POMELO

(NAVISP-EL1-036)

Final Presentation

ESAC

2nd February 2023

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POMELO

Precise pOsitioning for Mass-market – optimaL data dissemination demOnstrator

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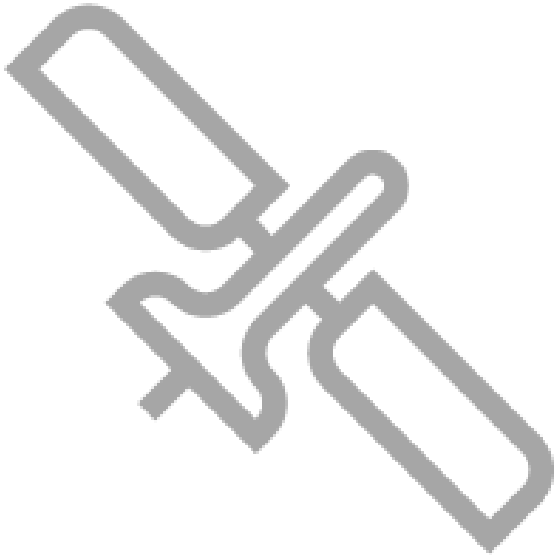
POMELO Objectives



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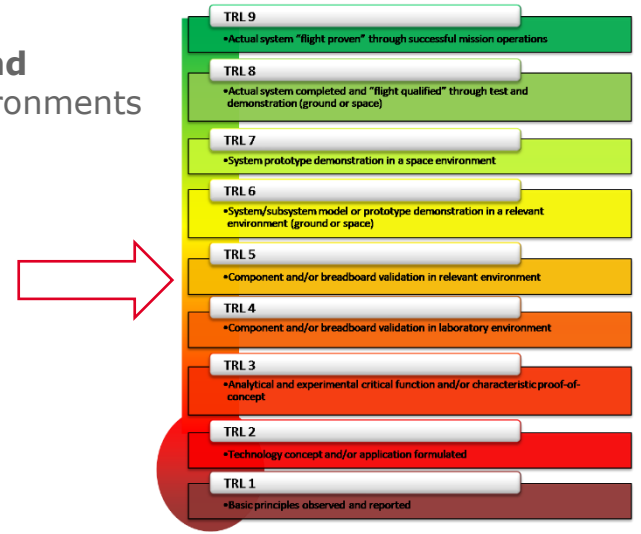
POMELO Objectives

- Implement a **demonstrator** for the broadcast of RTK and PPP corrections aligned with the **3GPP** protocols and architecture for positioning services in 4G and 5G

  - Exploit **terrestrial broadcast technologies** as means to provide mass-market users with **high-accuracy** multi-**GNSS** data and products hence to allow performing positioning strategies such as **RTK** and **PPP**

  - Prove the feasibility of the concept and demonstrate an **end-to-end** terrestrial broadcast service in **real** operational scenarios and environments

  - To assess the data rate, size of coverage area, end-to-end latency and positioning accuracy



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POMELO Performance Requirements

KPI and Target Requirements

- High Level: e.g. Drones applications
- Medium Level: ADAS, Mapping and GIS, Augmented Reality applications
- Low Level: the applications e.g. eHealth

TRR Test – Performance metrics

- TD03: PPP computation on the device
  - Target 5m
- TD04: RTK computation on the device
  - Target 5m

Target Performances for POMELO

Use case requirement	High Level	Medium Level	Low Level
Horizontal accuracy (95%)	10cm – 50cm	50cm – 100cm	> 1m
Vertical accuracy (95%)	10cm – 50cm	5m	5m
Measurement rate	1 Hz	1 Hz	1 Hz
Availability	> 99.9%	> 98%	Better than 95 %
TTFF	15 s	30s	1 minute
Integrity	Yes	Some	N/A
Authentication	Yes	Yes	Yes
Format	WGS84	WGS84	WGS84
PVT Latency	100 ms	100 ms	100 ms

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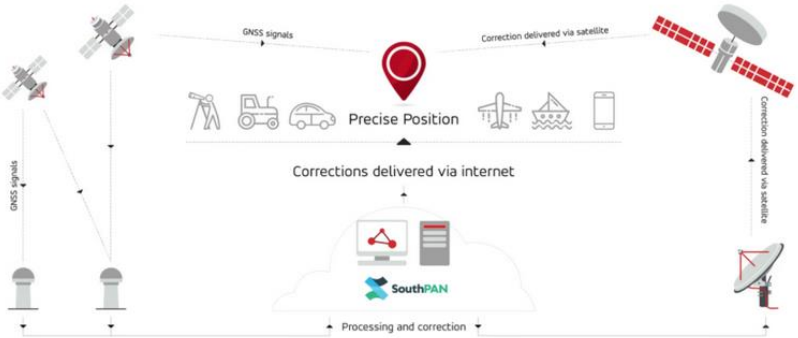
GNSS Data Dissemination

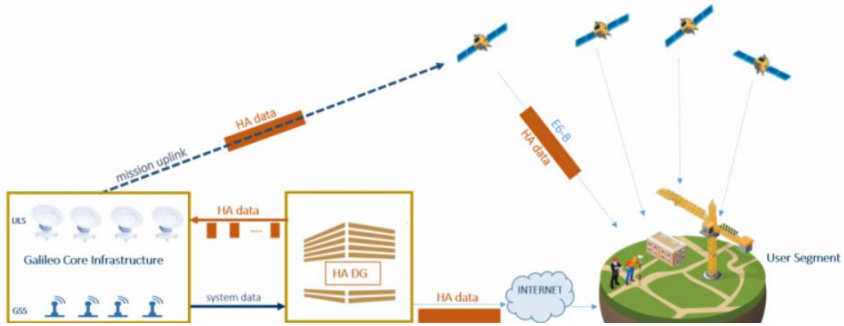
Broadcast via GNSS satellites

SouthPAN – Australia and New Zeland



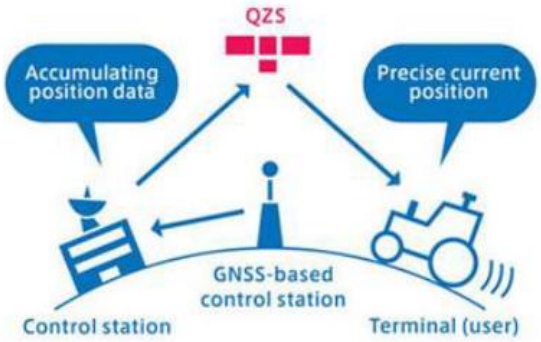
www.gmv.com

Galileo HAS - Europe



www.euspa.europa.eu

QZSS CLAS and MADOCA - Japan



https://home.csis.u-tokyo.ac.jp

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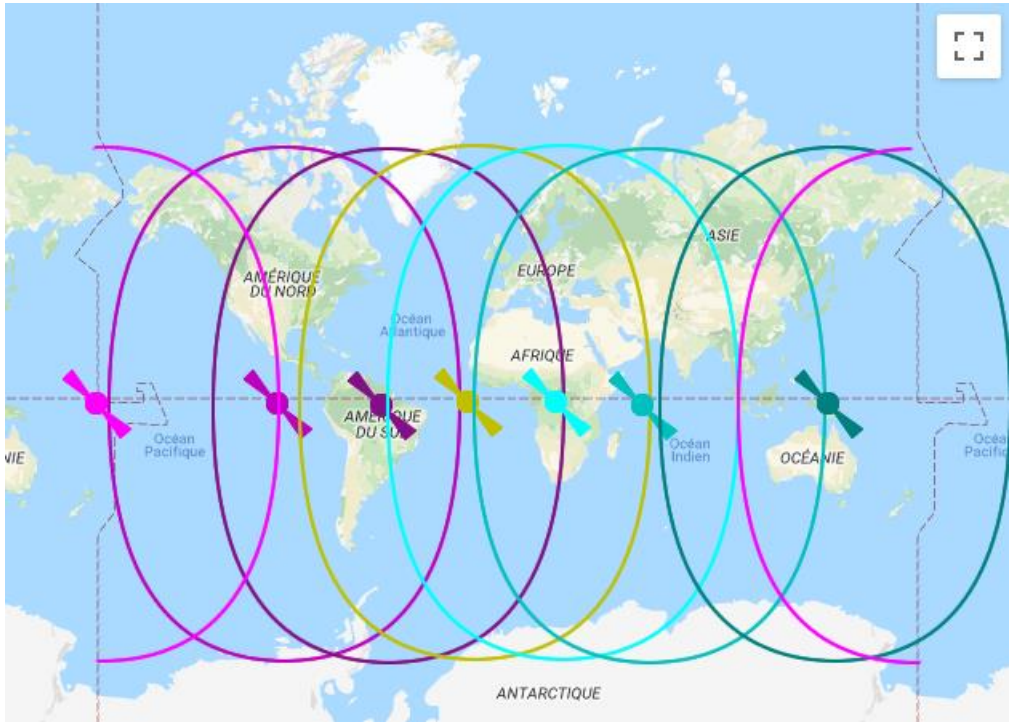
GNSS Data Dissemination

Broadcast via Telecom Geosatellite Channels



Private companies sell PPP correction broadcast via dedicated geostationary satellites

- The service is at a cost
- The format is proprietary

https://veripos.com/

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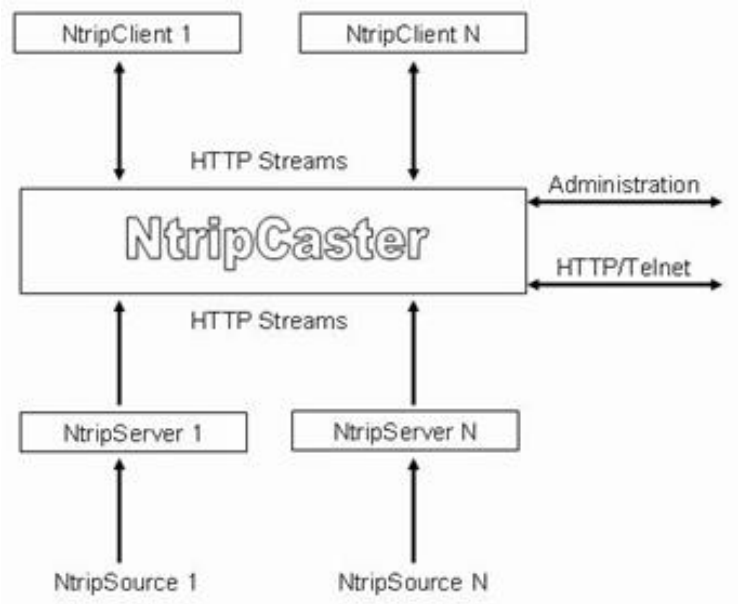
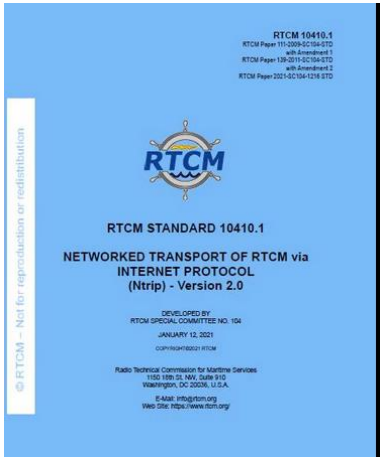
GNSS Data Dissemination

Broadcast via Internet





RTCM (Radio Technical Commission for Maritime Services) is a standard for transmitting differential corrections in GPS and GNSS systems

NTRIP protocol used to stream RTCM (and consequently PPP corrections) via Internet

- Not scalable

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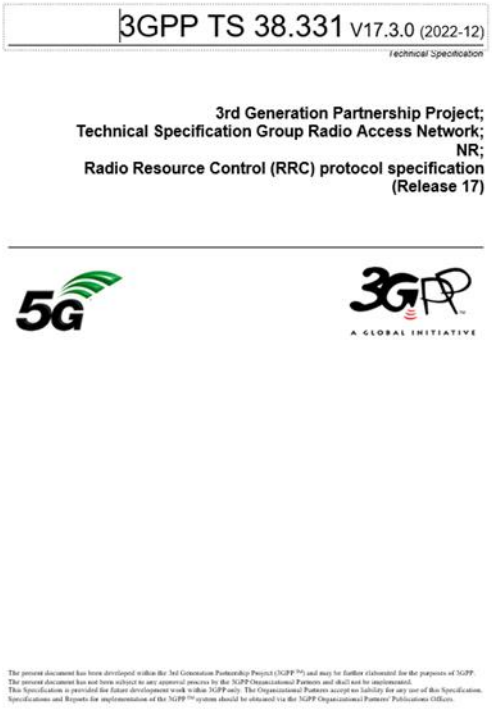
GNSS Data Dissemination

Broadcast via Cellular Networks



3GPP TS 38.331 V17.3.0 (2022-12)

Technical Specification

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
NR;
Radio Resource Control (RRC) protocol specification
(Release 17)

5G

3GPP
A GLOBAL INITIATIVE

The present document has been developed within the 3rd Generation Partnership Project (3GPP™) and may be further elaborated for the purposes of 3GPP.
The present document has not been subject to any approval process by the 3GPP Organizational Partners and shall not be implemented.
This Specification is provided for future development work within 3GPP only. The Organizational Partners accept no liability for any use of this Specification.
Specifications and Reports for implementation of the 3GPP™ system should be obtained via the 3GPP Organizational Partners' Publications Offices.

Assistance Data
Reference Time
Reference Location
Ionospheric Models
Earth Orientation Parameters
GNSS-GNSS Time Offsets
Differential GNSS Corrections
Ephemeris and Clock Models
Real-Time Integrity
Data Bit Assistance
Acquisition Assistance
Almanac
UTC Models
RTK Reference Station Information
RTK Auxiliary Station Data
RTK Observations
RTK Common Observation Information
GLONASS RTK Bias Information
RTK MAC Correction Differences
RTK Residuals
RTK FKP Gradients
SSR Orbit Corrections
SSR Clock Corrections
SSR Code Bias

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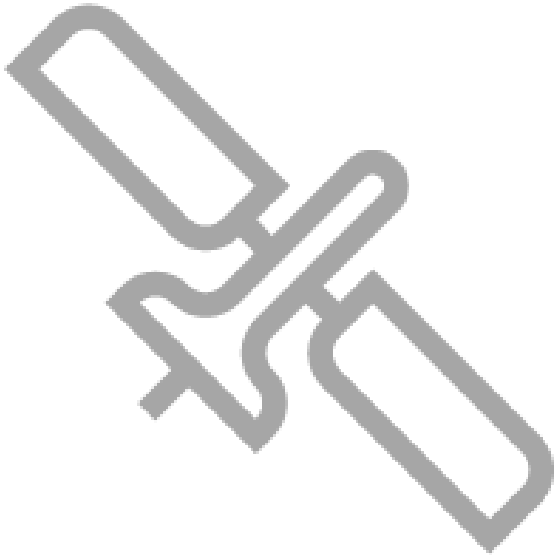
POMELO testbed



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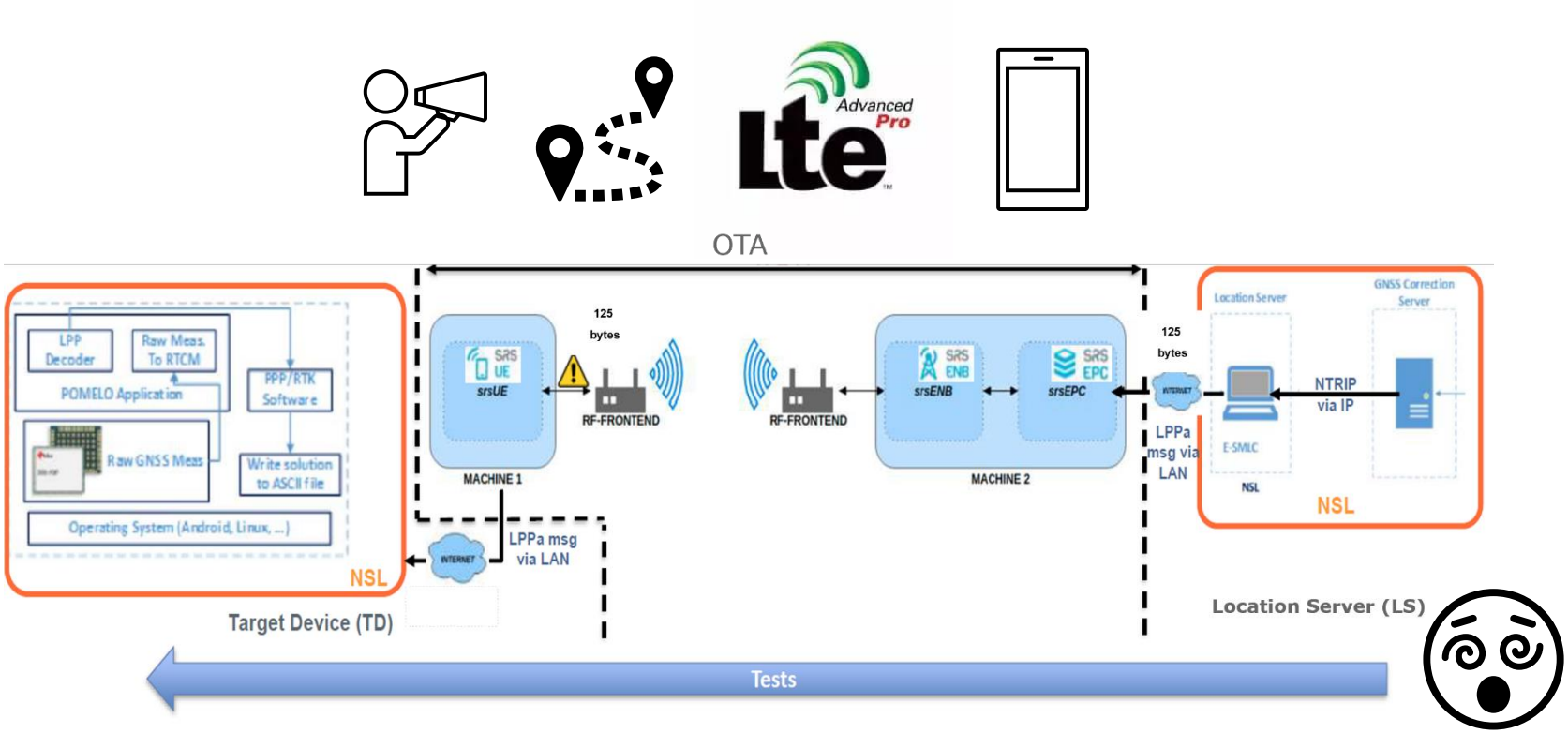
POMELO Testbed – How?



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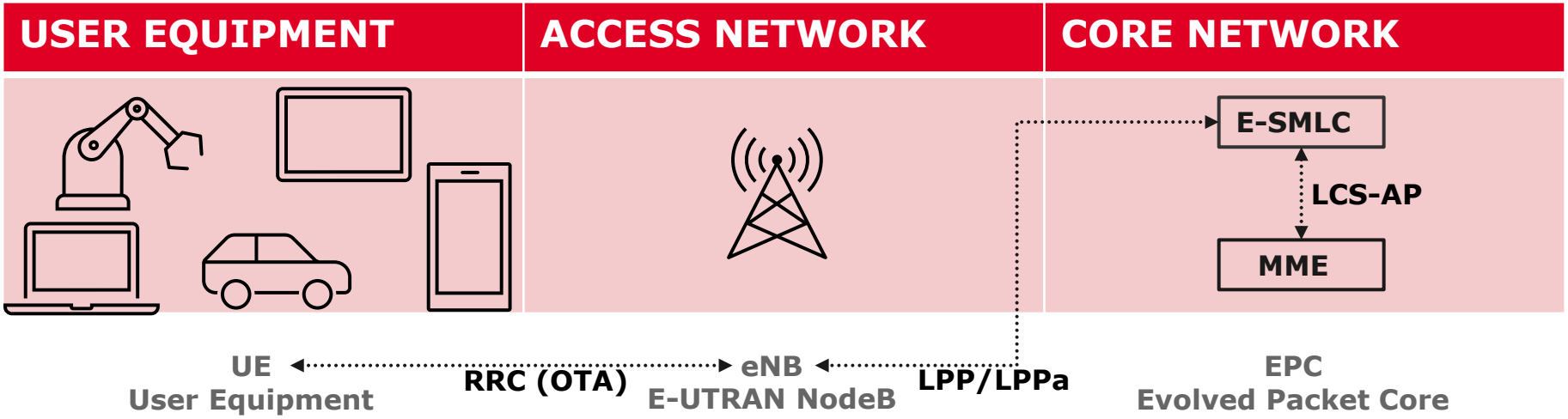
3GPP Standard (3GPP15 –LTE Advanced Pro)

- 3GPP (Third Generation Partnership Project) is a consortium of major Telecom Vendors and Operators formed to develop the future of mobiles communication systems.



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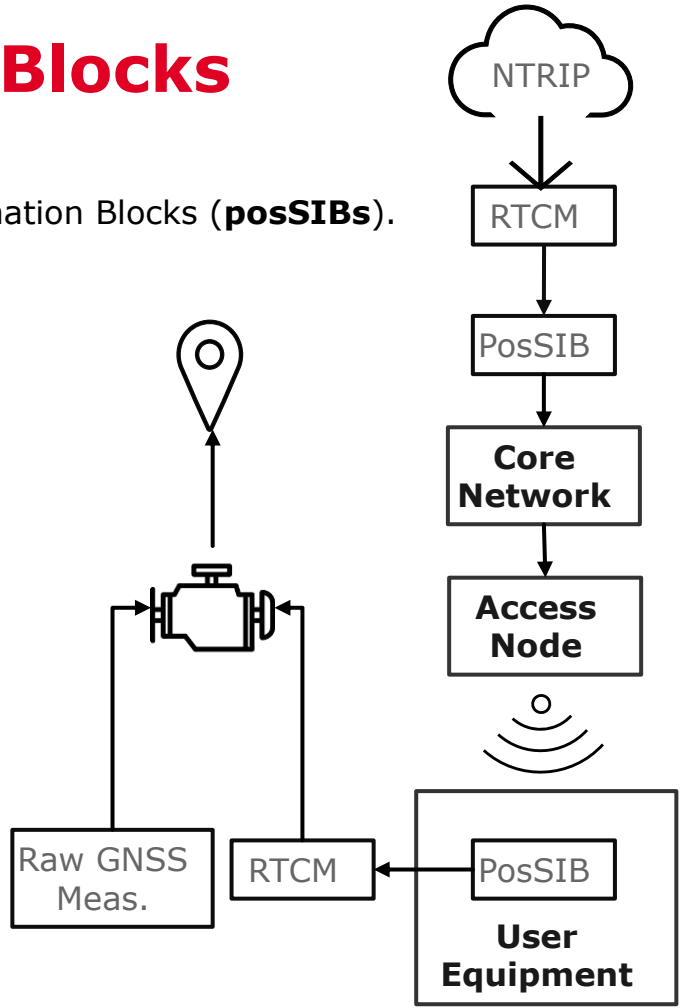
Positioning System Information Blocks

Positioning assistance data can be included in positioning System Information Blocks (**posSIBs**).

posSIB types:

$$\left.\begin{array}{c} posSIB\_type\ 1-5 \ \ -> \ Reference\ Station\ Info \\ posSIB\_type\ 1-6 \ \ -> \ Common\ Observation\ Info \\ posSIB\_type\ 2-12 \ -> \ Observations\ (GPS\ or\ GAL) \\ posSIB\_type\ 2-3 \ \ -> \ Navigation\ Model \end{array}\right\} RTK$$

$$\left.\begin{array}{c} posSIB\_type\ 2-3 \ \ -> \ Navigation\ Model \\ posSIB\_type\ 2-17 \ -> \ SSR\ Orbit\ Corrections\ (GPS\ or\ GAL) \\ posSIB\_type\ 2-18 \ -> \ SSR\ Clock\ Corrections\ (GPS\ or\ GAL) \\ posSIB\_type\ 2-19 \ -> \ SSR\ Code\ Bias\ (GPS\ or\ GAL) \\ posSIB\_type\ 3-1 \ \ -> \ SSR\ Phase\ Bias\ (GPS\ or\ GAL) \end{array}\right\} PPP$$



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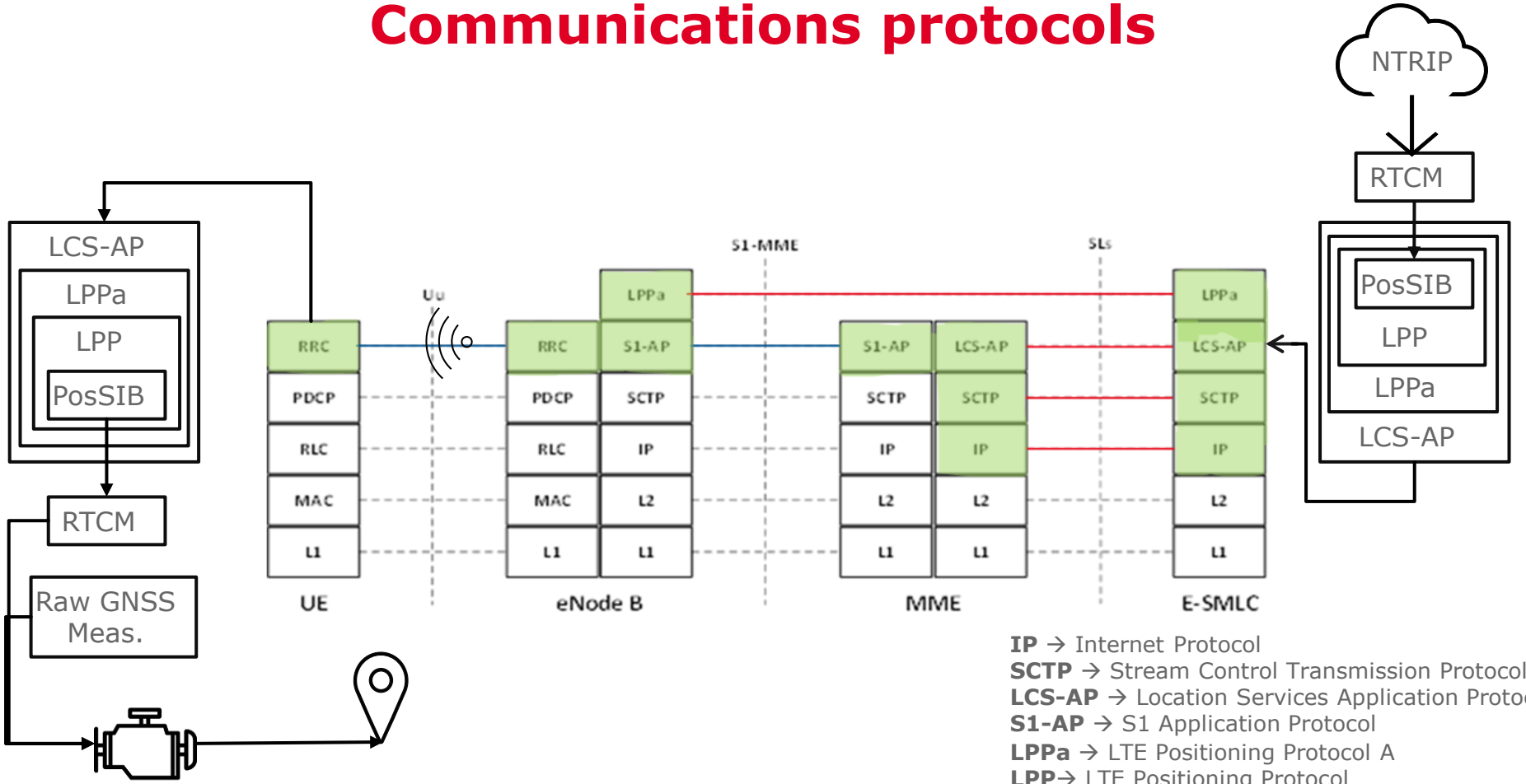
Communications protocols



IP → Internet Protocol
SCTP → Stream Control Transmission Protocol
LCS-AP → Location Services Application Protocol
S1-AP → S1 Application Protocol
LPPa → LTE Positioning Protocol A
LPP→ LTE Positioning Protocol
RRC → Radio Resource Control

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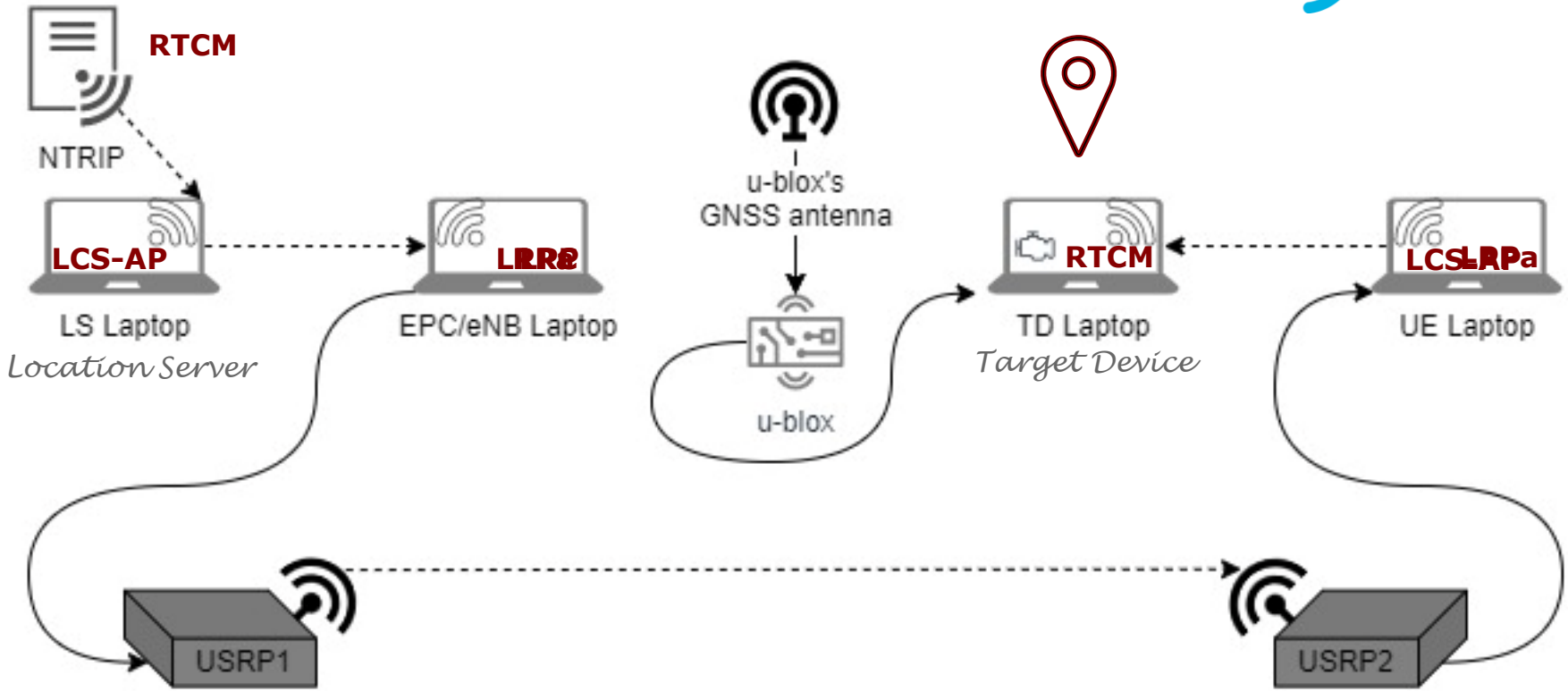
POMELO Testbed – How?



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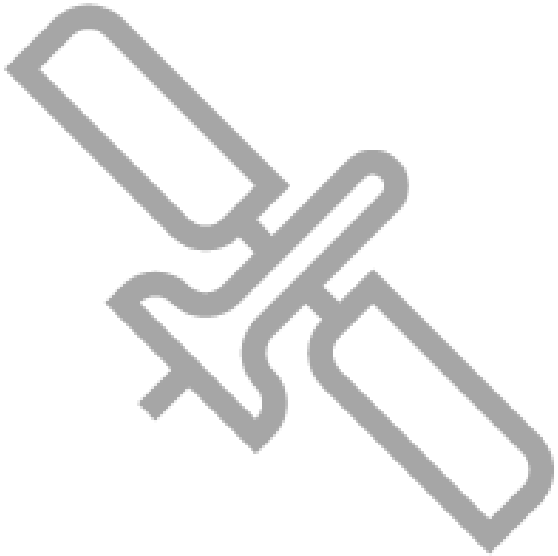
POMELO challenges



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POMELO challenges – Size of packages

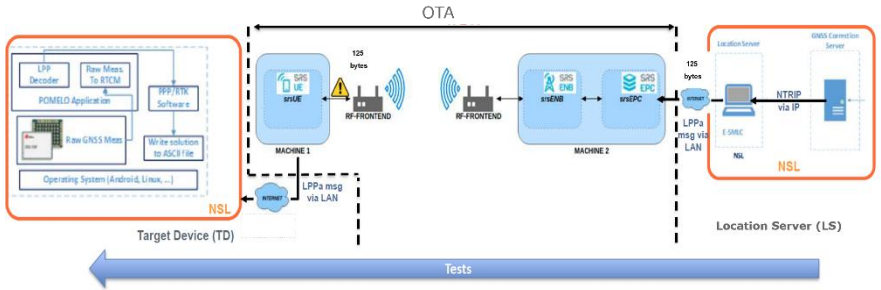
```
LPPA_PDU {
[…]
    posSIBs[1] {
        posSIB_Type = posSibType1-6
        posSIB_Segments[0] {
            assistanceDataSIBelement = 0x0b000400000000
        }
    }
    posSIBs[2] {
        posSIB_Type = posSibType2-12
        posSIB_Segments[0] {
            assistanceDataSIBelement = 0x0b000600000000
        }
        posSIB_Segments[1] {
            assistanceDataSIBelement =
                0a 00 80 d4 20 1d 7e b1 ff c0 02 98 74 fa fd e4
                30 b0 65 65 b7 9c a8 d4 79 6e 4d 31 6c ca ec 0f
                36 6d a8 f2 94 99 fc c4 26 4f 6e 71 09 83 68 b0
                be 08 ef a3 ca a1 72 83 66 de e7 7c a3 ff 47 94
                e2 ef 26 6d 98 58 f9 89 00 8f 30 05 d5 0c 52 6b
                24 e6 a0 98 23 f6 63 98 a9 f2 3c aa 28 76 b6 48
                d7 a7 3d 9a 24 79 5a 51 7b 66 8e ba ce 6b 3c 08
                f3 00 a1 ac c6 aa 61 8f 07 81 84 17 29 c0 47 c1
                23 c8 41 bf f3 1e a7 87 3b 74 16 11 10 75 04 1a
                d4 8f 23 48 89 0d a2 14 ba 09 d6 69 1e 44 90 f1
                59 04 4e 7e 01 40 30 63 ed 17 9c 80 c4 79 82 47
                0a 64 92 25 98 3d c4 c1 f5 34 e0 1a 6e 51 e5 d1
                42 b1 b3 e6 50 c0 68 bf 23 ca f2 85 93 37 dd bd
                81 7a ee 47 98 e5 15 b6
        }
    }
[…]
}
```

The main issue laid in the RRC protocol within the srsLTE software.

We can look at the LPPa message as a set of information blocks (posSIBs), each one divided into one or more segments.

Such a structured data package can easily reach a size of ~6000 bytes.

We discovered that only packages of max 125 bytes were able to be converted to RRC and correctly sent over the air.



PDU

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POMELO challenges – Size of packages (solution)

FIRST CHUNK

AB CD EF 05 00 C3 48 00 02 00 83 4F 00 00 04 00

13 00 02 80 01 00 03 00 09 00 02 4A AA 40 54 38

…

70 4D 89 63 50 CF D7 9D C0 C1 BC C2 1F 36 FA 13

E6 29 4A CD 8E 48 82 DD C0 13 76 6F E9 00 76 6F

E9 00

[…] Size 125 bytes

- AB CD EF: Unique pattern
- 05: Total number of chunks
- 00/01: Sequence number
- C3: Chunk size without header and footer (195bytes – grey message)
- 48: remainder of the division between the original size of the package and the maximum chunk dimension allowed (195 bytes).
  In this case 852/195 = 4 with reminder 72.
- 07 42 EB 00: CRC-24 computed on the header + data content (used for integrity check).
- 76 6F E9 00: CRC-24 of the FIRST chunk of the sequence (used as unique ID of the original message)

SECOND CHUNK

AB CD EF 05 01 C3 48 0B 19 C1 8D 6D D7 4F 97 23

58 26 D6 30 6D 1B DD 18 9F 2D 86 DE 8C EC 9F 4A

…

EE FF 06 6A 9F 25 87 8B 6D 9F DB B2 00 A4 9D 3E

4D 8F FC 99 BF 83 74 01 A2 A2 07 42 EB 00 76 6F

E9 00

[…] Size 125 bytes

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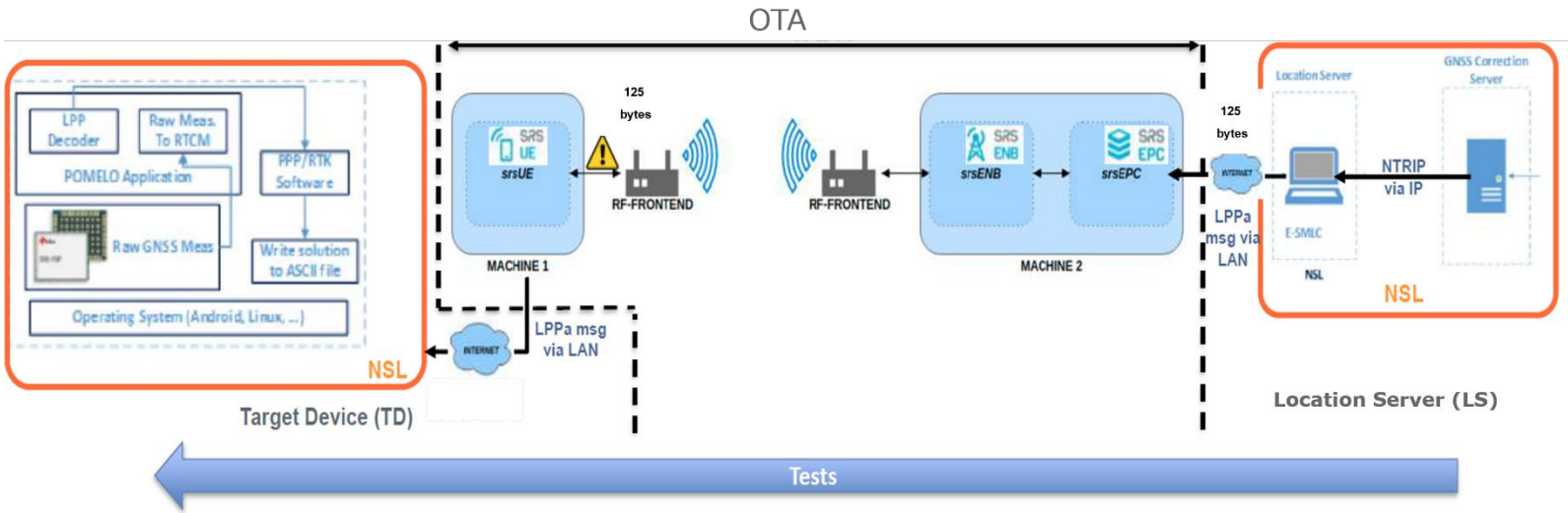
POMELO challenges – Collateral damage

The use of short messaged introduced the need to adjust and tune the synchronization between the submodules across the testbed.



A configuration of 1 second delay between the chunks is required, increasing the system latencies

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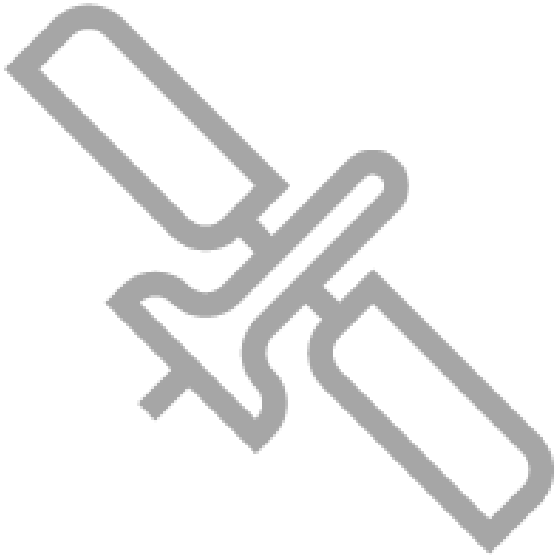
POMELO Experiments



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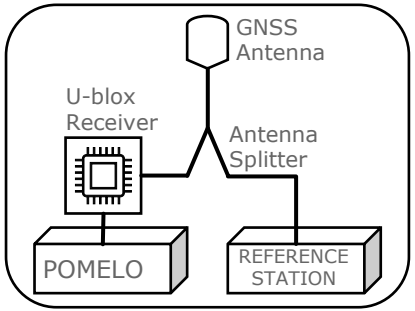
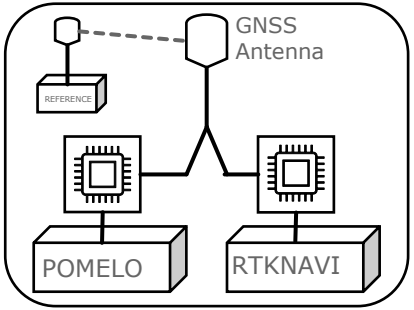
Experiments and demo equipment

Static tests



- **POMELO testbed**
- **Test 1. RTK Zero baseline configuration:**
  - **U-blox F9P,** configured as Rover, connected to the same antenna as the **GNSS Reference Station** used to stream the corrections**.**
- **Test 2. PPP,** with corrections supplied by **GEOFLEX**

Dynamic tests



- **POMELO testbed located on the** Wombat robot (**pedestrian** mode)
- **2 u-blox F9P** connected to a GNSS NavXP antenna via a splitter, one used as device under test and one as reference solution.
- **Test 1. RTK** correction stream from a nearby Reference Station
- **Test 2. PPP** corrections from **GEOFLEX**

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POMELO Testbed Results – RTK Static

Zero baseline – ublox F9P (rover)/FLM (base)

.\Results\POMELO_TD_20221005_105311_RTK_SwOFF_UBX_POMELO_POS.csv

RTK Static

11:15:09 → 11:44:57 ~ half an hour

SOLUTION AVAILABILITY:

- Available epochs:
  1063 / 1798 --> **59.12 %**
- Max time between solutions:
  55 seconds

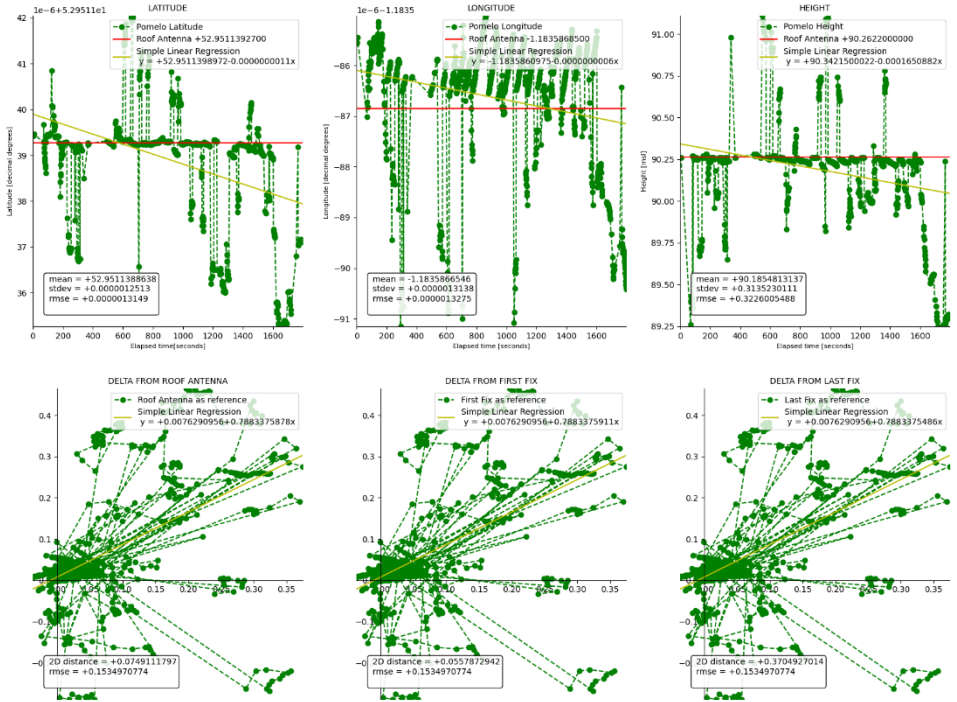
POSITIONING PERFORMANCE:

- Knowing exact position of roof antenna:
  Lat +52.9511392700,
  Lon -1.1835868500,
  H +90.2622000000

The 2D Distance from Roof Antenna:

(Considering the median of all 2D distances from the known roof antenna coordinates)

+0.075 m



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POMELO Testbed Results – RTK Static

Zero baseline – ublox F9P (rover)/FLM (base)

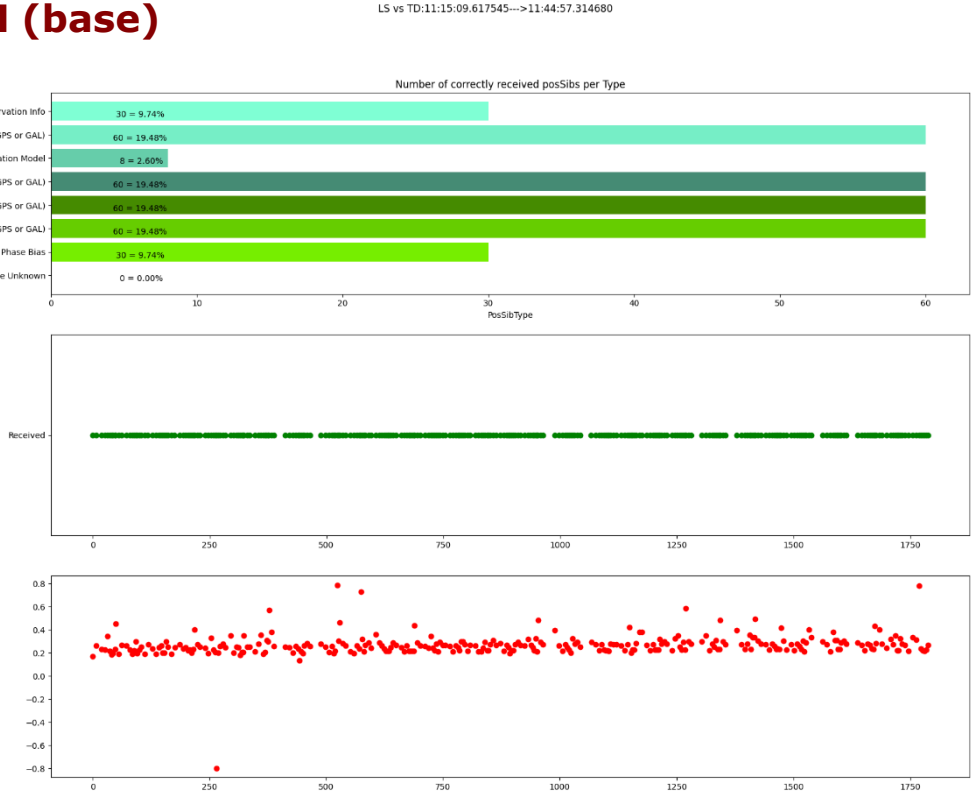
RTK Static

11:15:09 → 11:44:57 ~ half an hour

- Max latency: 0.786505 s

(from when the chunk is dispatched from the LS to when it is received at TD; please note this may include clock biases between machines)

- Received correctly: 308 / 308
- Received corrupted: 0
- Sent but not received: 0
- Availability: 100.00 %



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POMELO Testbed Results – PPP Static

Ublox F9P

13:40:04 → 14:09:57 ~ half an hour

SOLUTION AVAILABILITY:

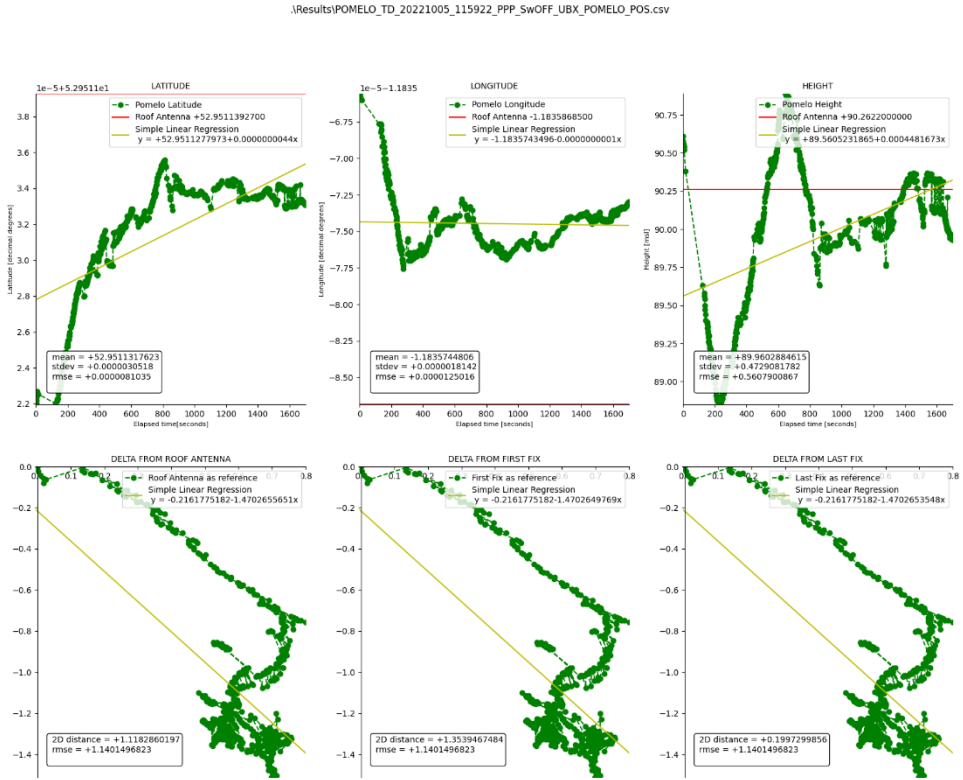
- Available epochs:
  834 / 1799 --> 46.36 %
- Max time between solutions:
  35 seconds

POSITIONING PERFORMANCE:

- Knowing exact position of roof antenna:
  Lat +52.9511392700,
  Lon -1.1835868500,
  H +90.2622000000

2D Distance from Roof Antenna:

+1.118 m



(Considering the median of all 2D distances from the known roof antenna)

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POMELO Testbed Results – PPP Static

Ublox F9P

13:40:04 → 14:09:57 ~ half an hour

- Max latency: 0.582807 s

(from when the chunk is dispatched from the LS to when it is received at TD; please note this may include clock biases between machines)

- Received correctly: 291 / 291
- Received corrupted: 0
- Sent but not received: 0
- Availability: 100.00 %

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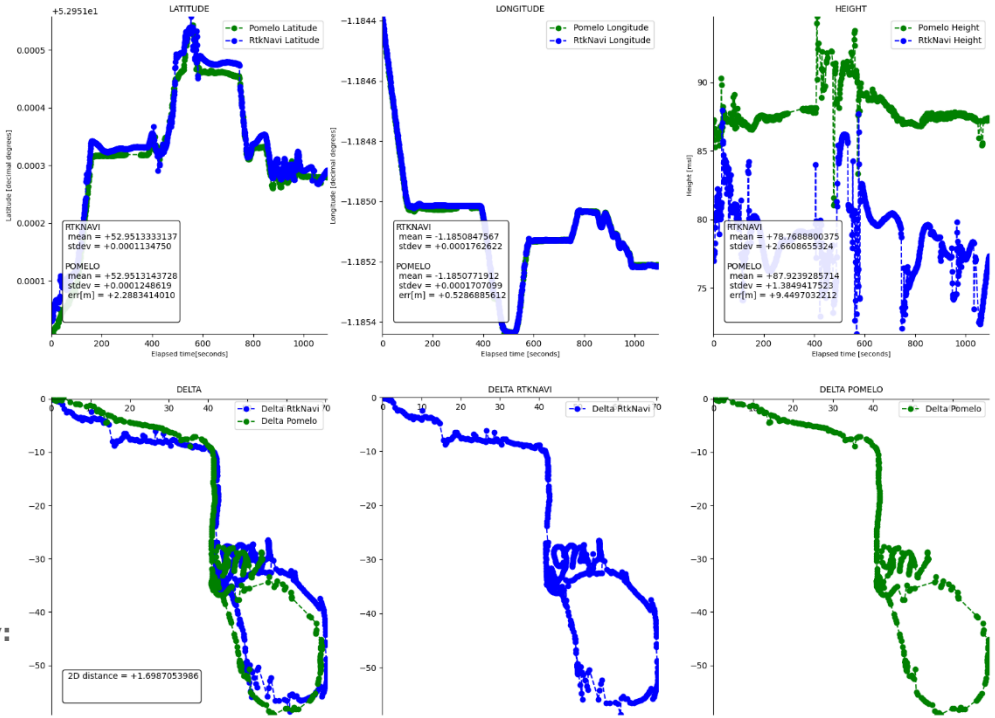
POMELO Testbed Results – PPP Dynamic

- 2D distance from reference solution (Rtknavi): ~1.70 m
- Availability: 63.95%



- Latency: 76.41s
- Received correctly: 162/249
- Received corrupted: 0
- Sent but not received: 87
- Availability: 65.06 %

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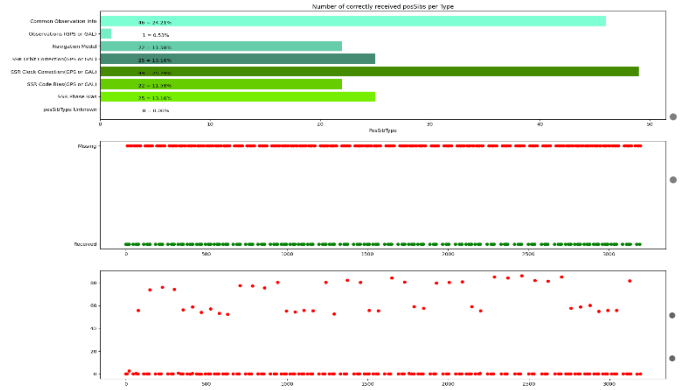
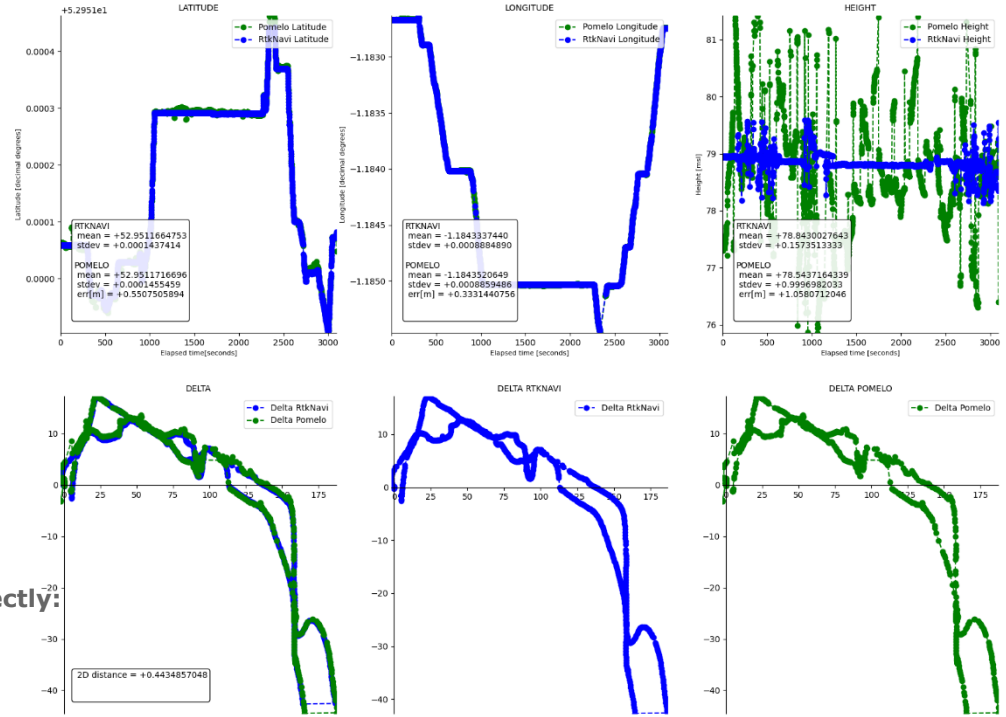
POMELO Testbed Results – RTK Dynamic

- 2D distance from reference solution (Rtknavi): ~0.44 m
- Availability: 60.20%



- Latency: 86.27s
- Received correctly: 190/496
- Received corrupted: 0
- Sent but not received: 306
- Availability: 38.31 %

C:\Users\LIGU\Desktop\DynamicTest\RTK\POMELO_TD_20221010_120913_RTK_SwOFF_UBX_POMELO_POS.csv: 11:11:24--->12:02:55



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Statistics

TEST	2D Distance from REF Solution [m]	RMSE [m]	AVAILABILITY [%]	MAX LATENCY [s]	Duration [mins]
ZERO BASELINE RTK + U-BLOX	0.08	0.15	59.12	55	15
ZERO BASELINE PPP + U-BLOX	1.12	1.14	46.36	35	15
DYNAMIC RTK + U-BLOX	0.44	0.59	60.2	57	40
DYNAMIC PPP + U-BLOX	1.70	2.08	63.95	59	40

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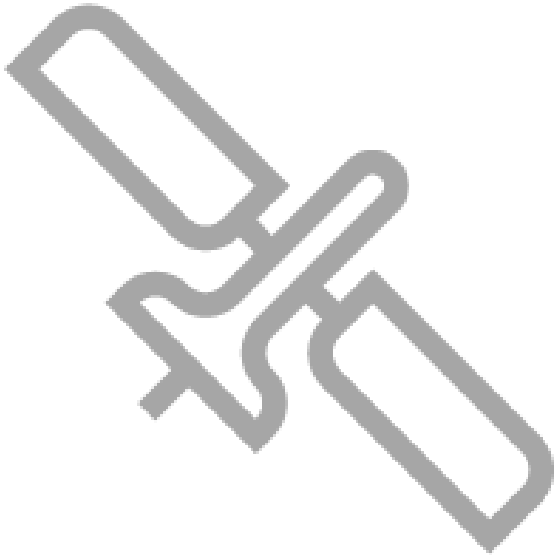
POMELO Demonstration at FR



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POMELO Demonstration at FR

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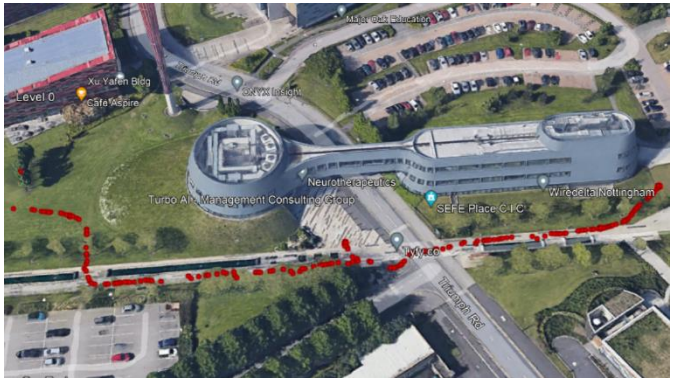
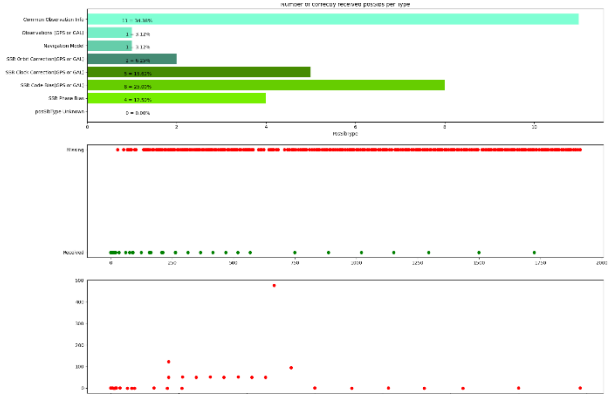
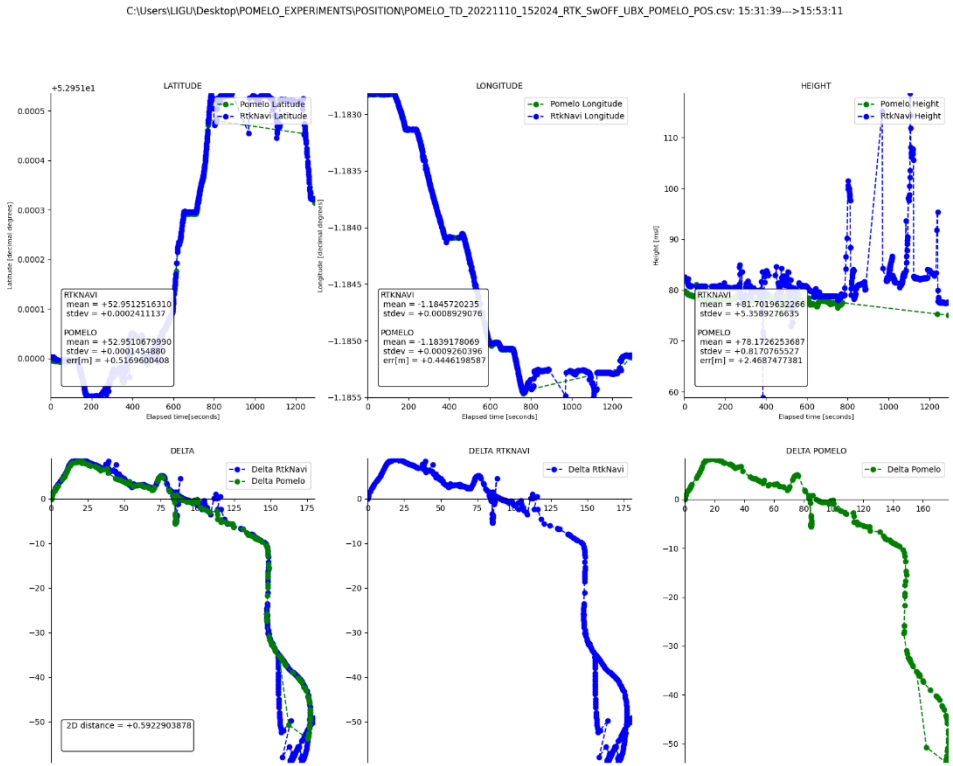
POMELO Testbed Results – RTK Dynamic Demo

- **2D distance from reference solution (RTKnavi): ~0.60 m**
- **Availability: 26.16%**







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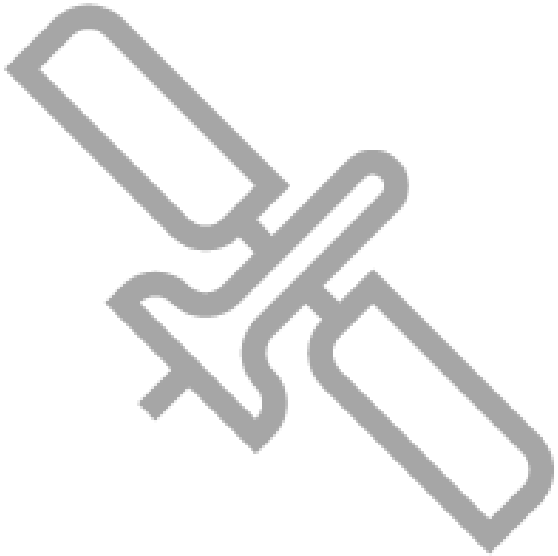
Recommendations & Future Steps



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Recommendations and future steps

- srsLTE library allows the transmission of data up to 125bytes at a time, which is significantly less compared to the total size of GNSS assistance data required in RTK and PPP. This affected the end-to-end latency, positioning accuracy and availability.
  - ***Rec #1: The testbed is based on the open library srsLTE version 20.10.1. As the library is continuously updated with new features, it is worth engaging with the srsLTE community, now called srsRAN, and discuss mitigation of the limitations encountered.***

- The POMELO demonstrator are currently based on SDR hardware (ettus USRP 2901) and the OTA tests made use of the 2.4 GHz band due to lean regulations constraints; however, because the 2.4 GHz band is a Wi-Fi frequency, this is very noisy, and we experienced many interruptions (which impacted the availability) and reduced the transmission range to no more than 5m distance.
  - ***Rec #2: Use high end USRP models and attempt OTA transmission in other frequency bands, preferably not Wi-Fi.***
  - ***Rec #2: Partner with mobile network operators and user equipment manufacturers to carry out high fidelity tests.***

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Recommendations and future steps

- The testbed has been tested with just one user at TD hence the potential of the testbed and the technology that it represents has not been explored in full considering multiple users
  - ***Rec #4: Repeat tests with one Transmitting Point and multiple users to demonstrate the scalability of this solution.***
- The concept supports the GNSS Assistance Data up to 3GPP Release 15 and it has been tested using standard SSR provided by Geoflex (partner of POMELO) and occasionally, with IGS
  - ***Rec #5: Tests can be done using different corrections providers (ESA,...) and additional data, such as complete SSR (corresponding to 3GPP Release 16).***

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Thank you

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