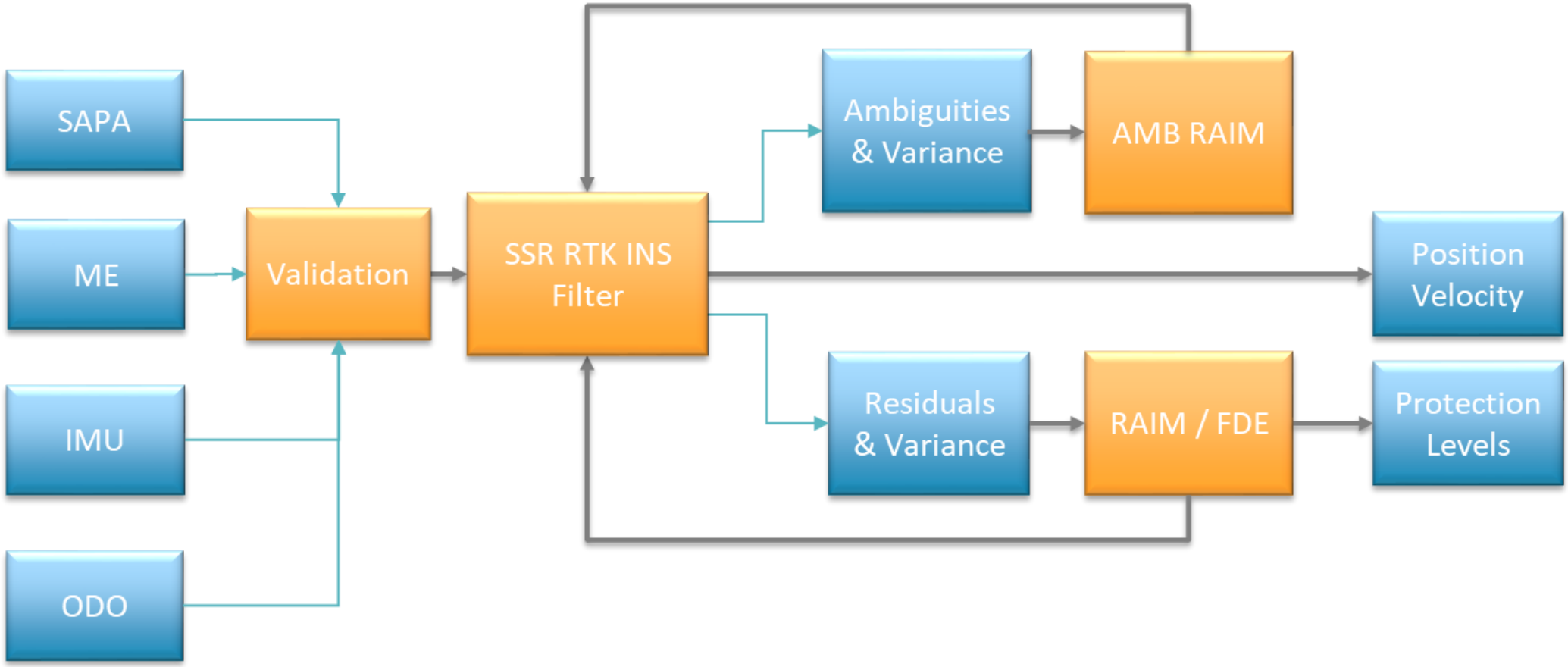
Position Computed by end user

Source: Sapcorda

Receiver side



Integrity concept for RTK-INS



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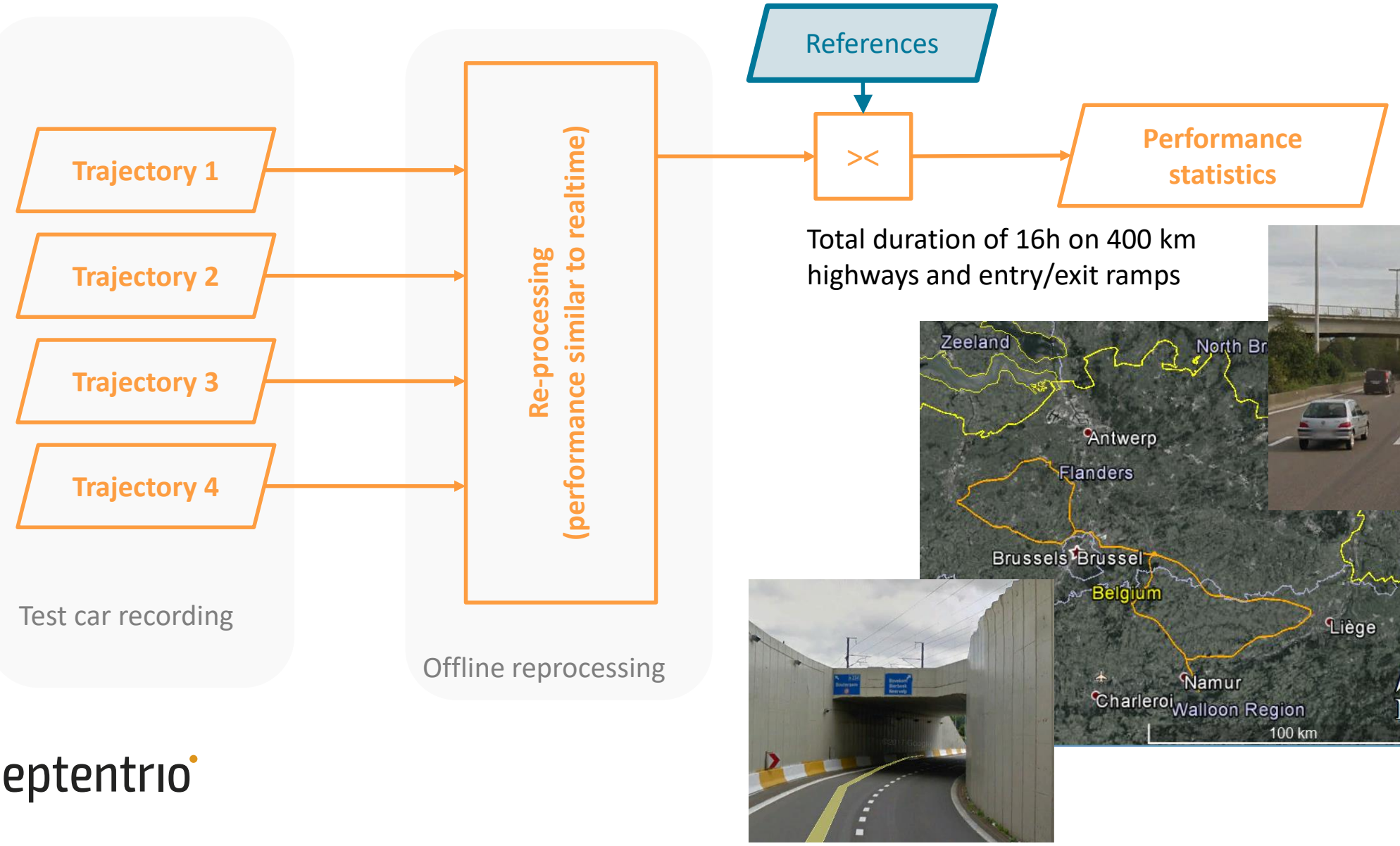
Proven reliability in automotive applications

Extensive test suite for performance statistics



High end reference system
based on ATLANS by iXblue

Numbers valid for post-processing
ATLANS without DMI aiding

open sky	Roll/Pitch	0.005°
	Heading	0.02°
	Horizontal	2cm
	Vertical	5cm
60s outage	Roll/Pitch	0.015°
	Heading	0.02°
	Horizontal	100 cm
	Vertical	50 cm

The ATLANS is a GNSS/INS system with:

- → Navigation grade Fiber-Optic Gyro
- → Combines forward and backward processing
- → Lever arm is calculated with a total station

The test car has 4 roof-antennas, each roof antenna can be connected to 8 different receivers

- → Reference computed from each antenna with RTK
- → Robust weighted averaging to compute master reference

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Presented performance statistics

Device under test: AsteRx-i S

- Off-the-shelf unit
- SBG Ellipse Micro IMU
- No odometer

Performance statistics

- Availability
- Accuracy
- Reliability

These statistics are available for

- Position
- Velocity

Presented performance statistics

Device under test: AsteRx-i S

- Off-the-shelf unit
- SBG Ellipse Micro IMU
- No odometer

Performance statistics

- **Availability** indicates the percentage of epochs with fixed RTK ambiguities.
- Accuracy
- Reliability

Presented performance statistics

Device under test: AsteRx-i S

- Off-the-shelf unit
- SBG Ellipse Micro IMU
- No odometer

Performance statistics

- Availability
- **Accuracy** is measured as the distance to the reference values, expressed in horizontal and vertical accuracy percentiles (P68, P95 and P99).
- Reliability

Presented performance statistics

Device under test: AsteRx-i S

- Off-the-shelf unit
- SBG Ellipse Micro IMU
- No odometer

Performance statistics

- Availability
- Accuracy
- **Reliability** tells us if the true error is within the reported deviation. We calculate a confidence ellipsoid E_1 for the rover based on the reported covariances and a similar confidence ellipsoid E_2 for the reference. We can then classify epochs:

Reliable

$E_2 \subset E_1$

Uncertain

$E_2 \cap E_1 \neq \emptyset$ and $E_2 \not\subset E_1$

Unreliable

$E_2 \cap E_1 = \emptyset$

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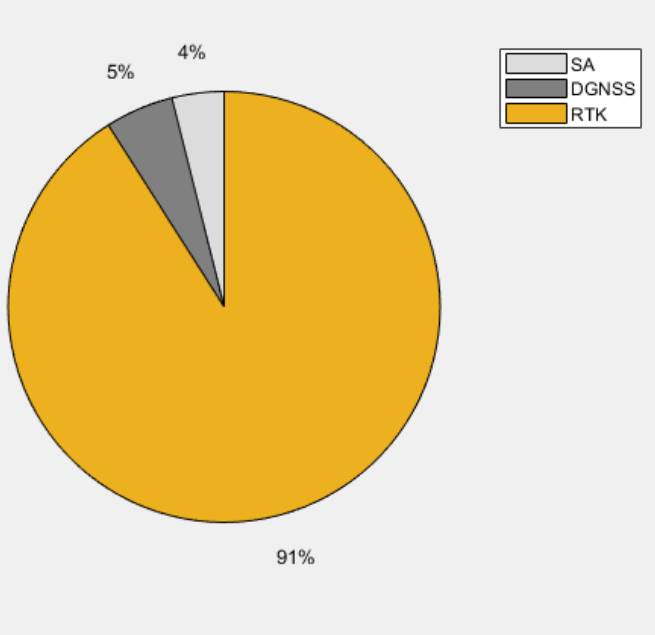
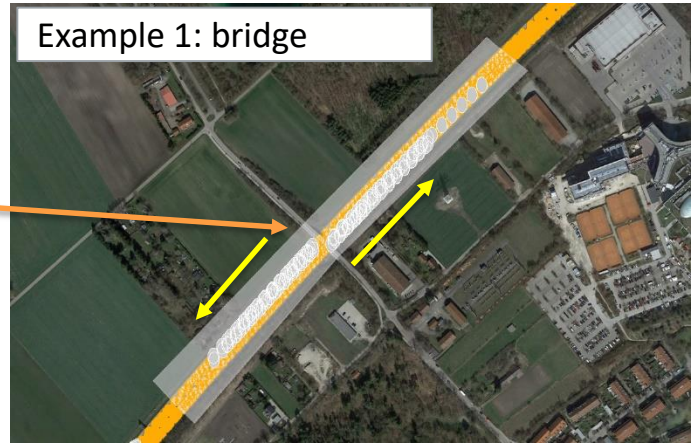
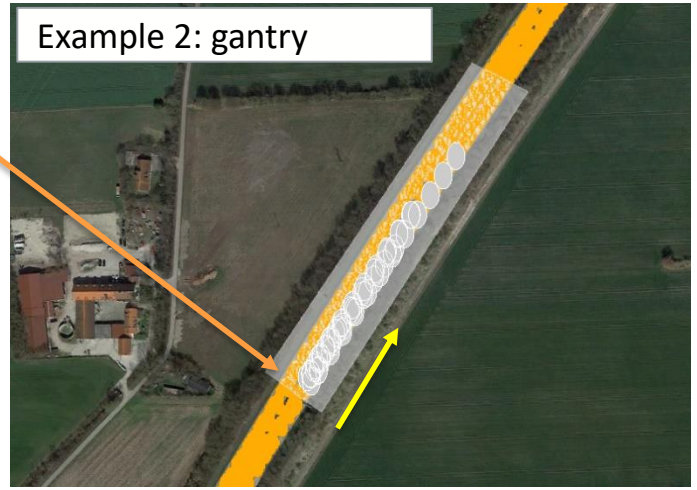
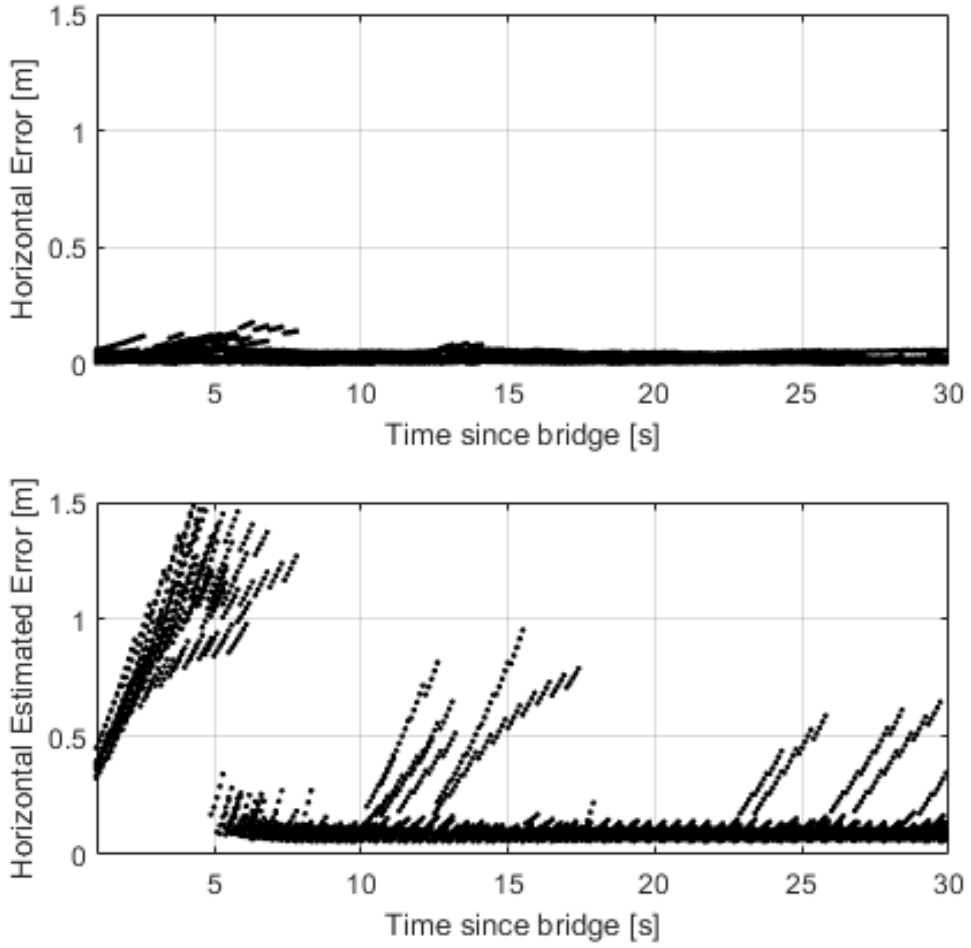
Solution Availability
Impact of overhead obstructions







Solution Availability
Impact of overhead obstructions

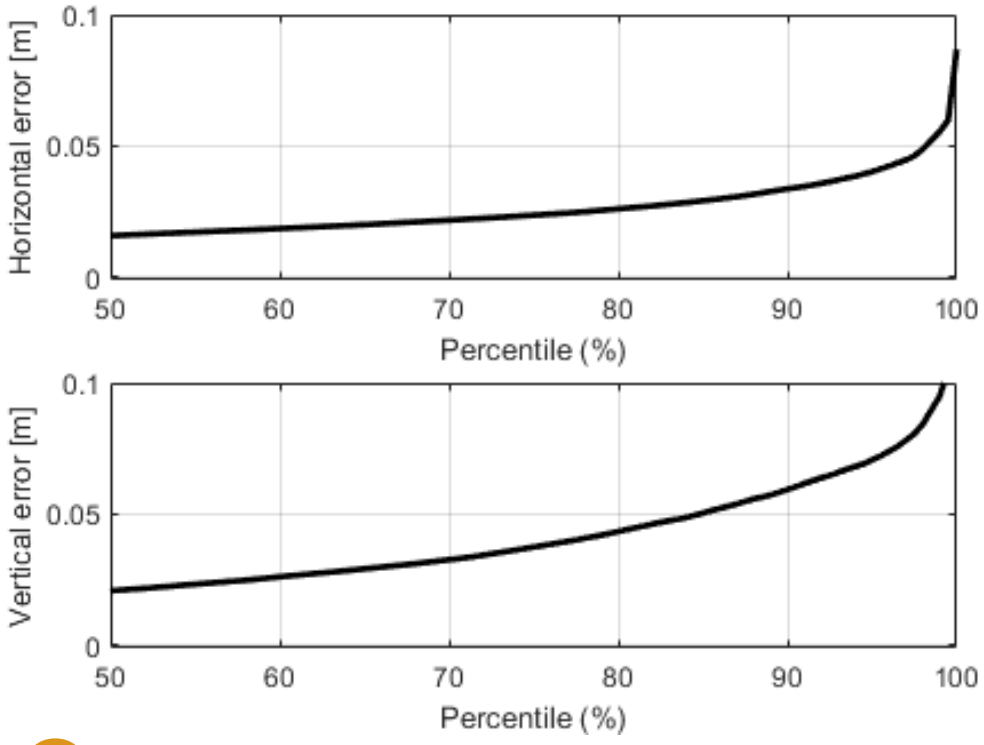


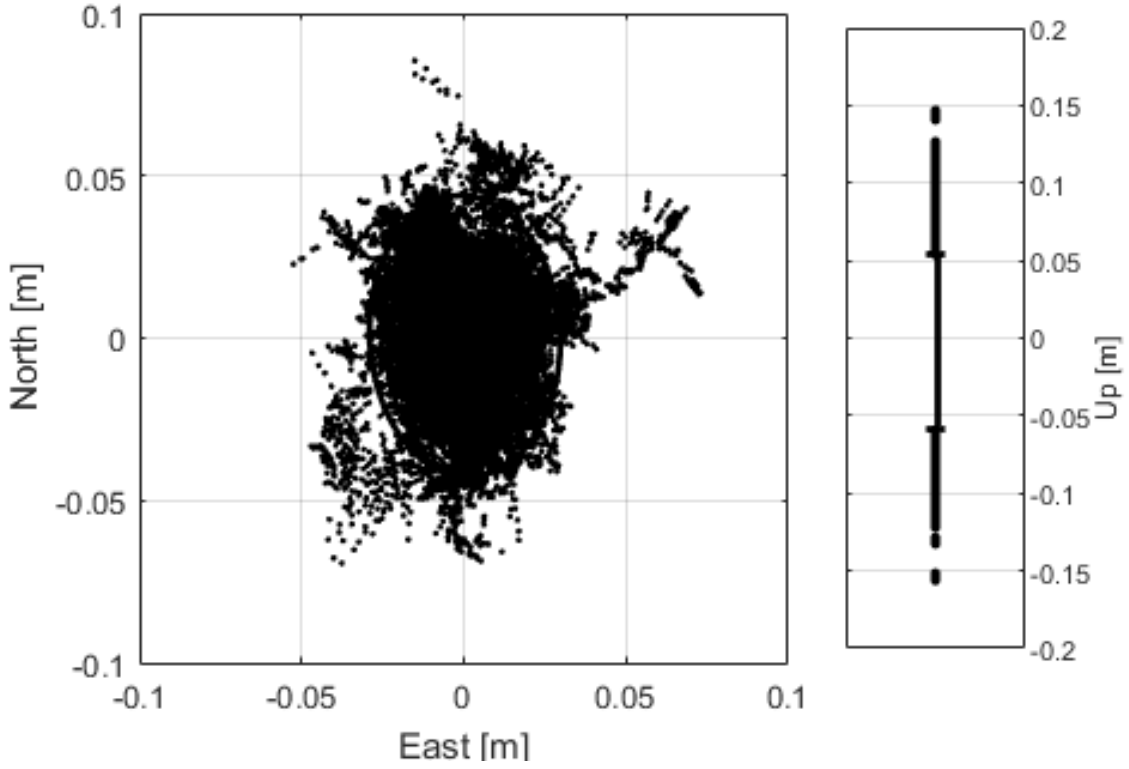
Animated real-time skyview of overhead obstructions

Position Accuracy
RTK epochs

Error [cm]	Horizontal			Vertical		
	P68	P95	P99	P68	P95	P99
AsteRx-i S	2.1	4.0	5.3	3.1	7.0	9.5

Solution at 1 Hz





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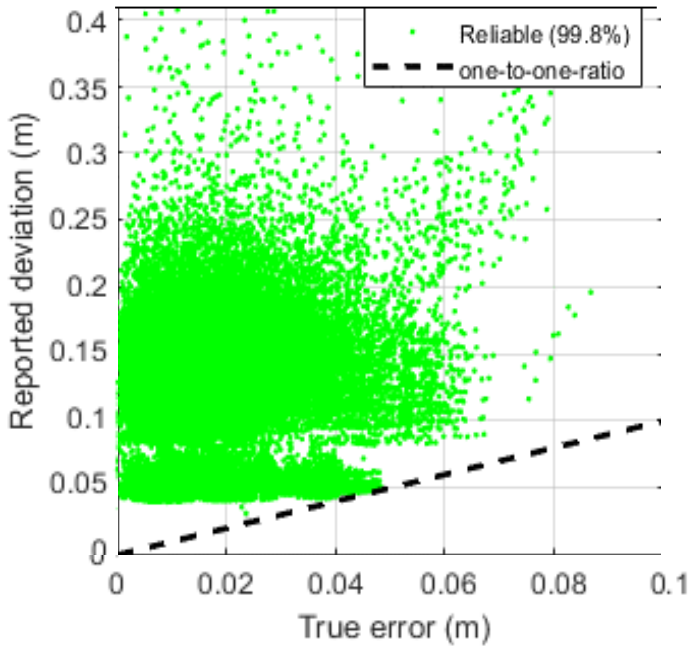
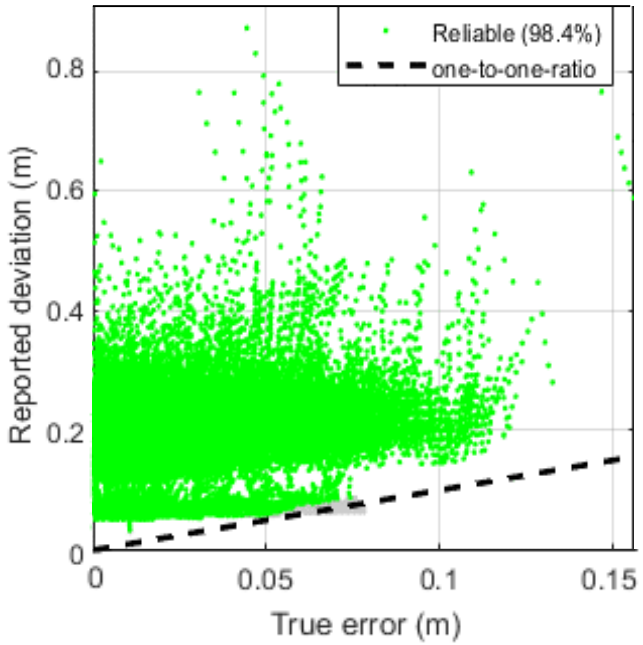
Position Reliability



[%]	Horizontal		
	REL	UNC	UNR
AsteRx-i S	99.8	0.2	0



[%]	Vertical		
	REL	UNC	UNR
AsteRx-i S	98.4	1.6	0

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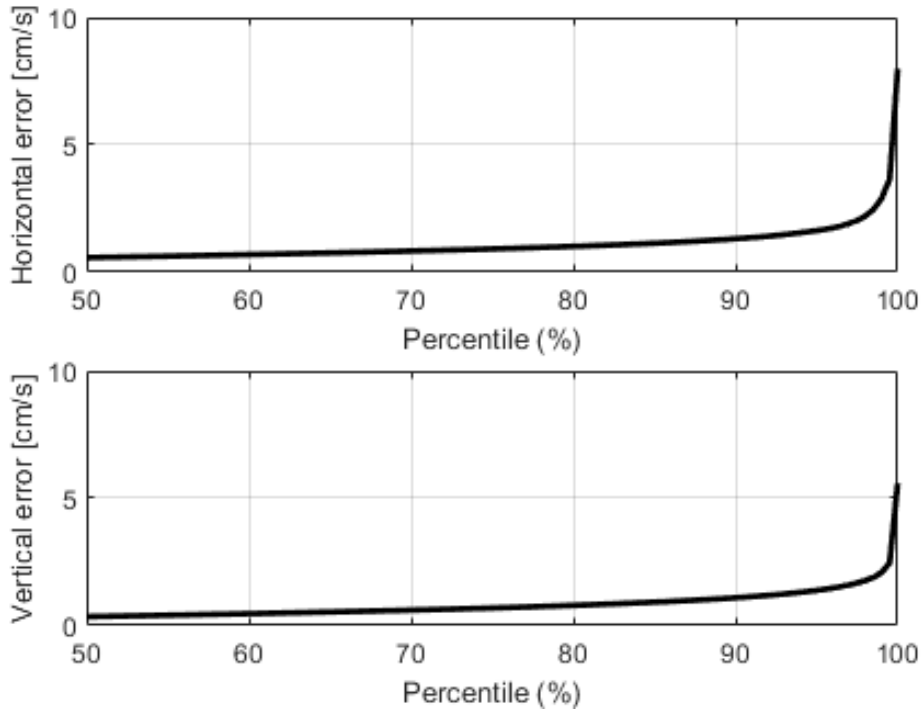
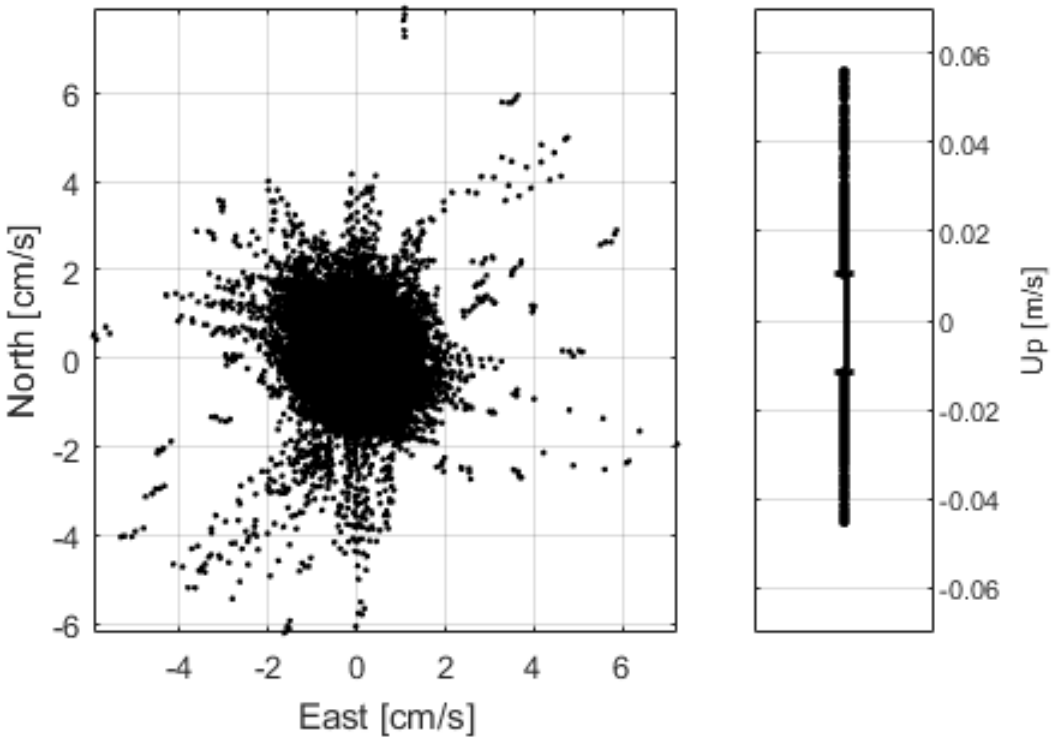
Velocity Accuracy
All epochs

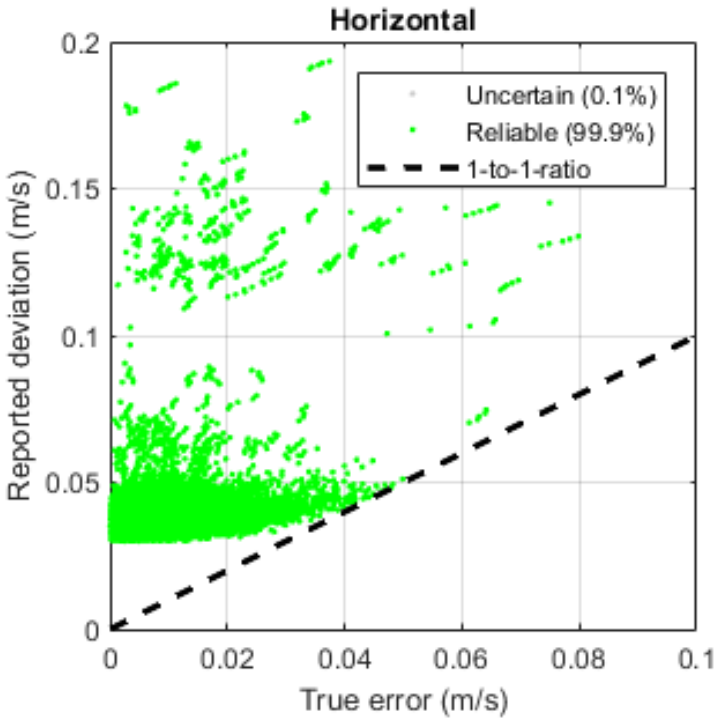
Error [cm/s]	Horizontal			Vertical		
	P68	P95	P99	P68	P95	P99
AsteRx-i S	0.8	1.6	2.9	0.6	1.4	2.1

Solution at 1 Hz

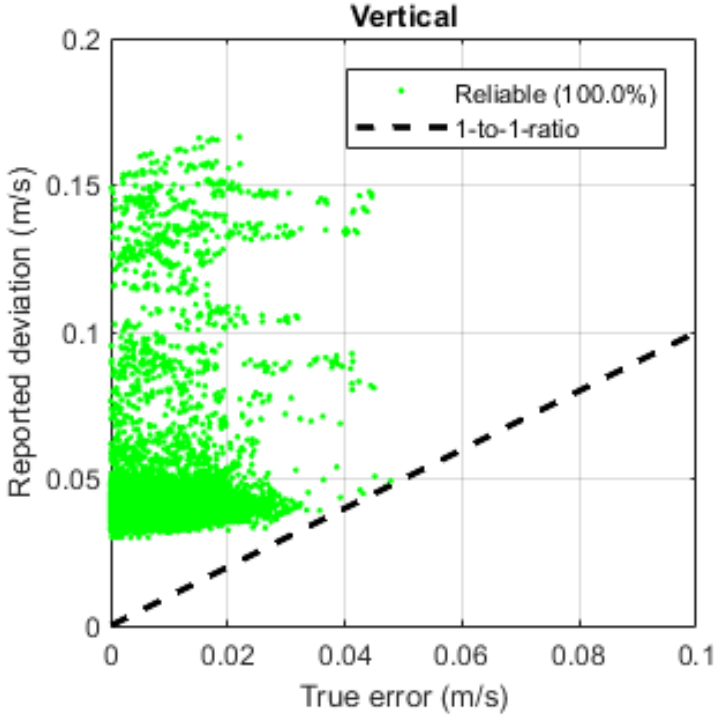




Velocity Reliability
All epochs



[%]	Horizontal		
	REL	UNC	UNR
AsteRx-i S	99.9	< 0.1	0



[%]	Vertical		
	REL	UNC	UNR
AsteRx-i S	100	0	0

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Conclusions

- SSR corrections enable scalable, high accuracy GNSS
- Septentrio applied corrections from Sapcorda to its RTK engine via a conversion to OSR
- The RTK solution is fused with IMU data for continued navigation in difficult environments
- Extensive automotive testing has shown the accuracy and reliability of the system

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