Brief Introduction into FocalPoint and Supercorrelation

About FocalPoint

We are a company of 46 highly qualified staff headquartered in Cambridge UK.

We develop groundbreaking technology that boosts the accuracy, reliability and security of radio receivers.

Chipset manufacturers and OEMs partner with us to enhance the capability of their devices and improve the lives of billions of people who rely on location technologies.

ION INSTITUTE OF NAVIGATION

THE EUROPAS EUROPEAN TECH STARTUP AWARDS

ROYAL INSTITUTE OF NAVIGATION

NTA National Technology Awards 2023 WINNER Security Innovation of the Year

IOP Institute of Physics

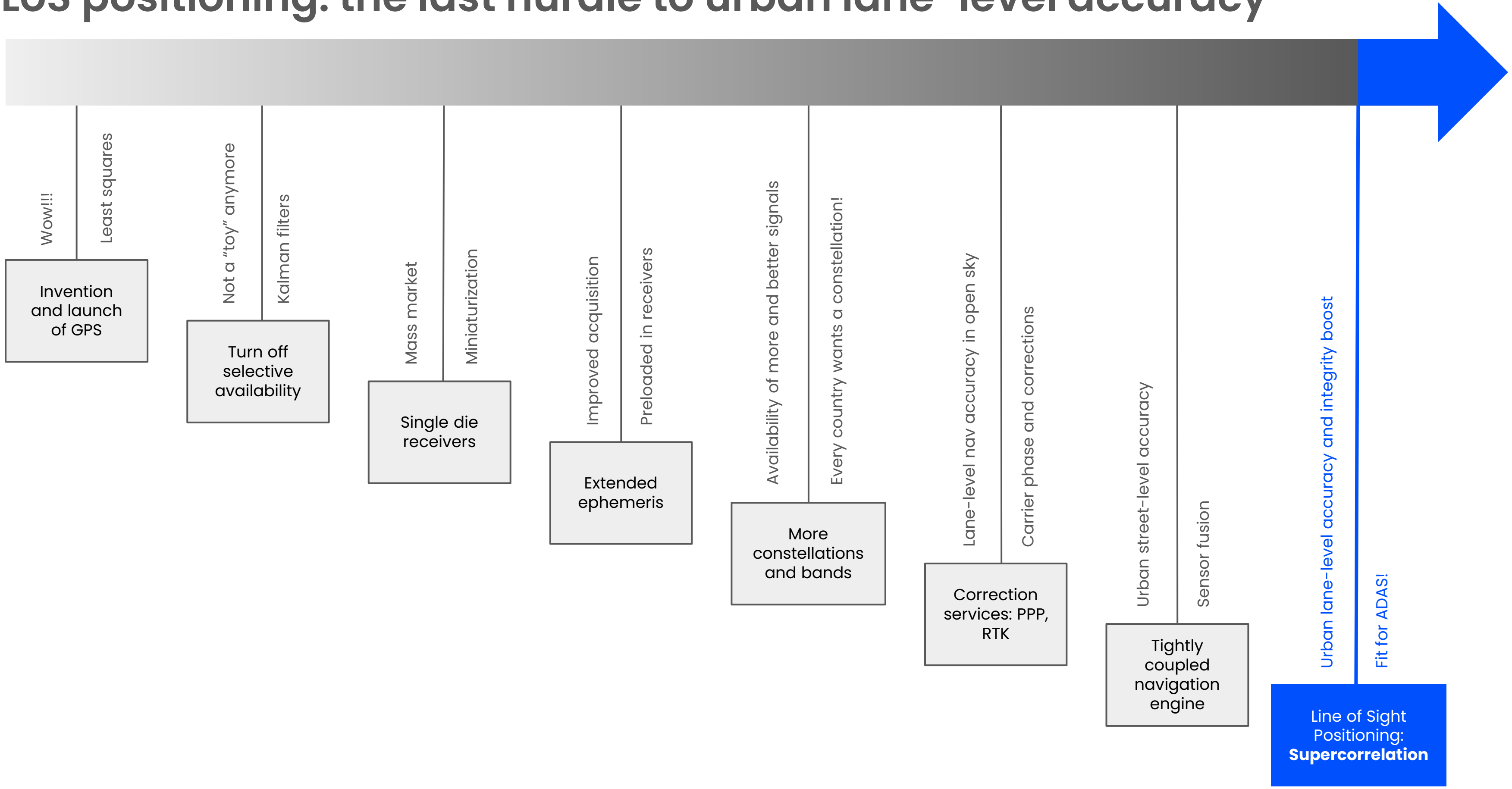
Strategic Investment from GM Ventures

"We're constantly researching technologies to support and enhance the growth and performance of our vehicles, both within our internal research and development operations and through collaborations with innovators beyond our company.

"This collaboration with FocalPoint targets a specific aspect of the ongoing expansion of Super Cruise and Ultra Cruise going forward."

Kent Helfrich
Former President, GM Ventures
Chief Technology Officer and Vice President, Global Research and Development for General Motors

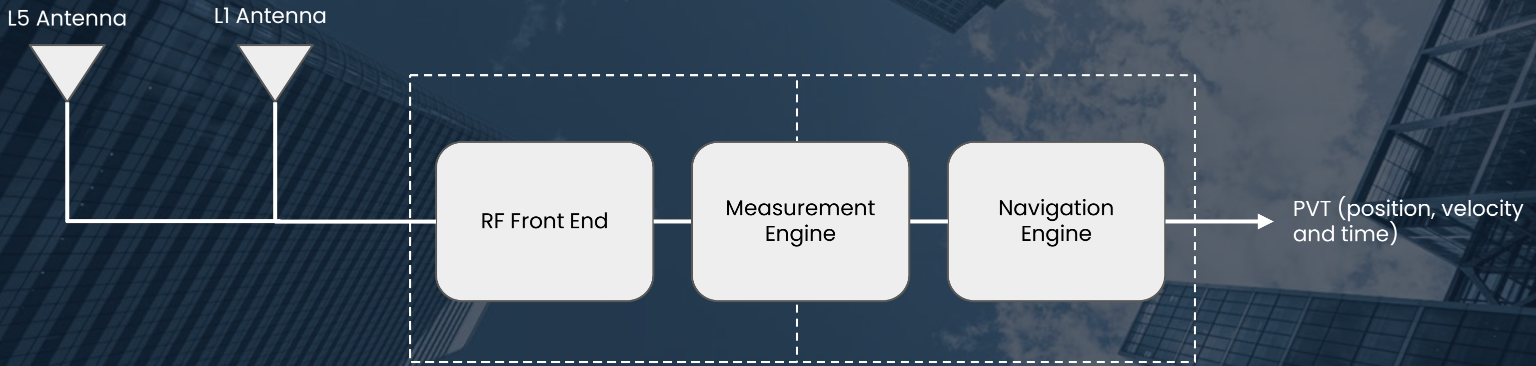
LoS positioning: the last hurdle to urban lane-level accuracy



Sources of error in a GNSS sensor in an urban scenario

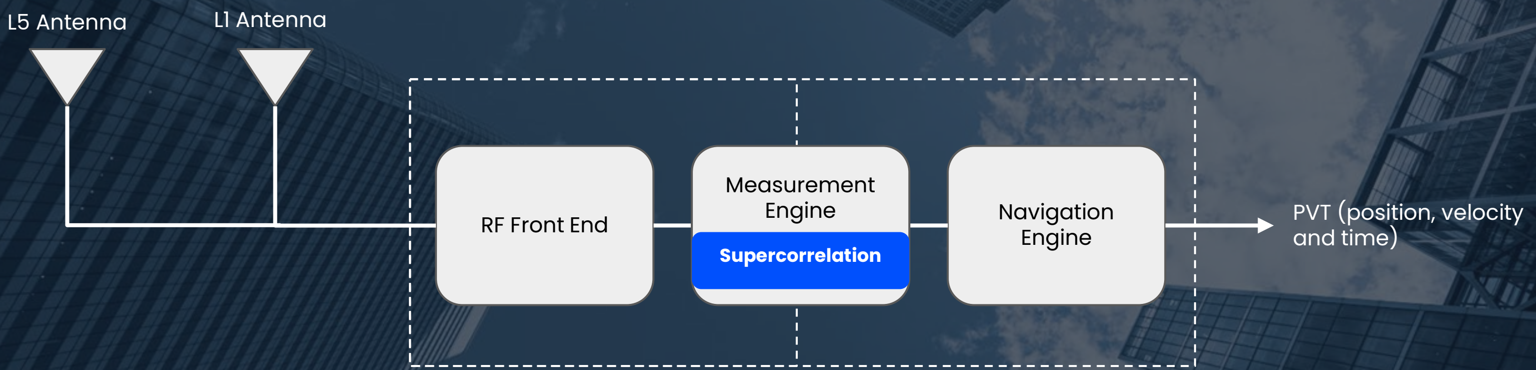
Source	Reason	Error	Way to fix it
Satellite clocks	Errors in satellites atomic clocks that are not corrected by updates from the ground control to the broadcast eph	2m	SBAS, PPP, RTK, DGPS
Orbit errors	Variations in sat orbits that are not corrected by updates from the ground control to the broadcast ephemeris	2.5m	SBAS, PPP, RTK, DGPS
Iono delay	Iono changes that are not well modelled	10m	Accurate iono model, dual frequency, RTK or DGNSS
Tropo delay	Tropo changes that are not well modelled	1m	Accurate tropo model, RTK or DGNSS
Receiver noise	Noise caused by receiver hardware	0.3m	Use higher end RF components
Multipath interference	Combined LoS and NLoS generate noisy and distorted measurements	L1 1m-200m L5 1m-20m	Traditional partial solution: navigation-level algorithms if there are enough good signals. Full solution: **new** innovative measurement-level algorithms
Only NLoS available	LoS blocked and only NLoS available	Can be 200m and over!	Traditional partial solution: navigation-level algorithms if there are enough good signals. Full solution: **new** innovative measurement-level algorithms

Typical GNSS architecture



Part of the Measurement Engine and the entire Navigation Engine can be sometimes physically hosted in a standalone Applications Processor

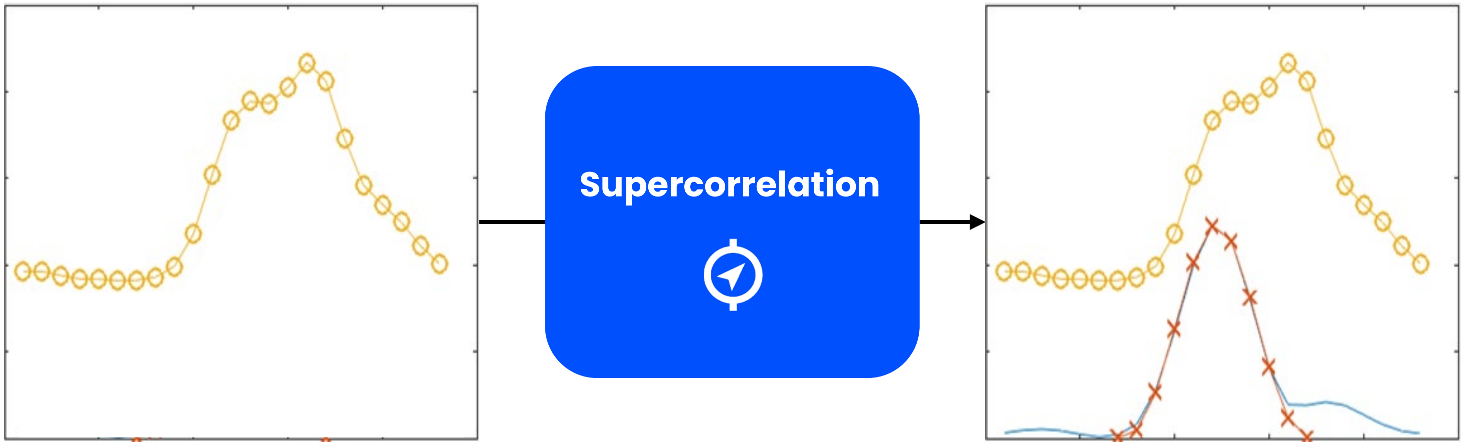
Typical GNSS architecture



Part of the Measurement Engine and the entire Navigation Engine can be sometimes physically hosted in a standalone Applications Processor

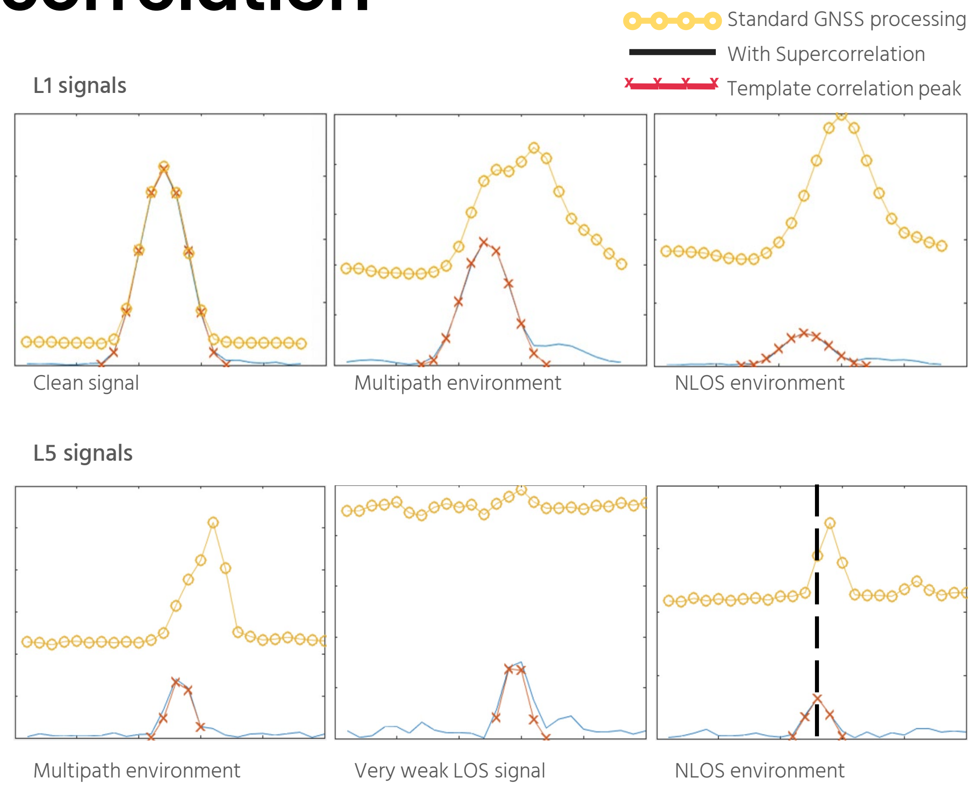
Typical GNSS architecture

Measurement Engine



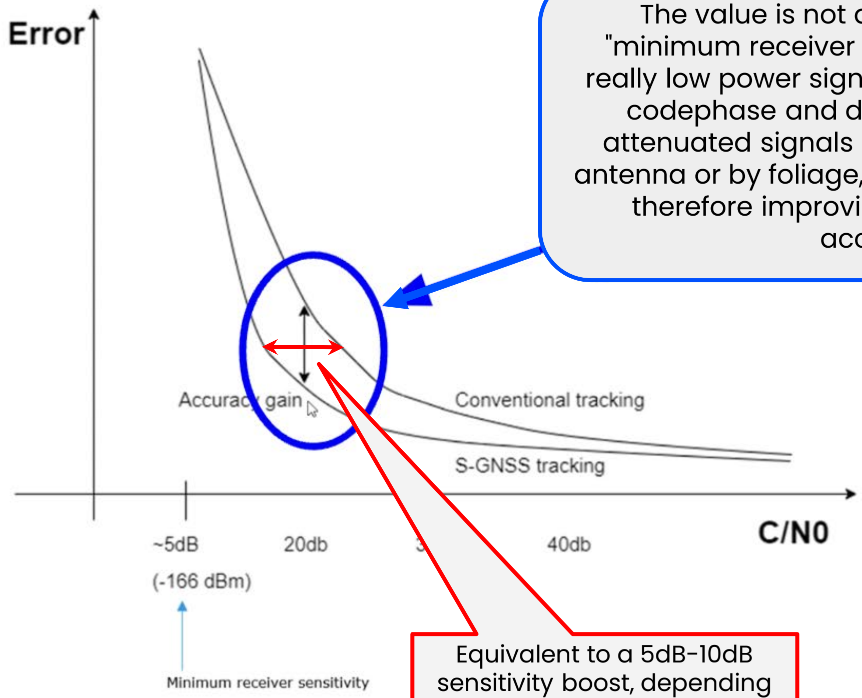
Key capabilities of Supercorrelation

- Supercorrelation is a patented, software-based technology that provides revolutionary new capabilities to consumer-grade GNSS receivers
  - Signal angle-of-arrival
  - Higher accuracy with low CN0 values (equivalent to 5dB-10dB increase in sensitivity)
- Unrivalled accuracy and integrity of positioning in urban environments
  - Rejection of reflected signals and spoofing signals (via angle-of-arrival)
  - Tracking of weak line-of-sight signals (via sensitivity boost)
  - Demonstrated improvement to L1 and L5 signals



The correlation peaks in the above plots show how Supercorrelation recovers the weaker and earlier line-of-sight (LOS) signal as a clean, corruption-free correlation peak, even in the presence of significant multipath and much stronger non-line-of-sight (NLOS) signals.
No other technology available today can achieve this.

Supercorrelation: holding on to low error with low CN0 values



The value is not about improving the "minimum receiver sensitivity" (ie tracking really low power signals), but decreasing the codephase and doppler error of mildly attenuated signals (either by a concealed antenna or by foliage, or by a sound wall), and therefore improving line-on-the-map accuracy

Equivalent to a 5dB-10dB sensitivity boost, depending on doppler

What is S-GNSS® from FocalPoint?

- Software upgrade to a GNSS chip to improve performance in challenging scenarios
- Long coherent integrations - 1 second +
- Enhances GNSS measurements to boost the line-of-sight signals and reject unwanted signals
- Enables lane-level accuracy in challenging scenarios, and higher integrity levels

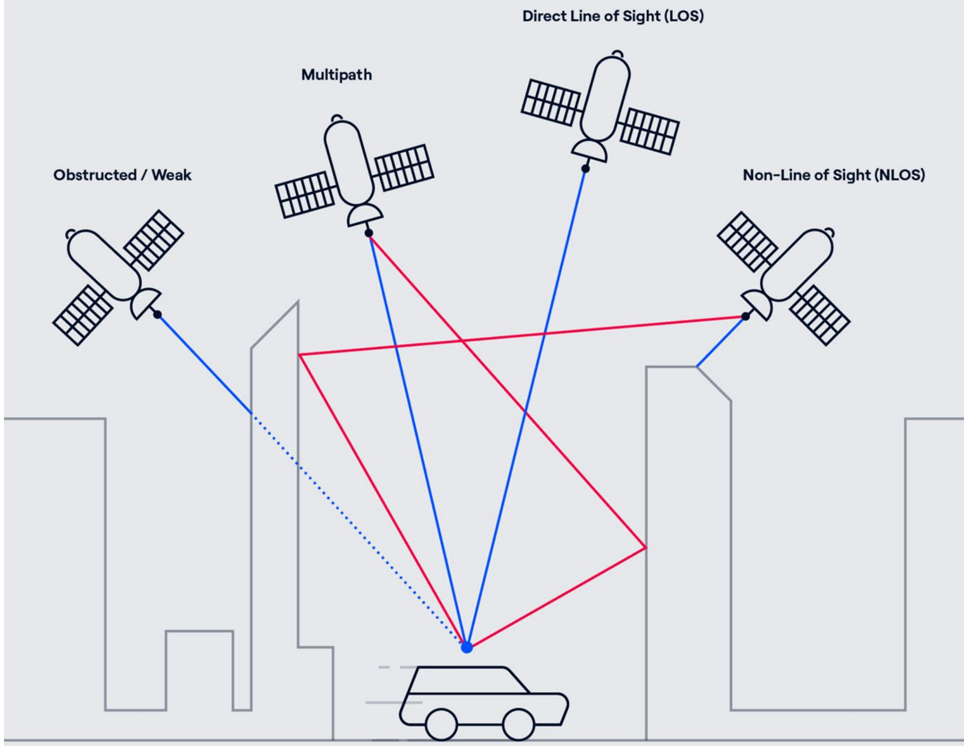
What is the end result?

- We make existing GNSS sensors more accurate and more reliable
- Allowing to hold performance with poor quality antennas
- OEMs all around the world love our value propositions

Project Implementation and Results

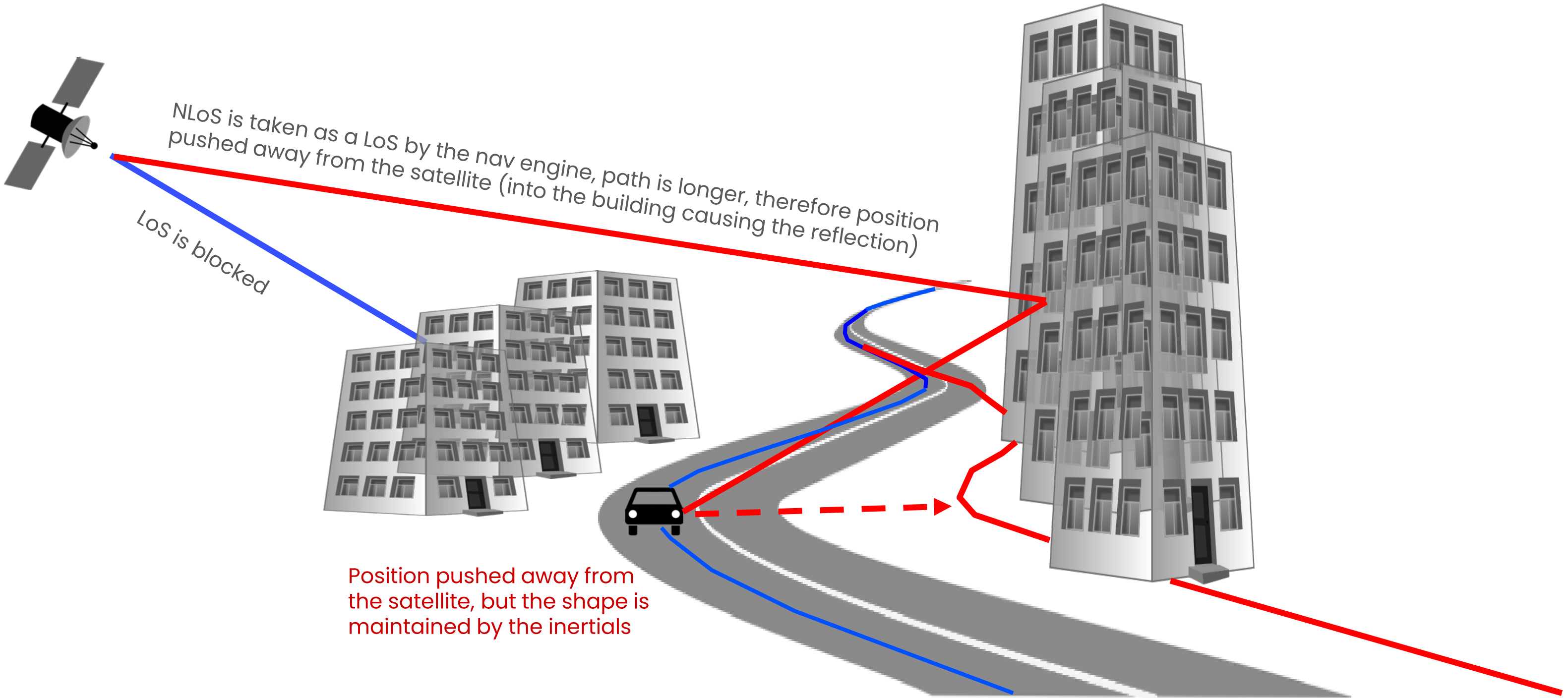
There is a big, structural problem with GNSS in cities.

- GNSS performs poorly in cities because signals are blocked or reflected from buildings
- The reflected signals dominate or interfere with the true line-of-sight (LOS) signals
- Receivers cannot rely on power level to distinguish between LOS and NLOS (e.g. weak LOS penetrating a canopy, versus lossless reflections from metal)

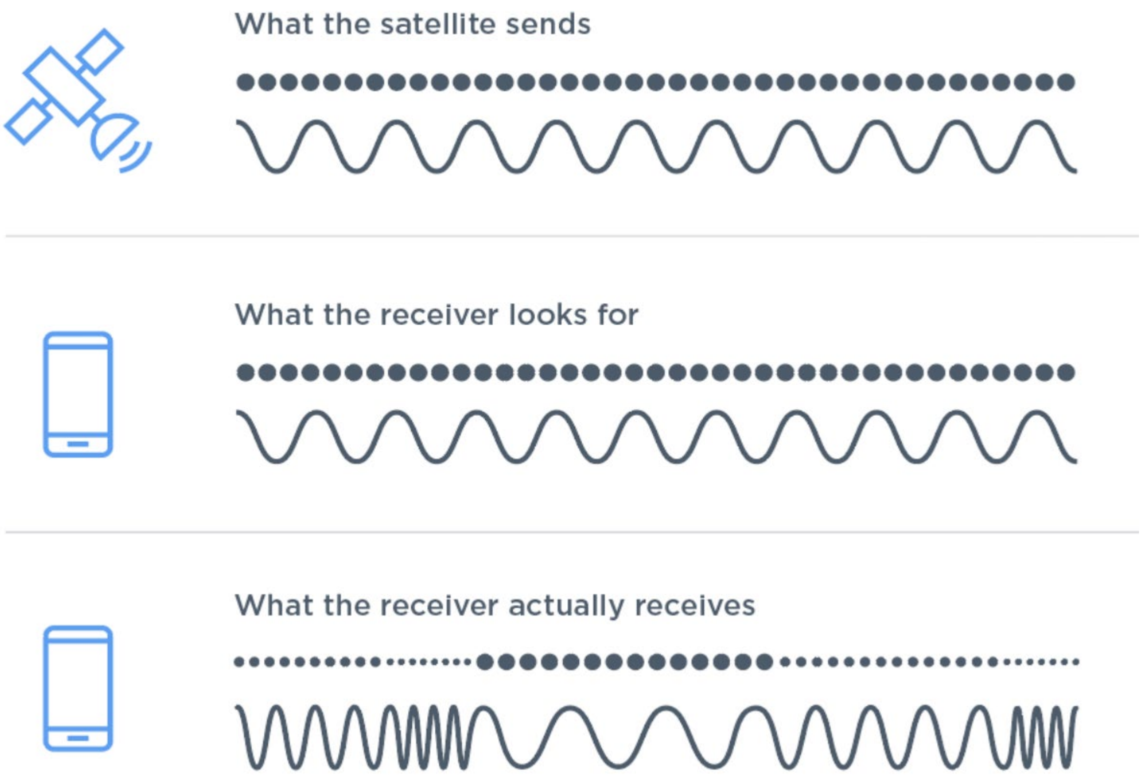


Effect of NLoS in automotive applications

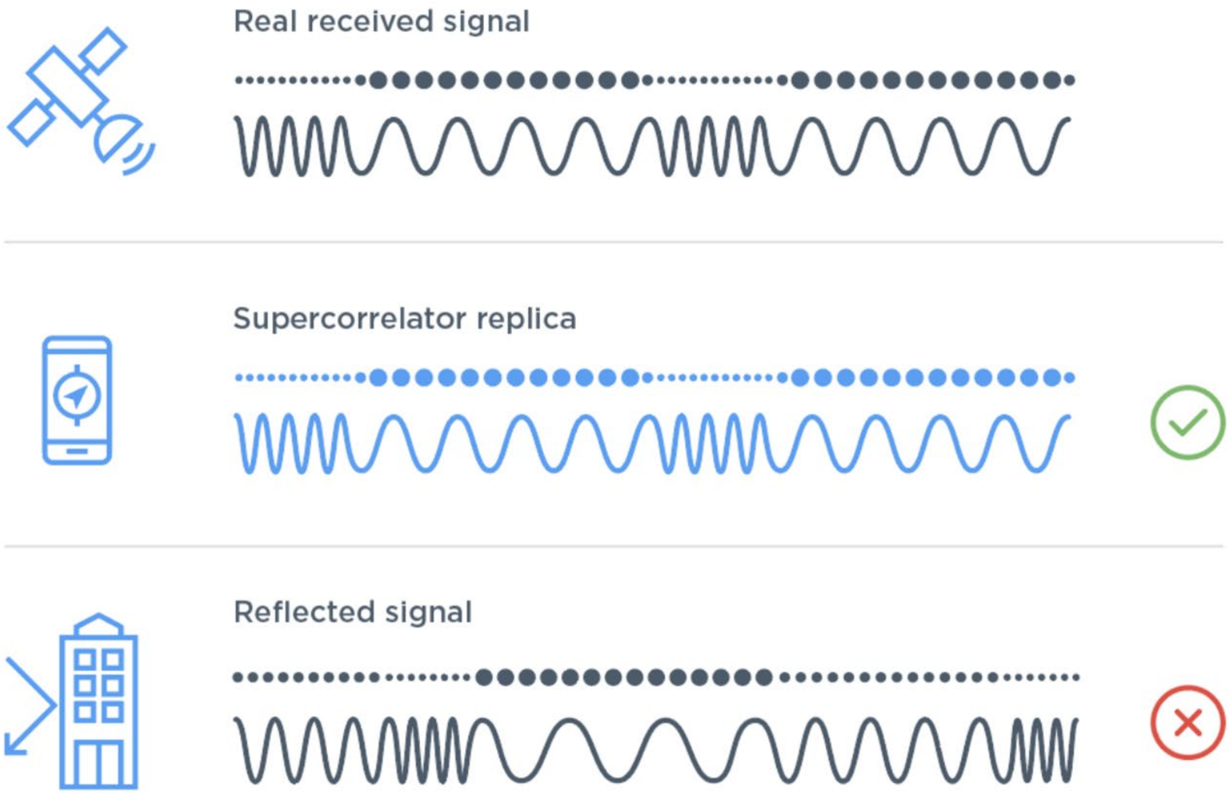
- NLoS signal taken as a LoS signal by the nav engine will push the estimated position towards building where the reflection happens, generating an error.
- After that, inertials in the nav engine will continue to propagate the error as a bias but with an accurate shape -even for a certain amount of time after the LoS is visible again



Supercorrelation in action I



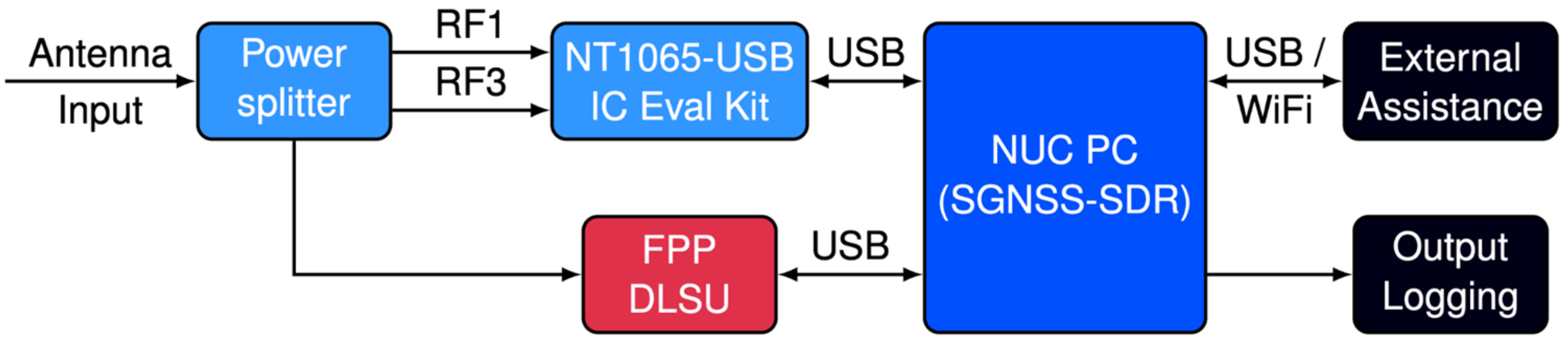
Supercorrelation in action II



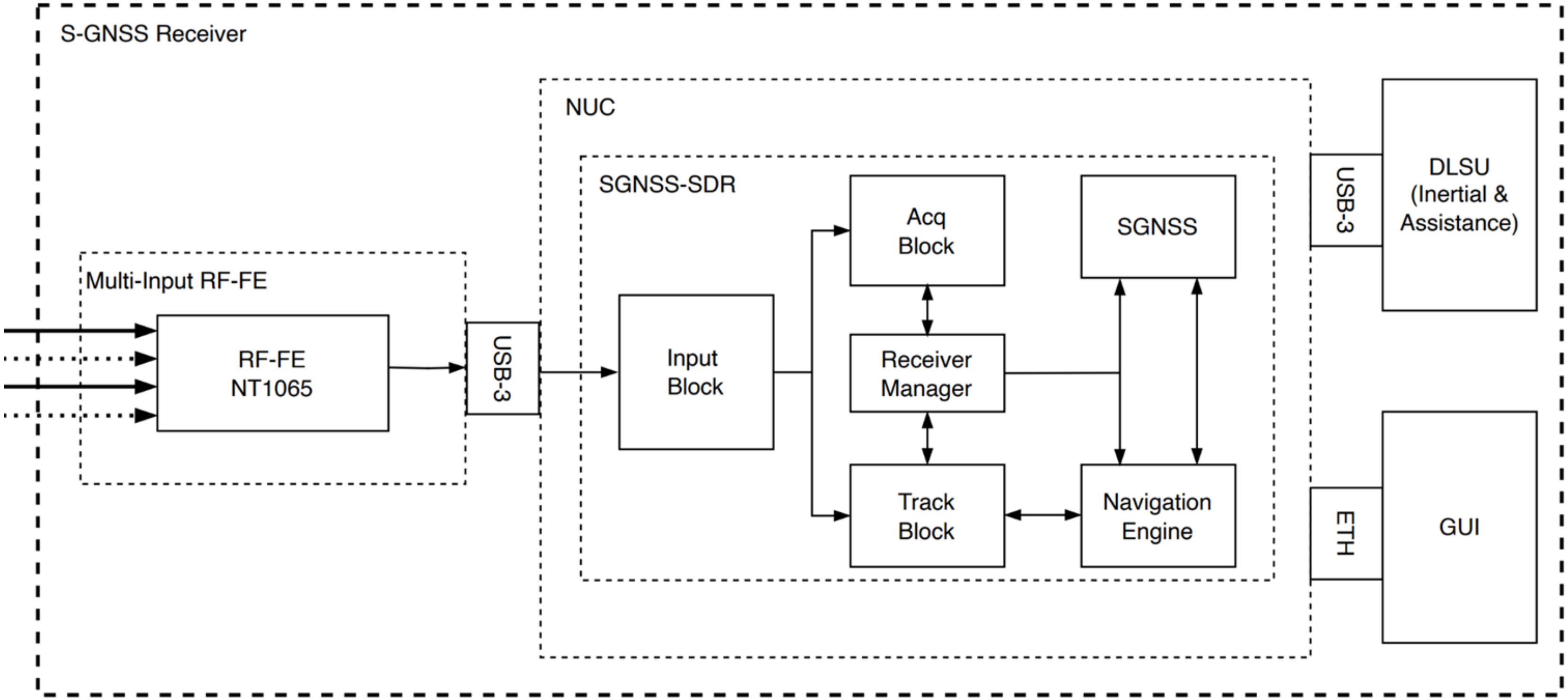
S-GNSS Real Time Receiver

Hardware and software platform for the development and **live** demonstration of the S-GNSS technology

- COTS hardware components
  - Standard PC (compatible with Linux/Mac)
  - NT1065-USB3 NTLab RF Front End - configured to support GPS L1/L5 and Galileo E1/E5a
  - FPP DLSU - Focal Point's INS sensors data logging and streaming unit
- Software ***S-GNSS SDR***
  - Fully configurable multi-threaded C++ coded to maximise performance



S-GNSS SDR Software Architecture



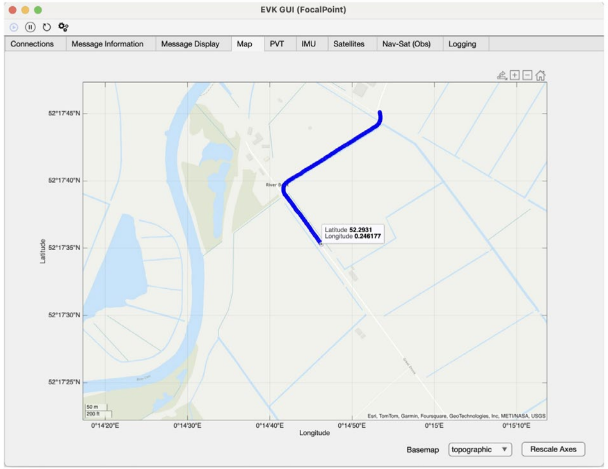
S-GNSS SDR Specs

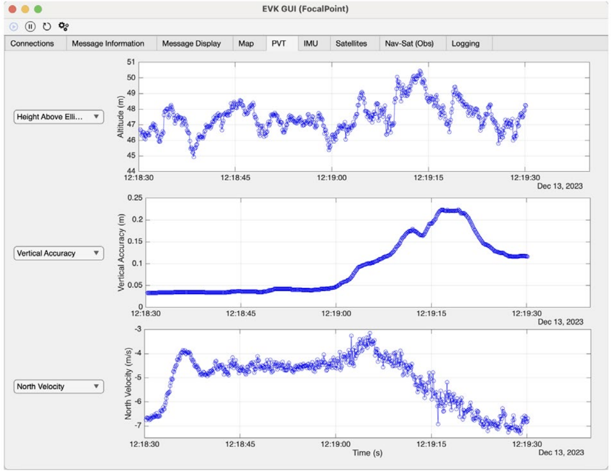
The current version of SGNSS-SDR supports:

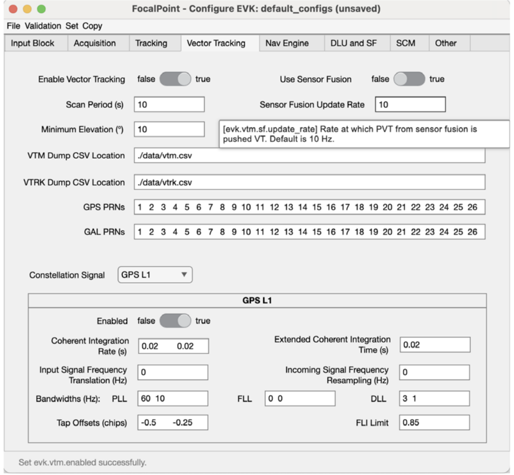
- Autonomous acquisition of GPS L1 and Galileo E1B and E1C
- Tracking of GPS L1/L5I/L5Q and Galileo E1B/E1C/E5aI/E5aQ
  - Supports live and off-line operation (reading from a recorded IF samples file)
  - Fully configurable (sampling frequency, Integration time, number of IQ correlator taps, correlator taps spacing, tracking loops filter bandwidth, etc.)
  - Tested with up to 40 signals in real-time (depending on the computer and the receiver configuration). No number of signals limitation when running from recorded files.
  - Tracking sensitivity better than 23 dB-Hz with coherent integration time of 20ms.
- Navigation Engine
  - Sensor Fusion Kalman Filter
- Vector Tracking
  - Further improvement in tracking sensitivity
  - No need for reacquisition
- S-GNSS closed loop operation

S-GNSS Real Time Receiver GUI

- Written in MATLAB using App Designer
- Enables visualisation of results during live and replayed trials
- Data is transmitted via Transmission Control Protocol/Internet Protocol (TCP/IP).
    - Enables flexibility:
        - during auto trials: with a physical (wired or wireless) ethernet connection between the S-GNSS SDR and a laptop PC inside the test vehicle.
        - during offline testing: via a localhost.

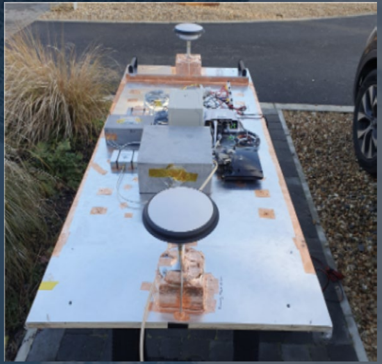


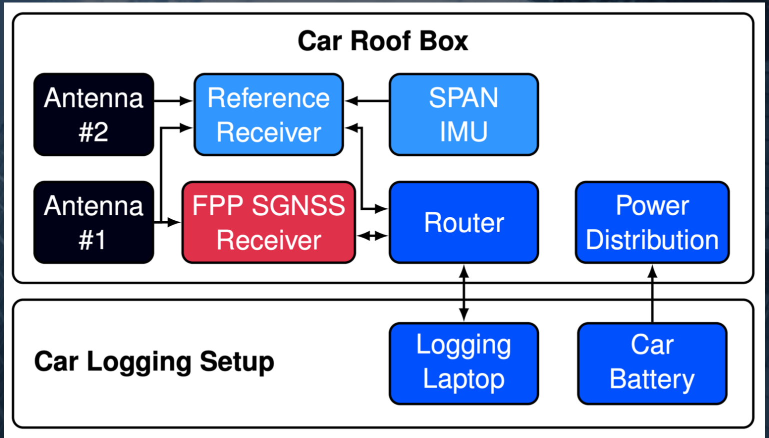




Test Setup - Hardware/Software

- Equipment:
  - Novatel PwrPak7 OEM7720 GNSS Receiver
  - Novatel SPAN IMU ISA-100C (200 Hz)
  - 2x Novatel GNSS-850 antenna
  - FocalPoint S-GNSS Receiver
- S-GNSS SDR configuration:
  - S-GNSS on/off: GPS L1 + GAL E1 + IMU
  - S-GNSS on/off: GPS L1/L5 + GAL E1/E5a + IMU
- Reference commercial GNSS receiver
  - U-Blox F9T featuring GPS L1/L5 + GAL E1/E5 + BDS B1I/B1C, no IMU

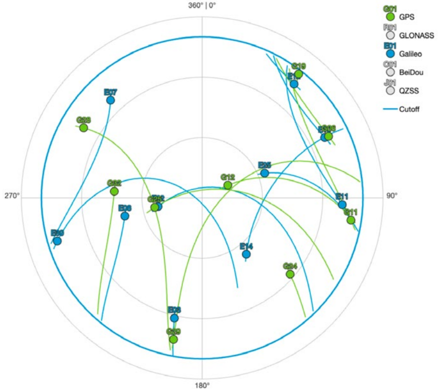




Test Setup - Scenario description

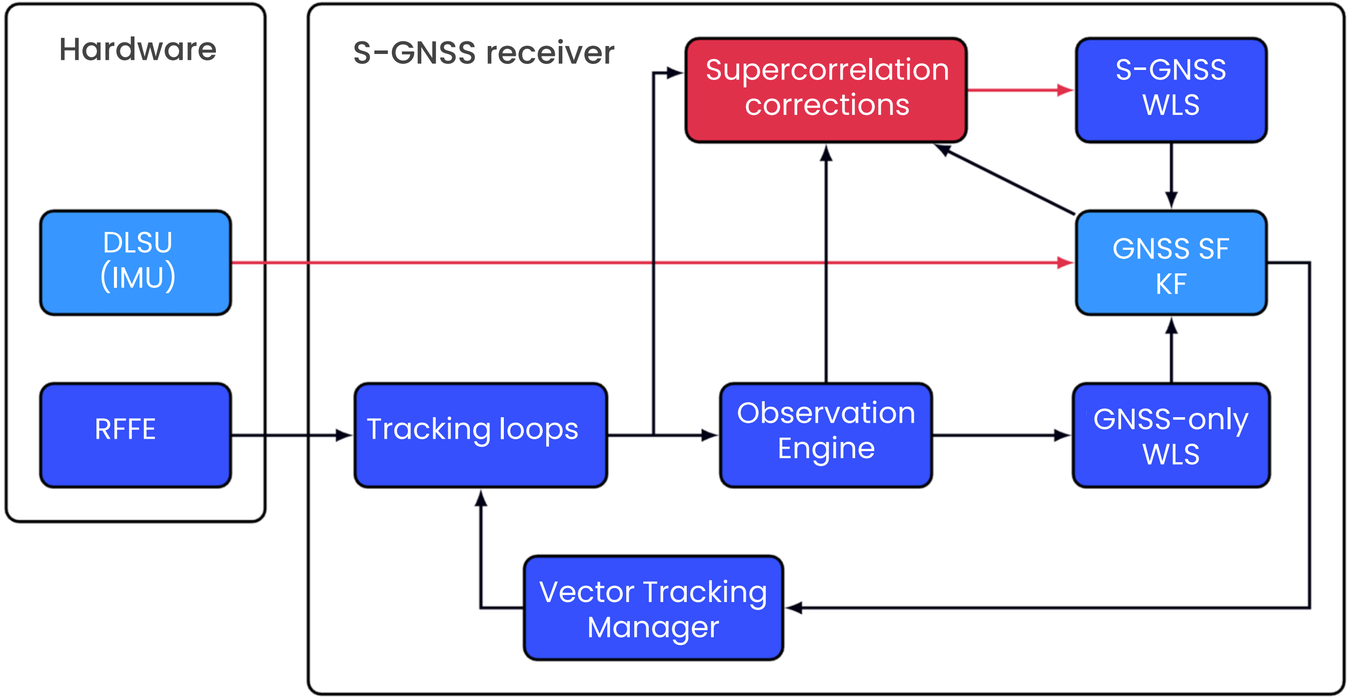
Canary Wharf

- London, UK
- Data collected on 1/2/2024
- Length: ~90 min

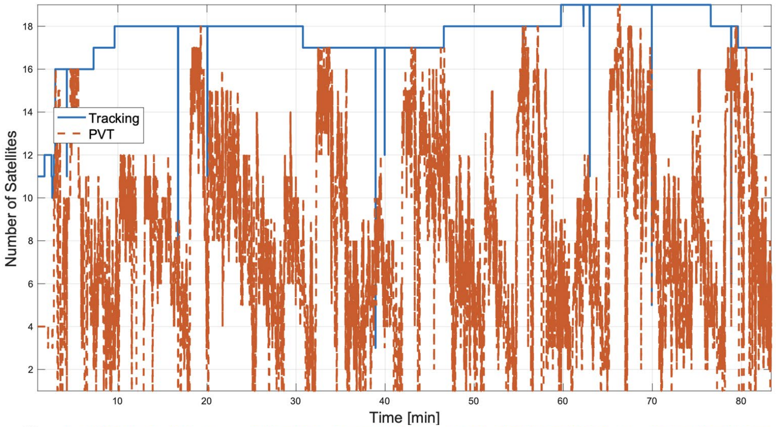


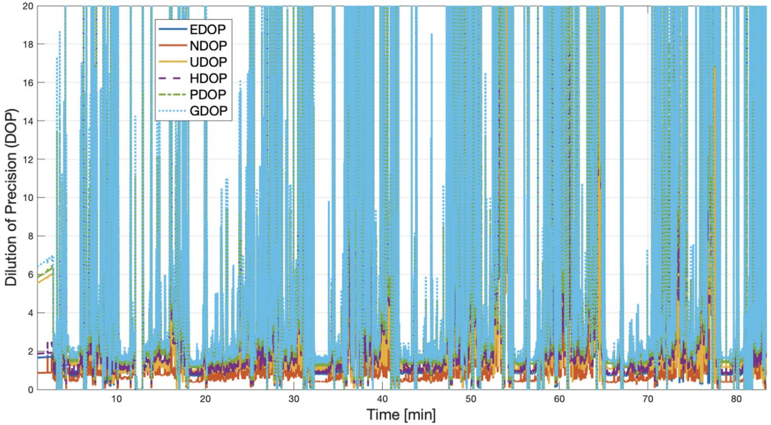
Results - Methodology

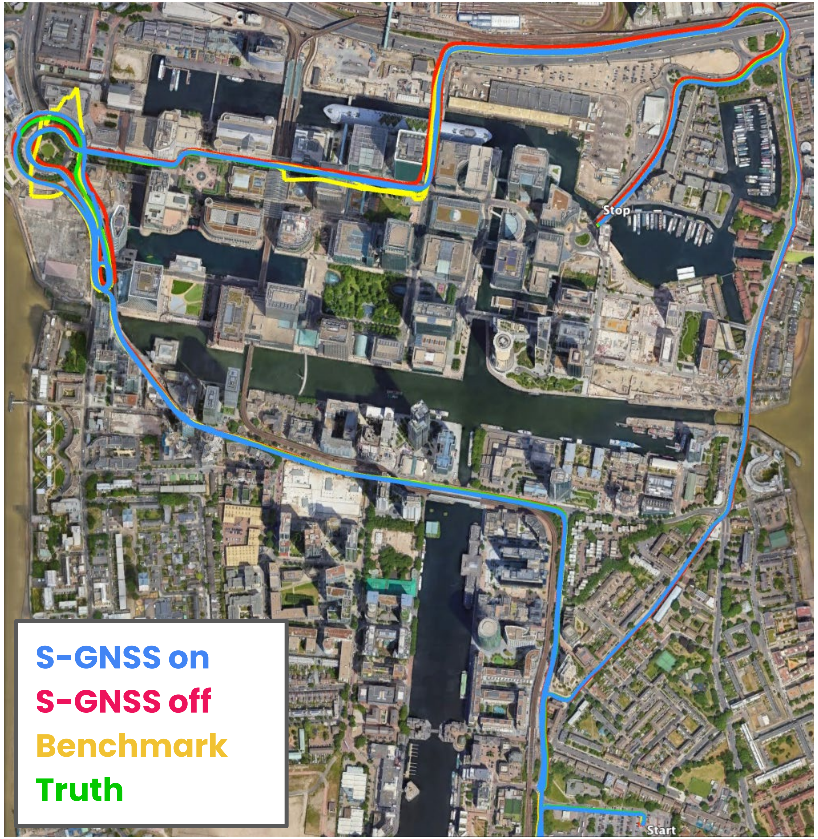
'S-GNSS off' and 'S-GNSS on' results are generated in different runs with the same inputs (recorded RFFE raw IF file and DLSU file)



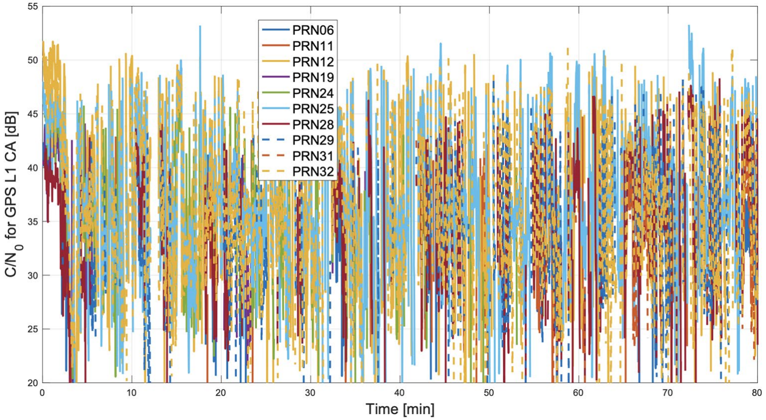
Results I - # sats & DOP

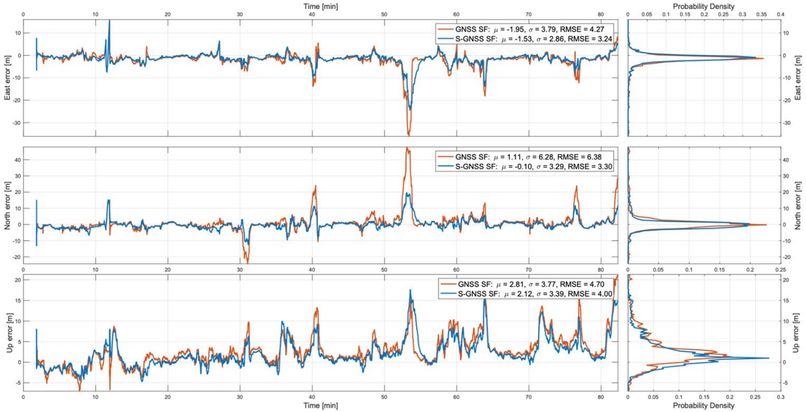


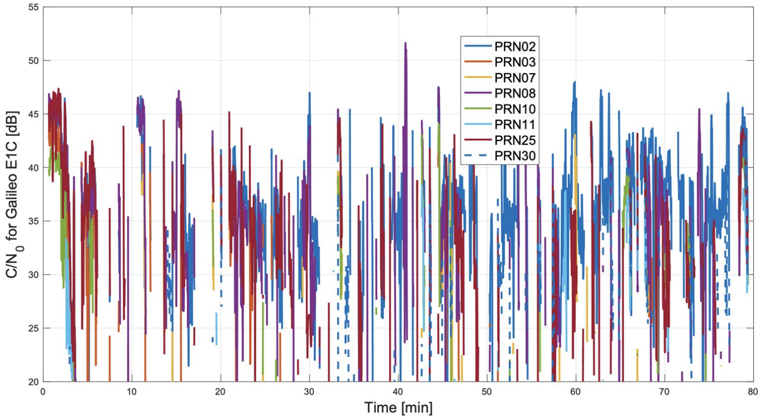


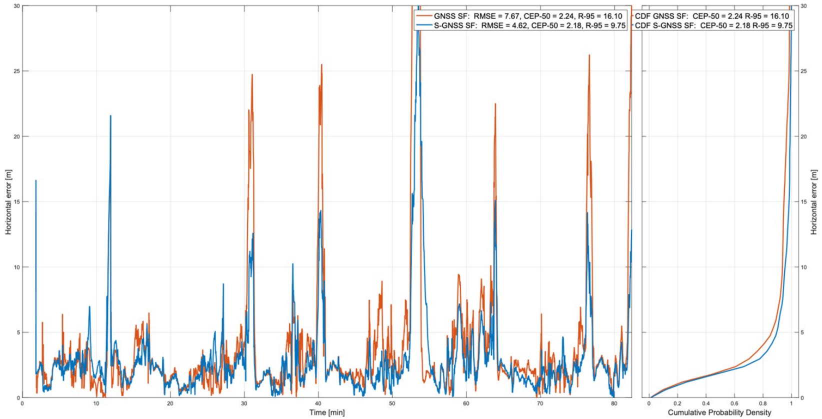


Results II - CN0 & Position errors wrt GTS

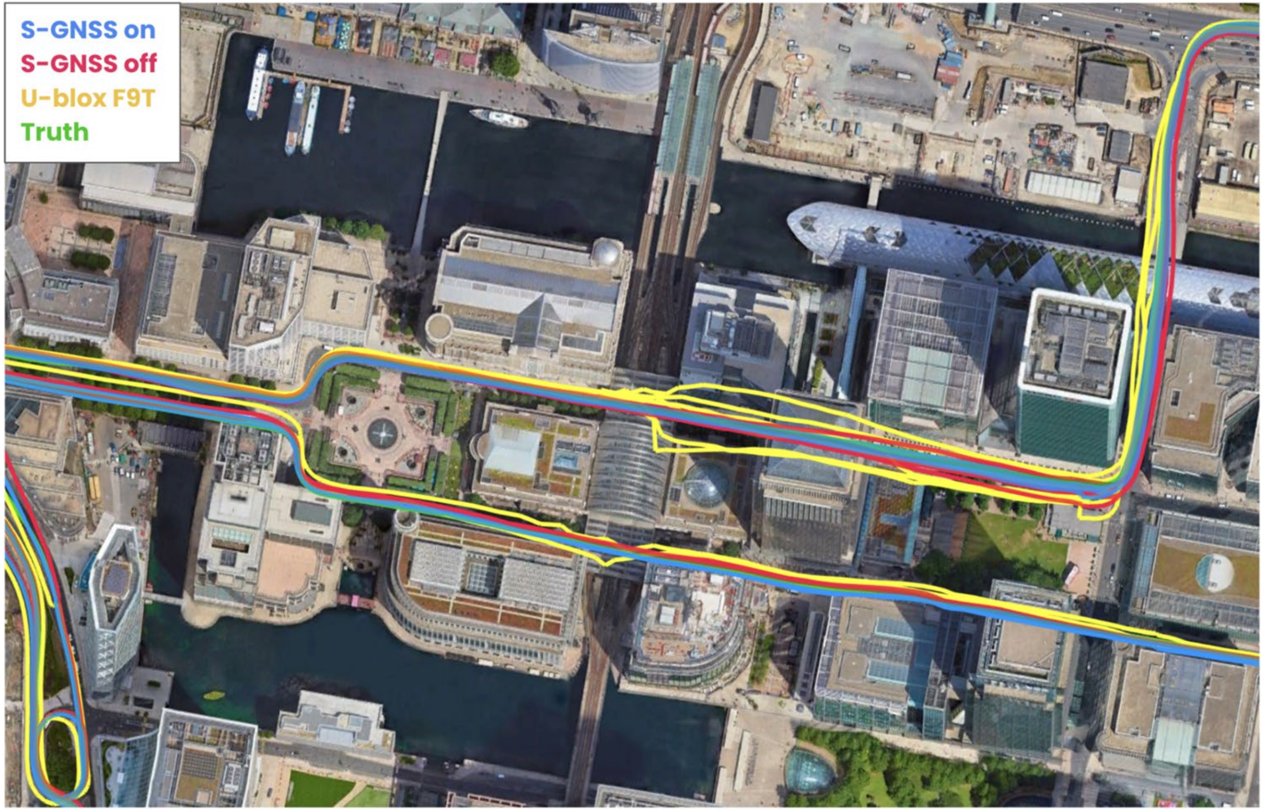








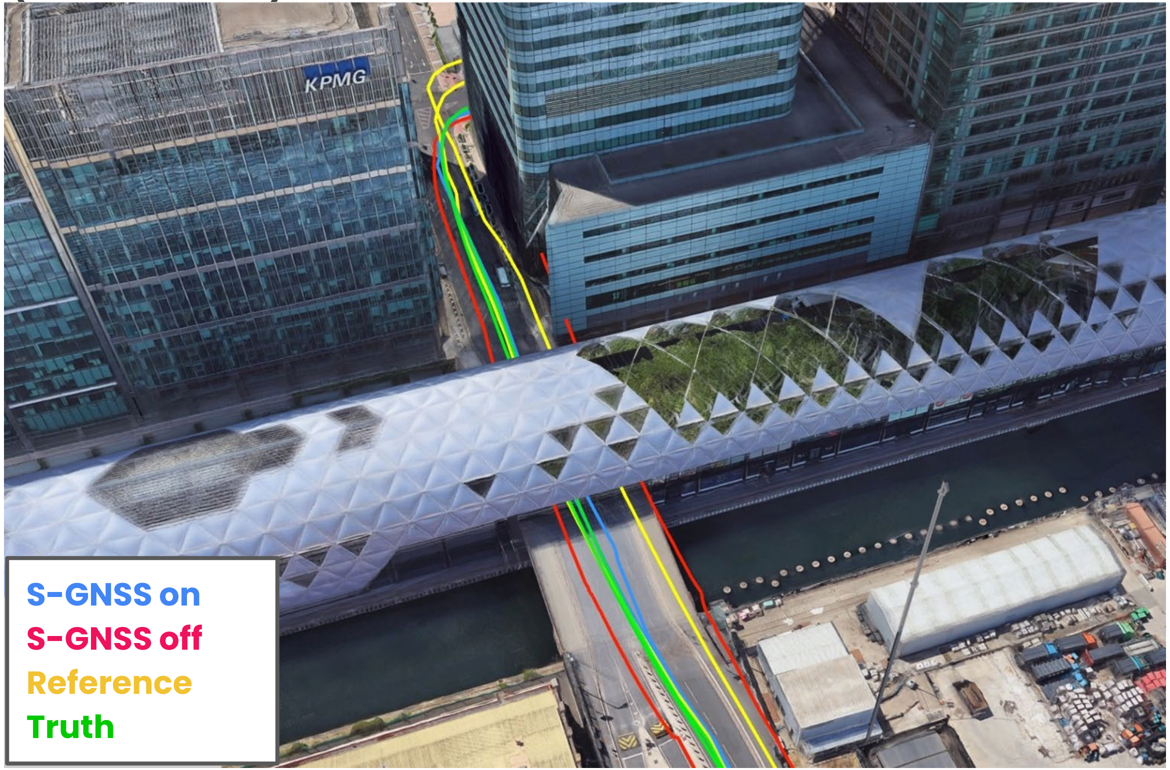
Results - Qualitative Analysis I



Zoomed-in version of the challenging parts of the map - Dual Frequency run.

Results – Qualitative Analysis II

'S-GNSS off' has equivalent performance to an automotive commercial product (benchmark)

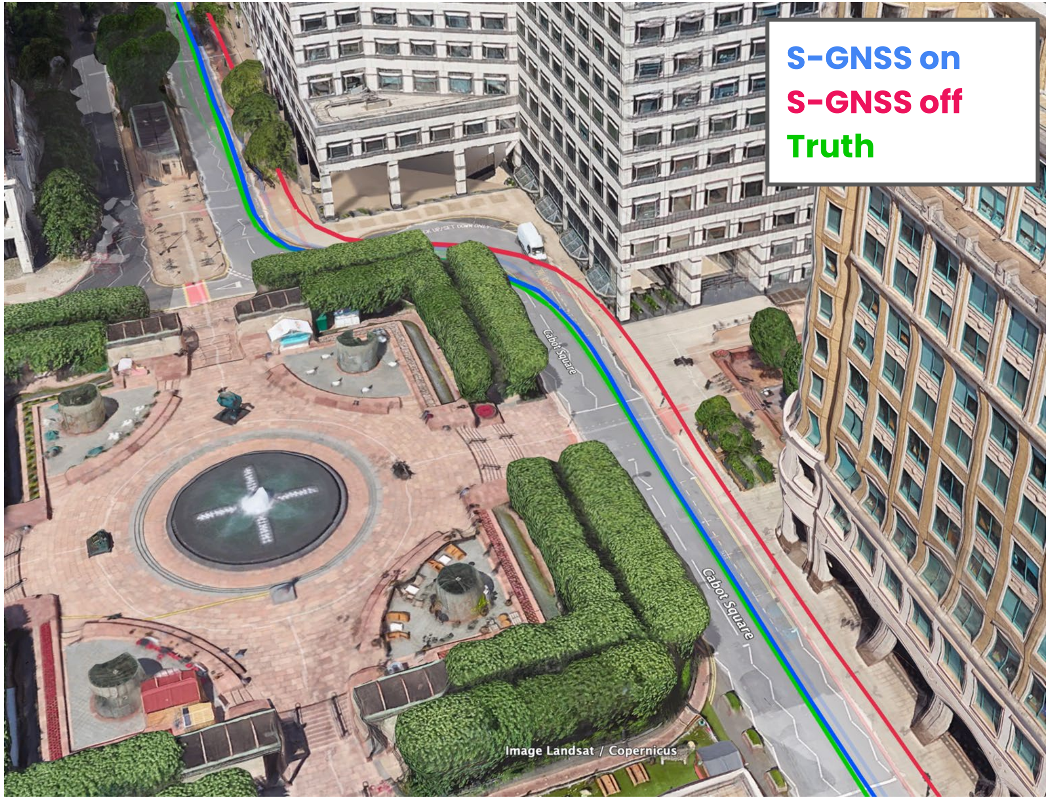


Results - Qualitative Analysis III

'S-GNSS on' is on the lane; 'S-GNSS off' is on the walkway

Lap 1

Lap 2

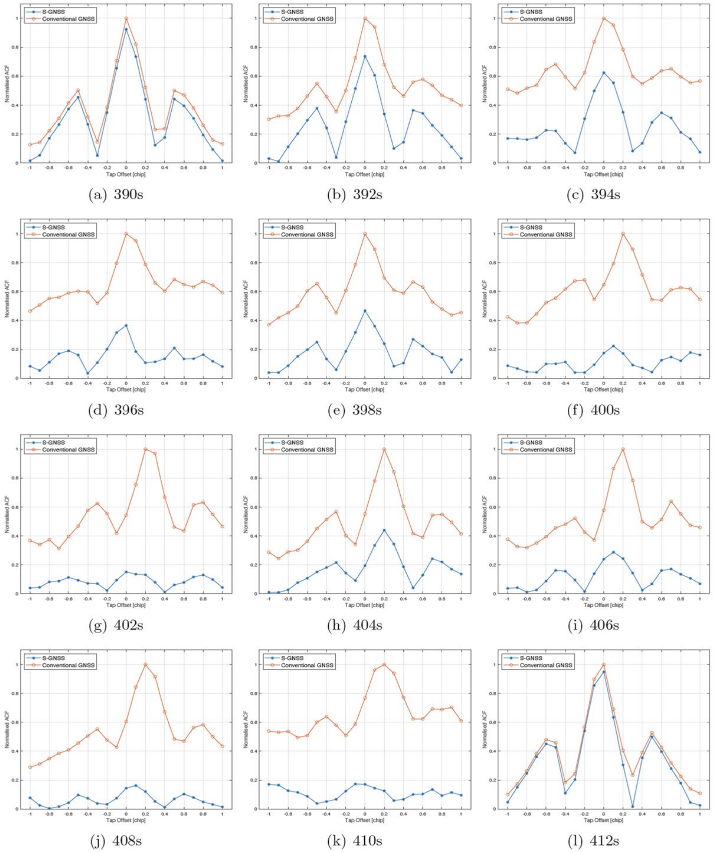


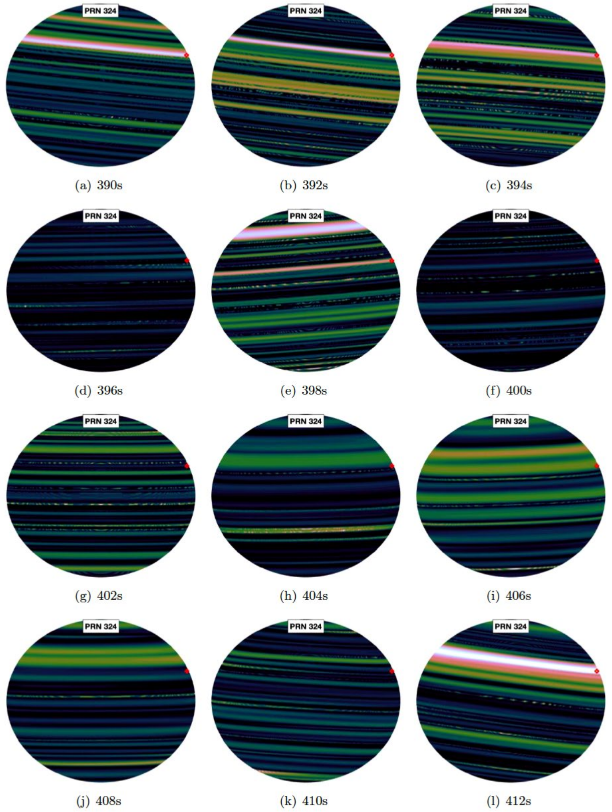
On both passes, S-GNSS is within less than 1 meter of the ground truth all along, while non S-GNSS is 5+ meters off all along

Results - Qualitative Analysis IV - ACF and Skyscan

E24-E1C

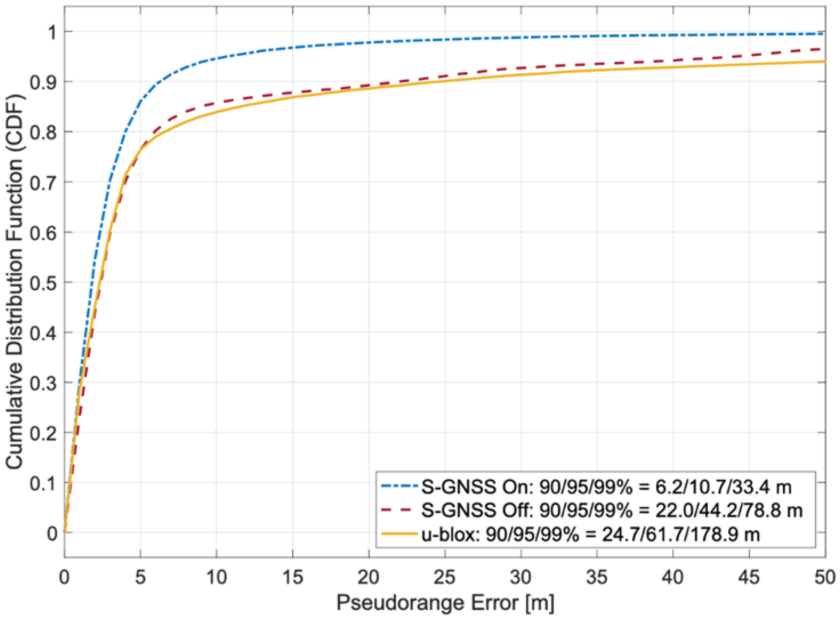
390-412s



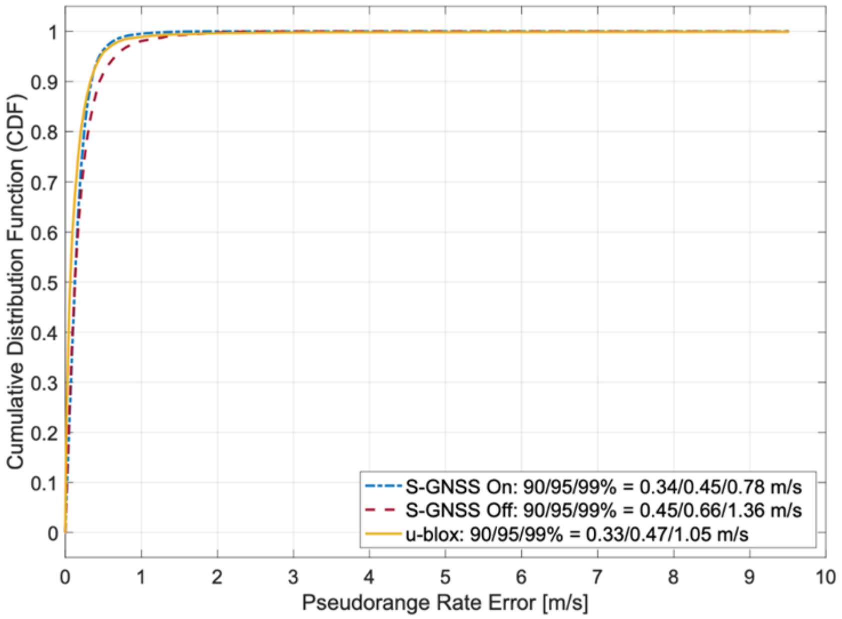


Results - Qualitative Analysis I

Measurement Domain CDFs - Galileo E1C



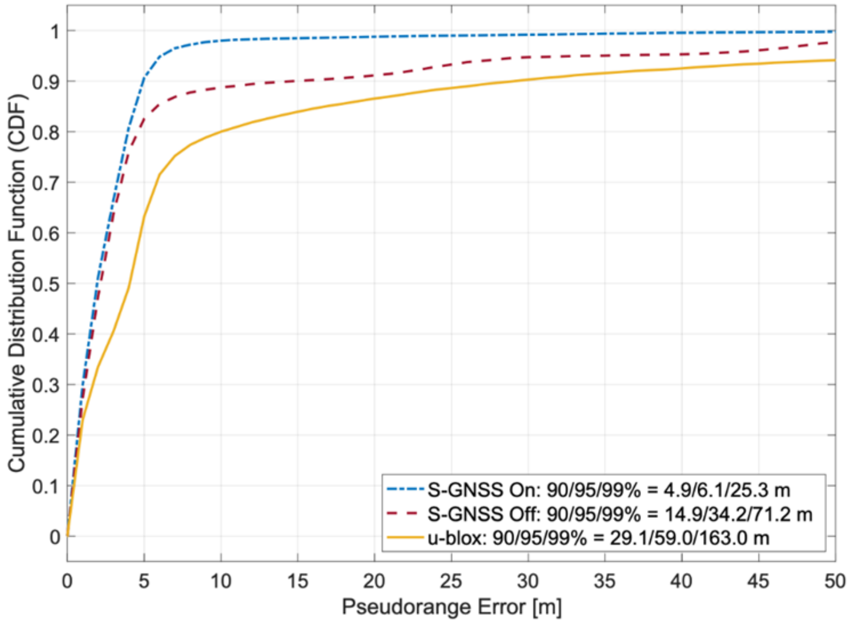
(a) pseudo-range measurement error



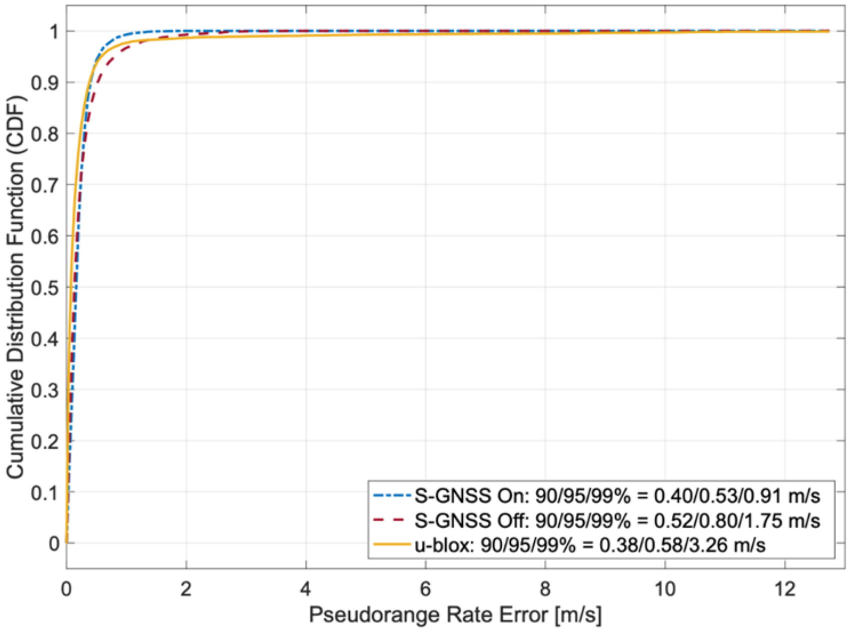
(b) pseudo-range rate measurement error

Results – Qualitative Analysis II

Measurement Domain CDFs – GPS L5Q

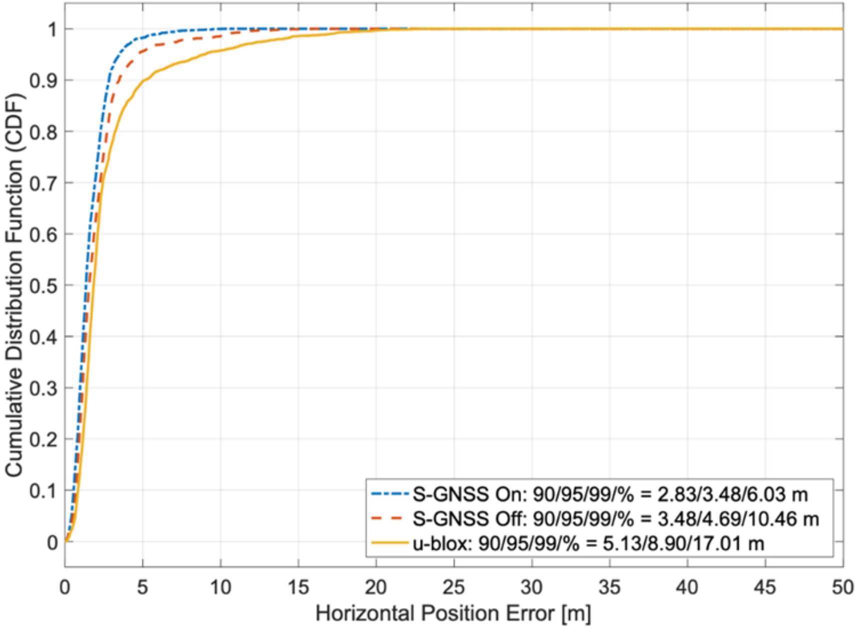


(a) pseudo-range measurement error

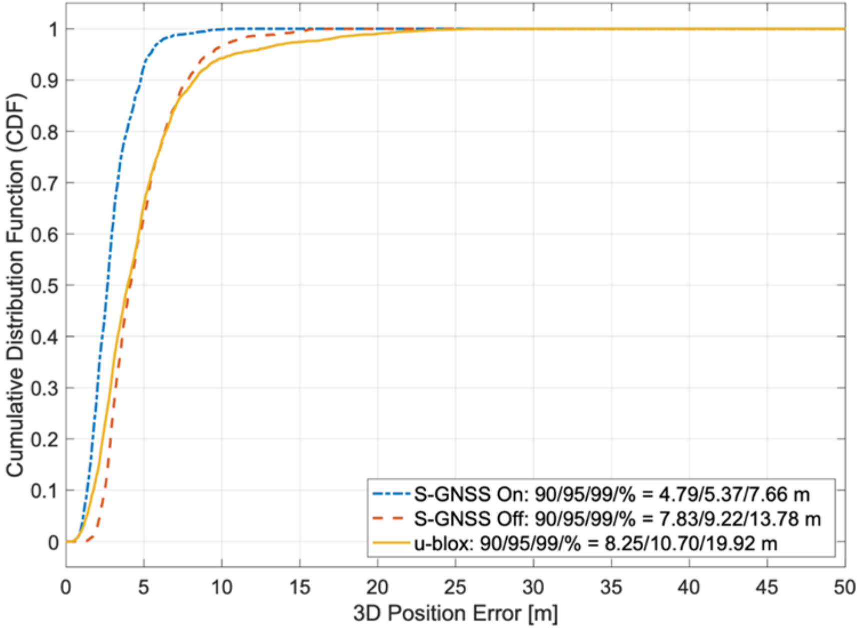


(b) pseudo-range rate measurement error

Results – Qualitative Analysis III
Position Domain CDFs – Dual Frequency Run



(a) 2D (Horizontal)



(b) 3D (Position)

Results – Qualitative Analysis IV

Position Domain – Overall Results

Statistic [unit]	Single Frequency		Dual Frequency	
	S-GNSS OFF	S-GNSS ON	S-GNSS OFF	S-GNSS ON
Position 2D R-90 [m]	5.09	3.54	3.48	2.83
Position 2D R-95 [m]	6.38	4.30	4.69	3.48
Position 2D R-99 [m]	11.94	7.36	10.46	6.03
Position 3D R-90 [m]	7.15	4.73	7.83	4.79
Position 3D R-95 [m]	8.58	5.47	9.22	5.37
Position 3D R-99 [m]	13.13	8.26	13.78	7.66
Velocity 2D R-90 [m/s]	0.33	0.29	0.31	0.25
Velocity 2D R-95 [m/s]	0.43	0.37	0.39	0.32
Velocity 2D R-99 [m/s]	0.67	0.63	0.55	0.49
Velocity 3D R-90 [m/s]	0.34	0.29	0.32	0.26
Velocity 3D R-95 [m/s]	0.55	0.38	0.40	0.33
Velocity 3D R-99 [m/s]	0.68	0.63	0.56	0.49

Conclusions

- A complete S-GNSS receiver was developed and subsequently evaluated using live data recordings captured using a custom-built trials system.
- Supercorrelation analysis was presented, including the demonstration of Skyscan processing.
- The results showed significant improvement in GNSS measurement and positioning performance by using Supercorrelation.
- These first live data results demonstrate the significant improvements to raw measurements and PVT accuracy provided by Supercorrelation, particularly in harsh environments such as deep urban canyons.
- Further development of the receiver aims to expand the supported signal types beyond GPS and Galileo, and to optimise the exploitation of the improved measurement accuracy within the PVT solution.