Galileo Mass Market Receivers

Paolo Crosta

11/10/2019

Galileo Workshop Status en Toepassingen,
Galileo Reference Centre, Noordwijk

ESA UNCLASSIFIED - For Official Use

Smartphones and GNSS

First GPS Phone
Benefon Esc!

1999

+ GLONASS
MTS 945

2011

+ QZSS
Samsung Galaxy Note

2011

+ Beidou
Samsung Galaxy S5

2014

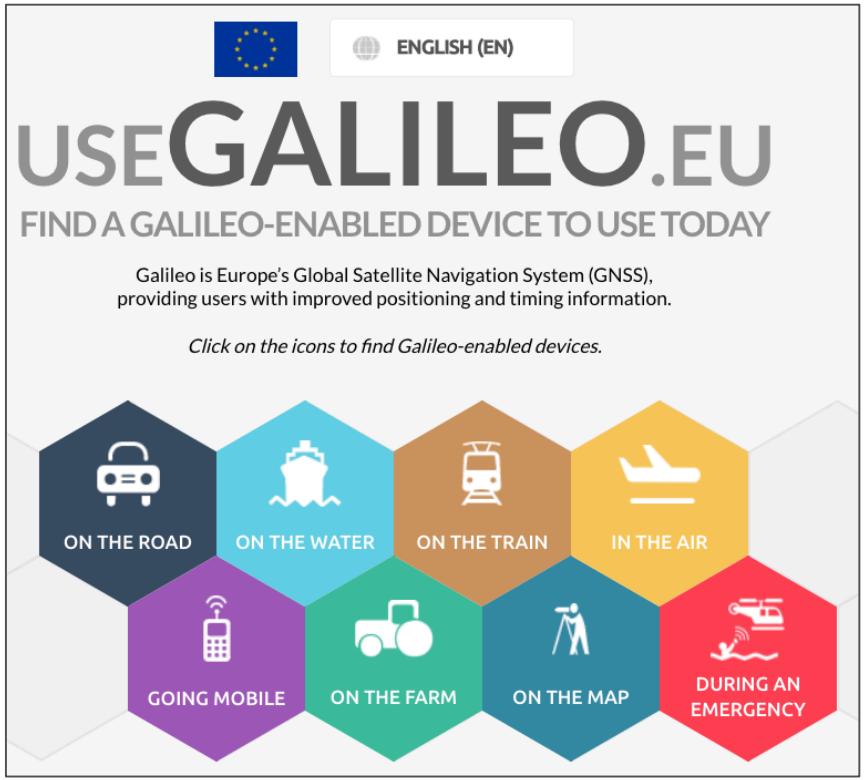
+ Galileo
BQ Aquaris X5 Plus

2016

2018

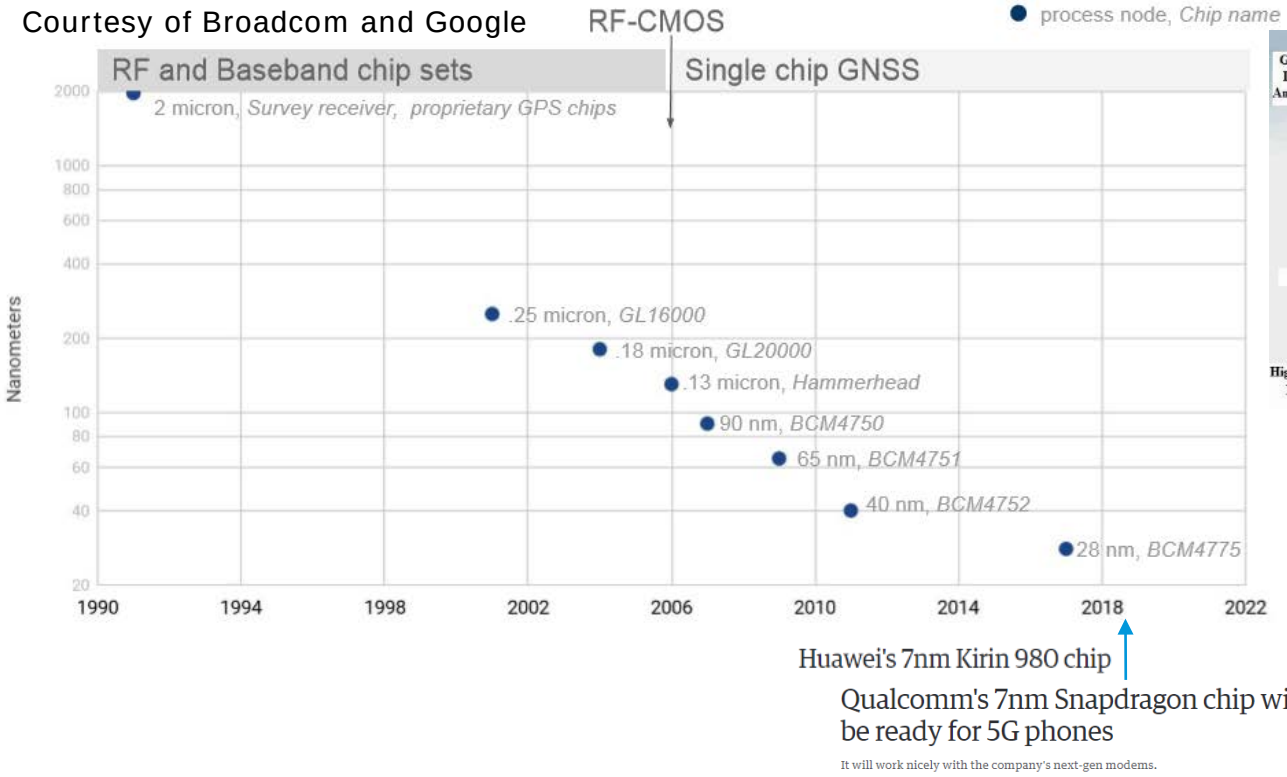
First Dual Frequency
Xiaomi Mi8

Sources: gsmarena, samsung, xiaomi, google, bq, wikipedia

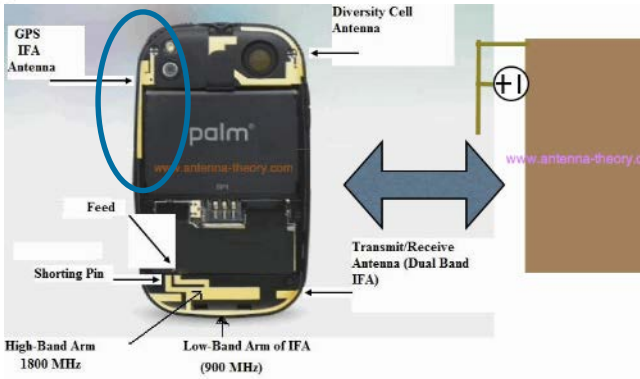

ENGLISH (EN)
USEGALILEO.EU
FIND A GALILEO-ENABLED DEVICE TO USE TODAY
Galileo is Europe's Global Satellite Navigation System (GNSS),
providing users with improved positioning and timing information.
Click on the icons to find Galileo-enabled devices.
ON THE ROAD
ON THE WATER
ON THE TRAIN
IN THE AIR
GOING MOBILE
ON THE FARM
ON THE MAP
DURING AN EMERGENCY

GNSS HW evolution in the phone

Courtesy of Broadcom and Google



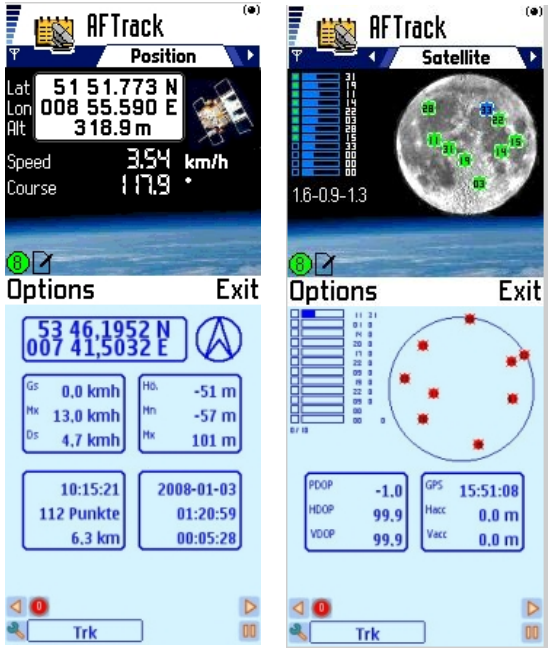
2009 Palm Pre
Single frequency L1 PIFA



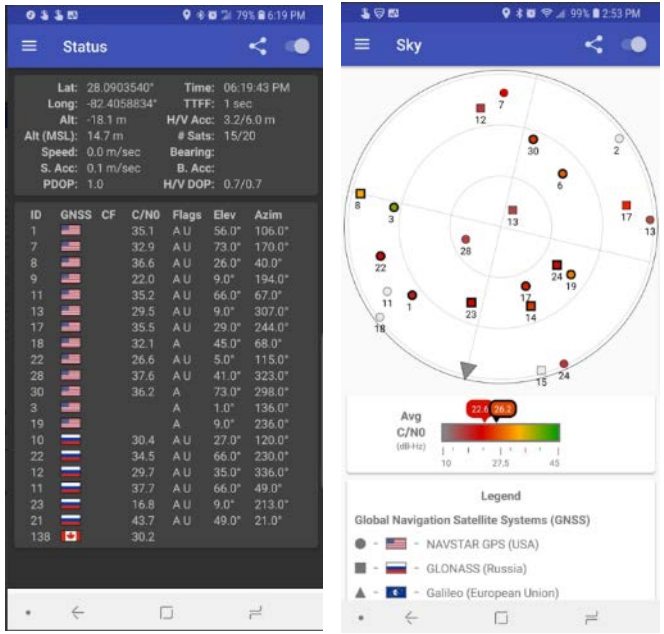
2018 Multi-frequency PIFA
From Xiaomi mi8 teardown

O/S Evolution and GNSS observables

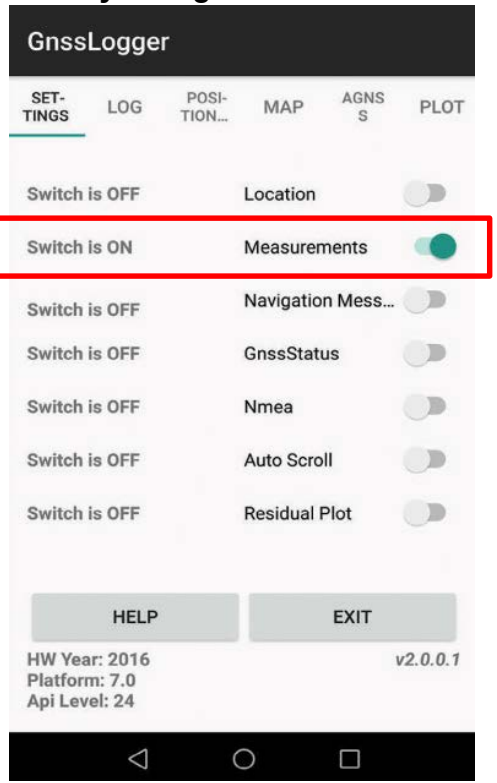
Symbian O/S App
2009-2013



Android O/S - GPS Test by S. Barbeau
2013-now



GNSSLogger App
By Google 2016 - now



http://www.afischer-online.de/sos/AFTrack/index.html
https://github.com/barbeau/gpstest
http://insidegnss.com/gnss-analysis-tools-from-google/

GNSS Raw Measurements White Paper

- To support Android developers, the GSA has just published a White Paper describing a step by step approach on how to use the raw measurements.

- ESA was one of the key members of the Task Force preparing the White Paper.

Second Galileo App Competition 2018-2019

- Milestone 1 held on **23 January: all teams successfully passed to phase 2**

ID	EVENT	DATE
1	Announcement of Competition	24 Sep. 2018
2	Registration deadline for Information Day	8 Oct. 2018
3	Information Day	16 Oct. 2018
4	Proposal submission deadline	12 Nov. 2018
5	Announcement of selected teams to proceed to development phase	26 Nov. 2018
6	App Development Milestone 1 (M1)	15 Jan. 2019
7	App Development Milestone (M2)	28 Feb. 2019
8	App Development Milestone (M3)	31 Mar. 2019
9	Competition Final at ESA-ESTEC (with live web streaming and on-line voting)	18 Apr. 2019

- Final award ceremony on **18 April 2019** at ESA site in Netherlands with live web streaming and on-line voting

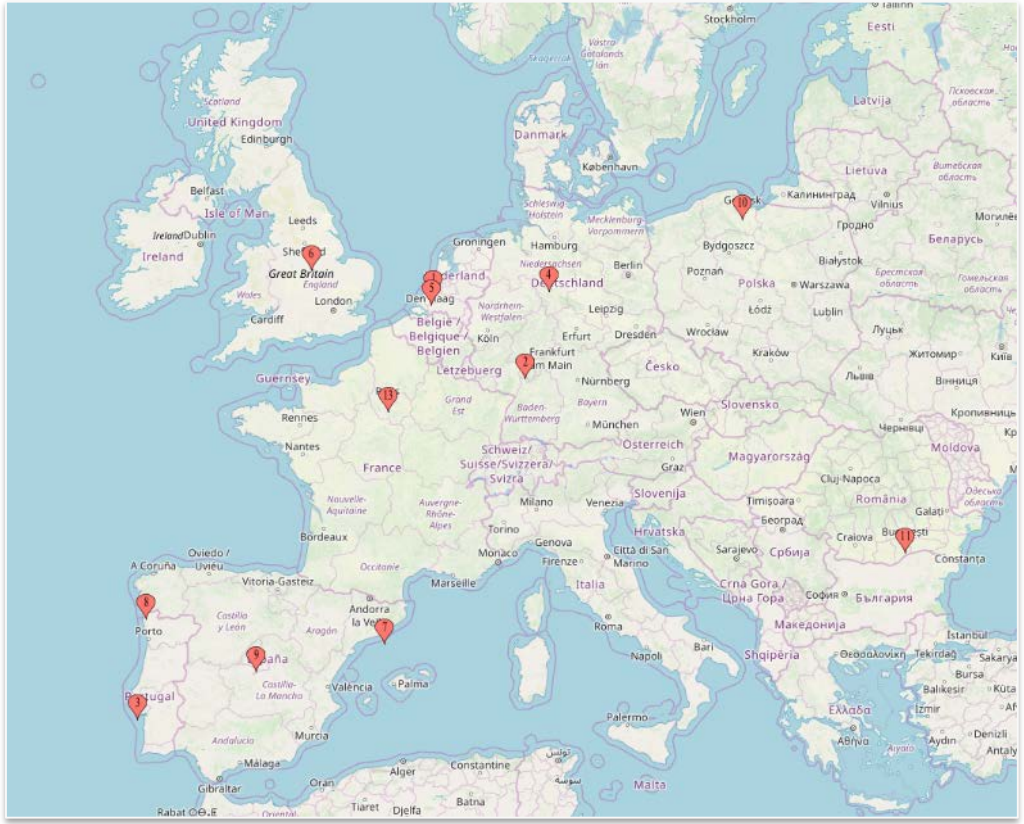
Applications

12 proposals

received 12 November 2018

8 selected

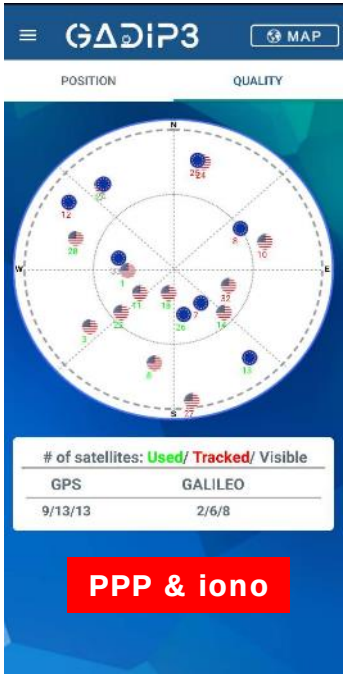
to proceed to Step 2



Final Competition

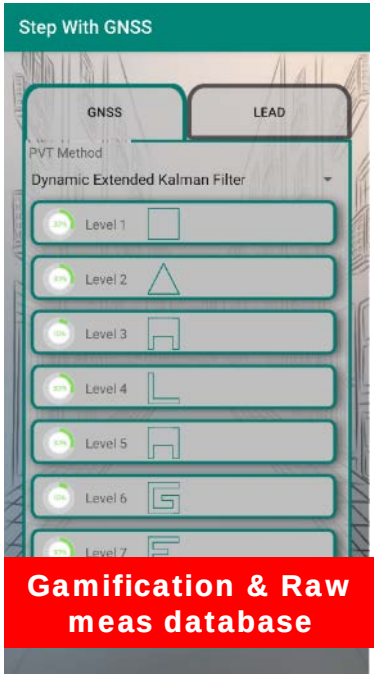
- Final event took place on 18/04/2019 at ESTEC
- **5 teams** selected for the Final:
  - GADIP3 by O'ThiSaVRoS Team
  - Inari by Inari Team
  - NavGate by GNSS Tonic Team
  - Step with GNSS by Space Walkers Team
  - POINTapp by University of Nottingham
- Prior to the Final the apps were extensively tested by ESA at ESTEC
- The target was to match the results produced by processing of measurement logs of ESA reference app with Google tools and ESA PPP s/w.

Competition Apps Outline

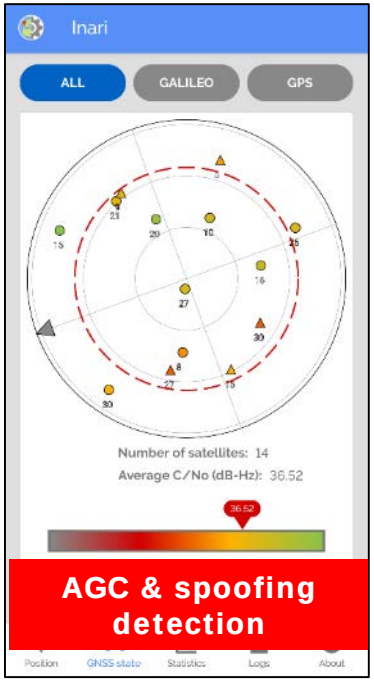


GADIP3

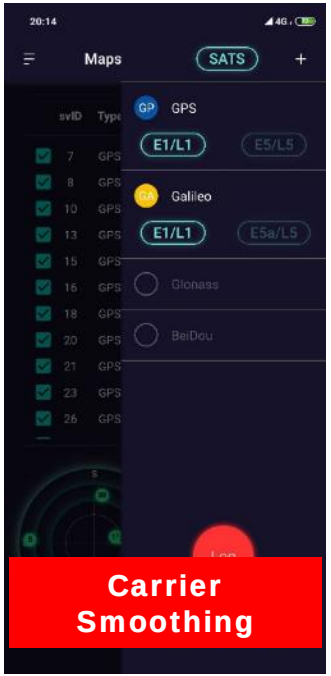
NavGate



Step with GNSS

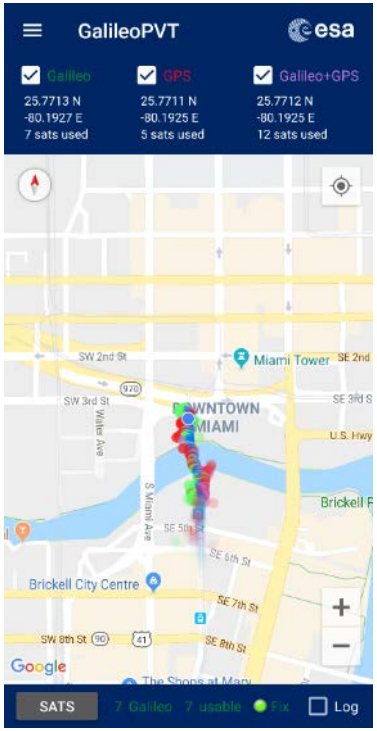


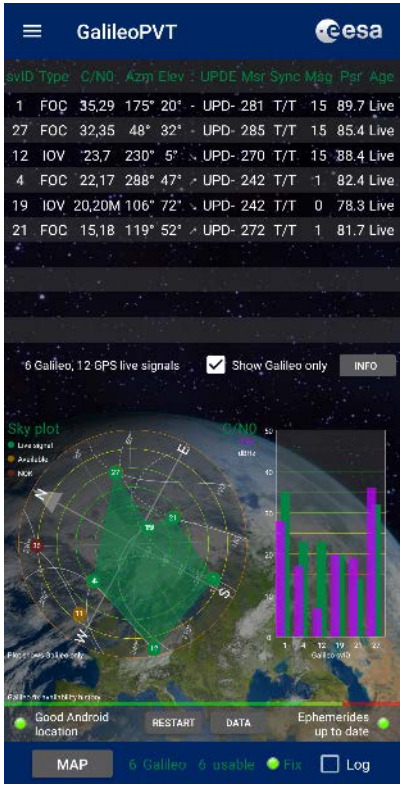
INARI

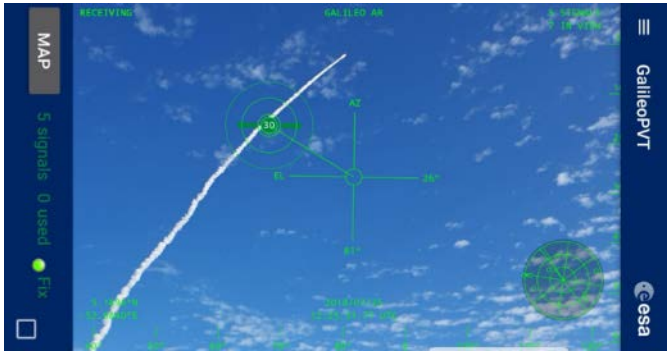


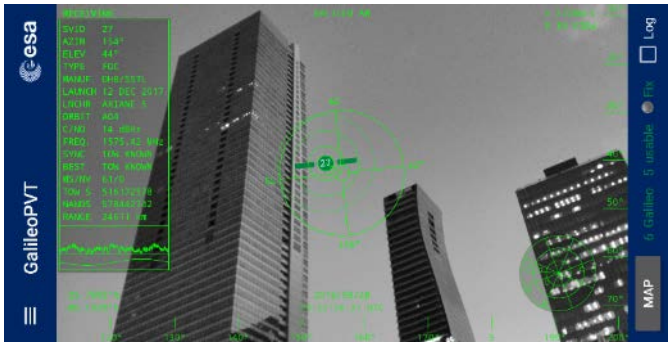
PointApp

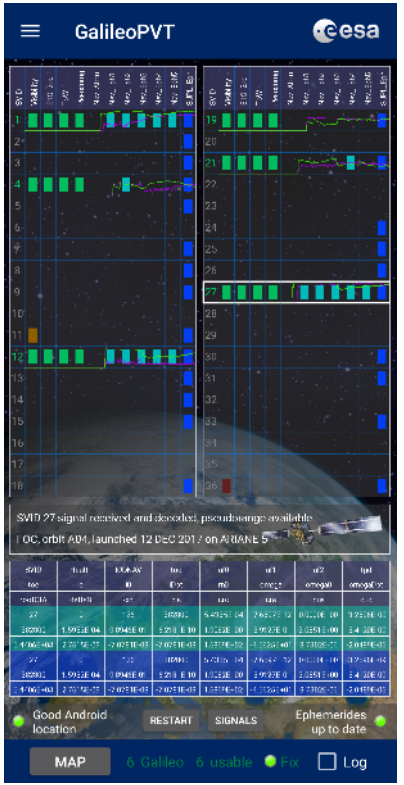
GalileoPVT: ESA reference Android app





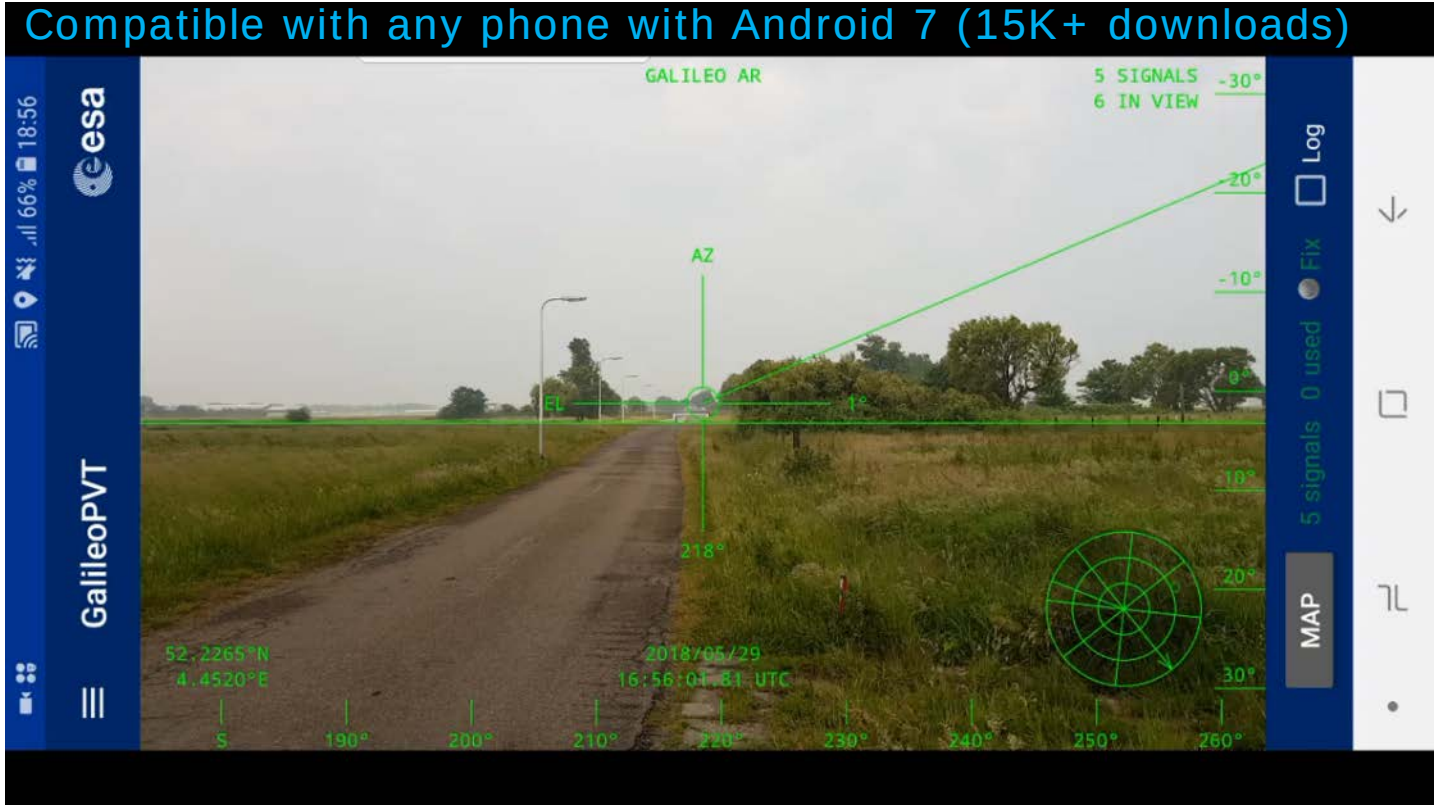


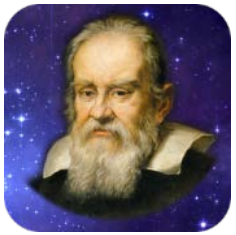




GalileoPVT - Augmented Reality View

Compatible with any phone with Android 7 (15K+ downloads)



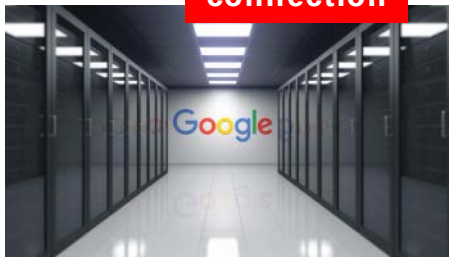


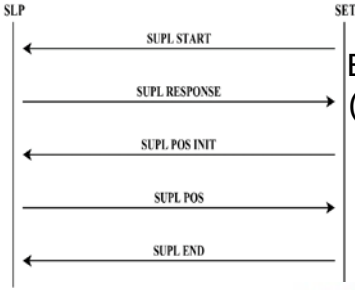
GalileoPVT

GET IT ON Google Play

Retrieval of Satellite and Clock Orbits

SSL data connection





SLP – SUPL Location Platform (server)

Broadcast ephemerids (near real-time)

Navigation message broadcast on L-Band

Broadcast ephemerids (real-time)

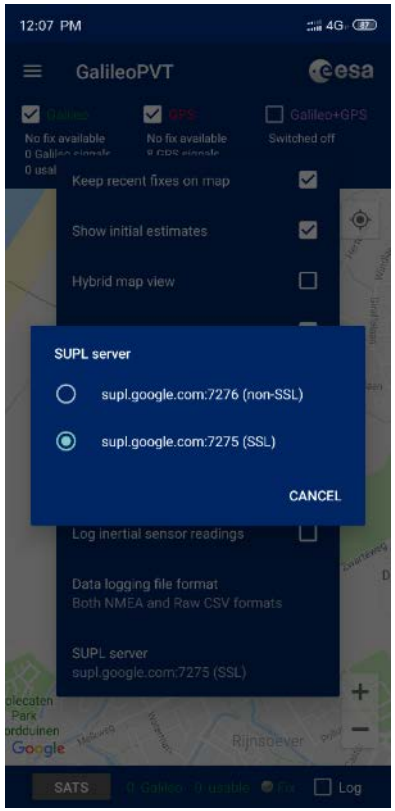
Android GnssNavigation Message Callback

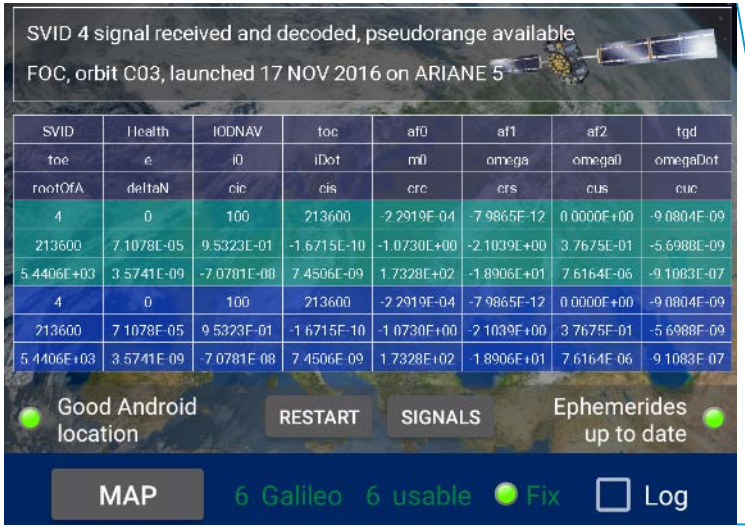
NTRIP CASTER (CNES, ESOC)

http://www.ppp-wizard.net/caster.html

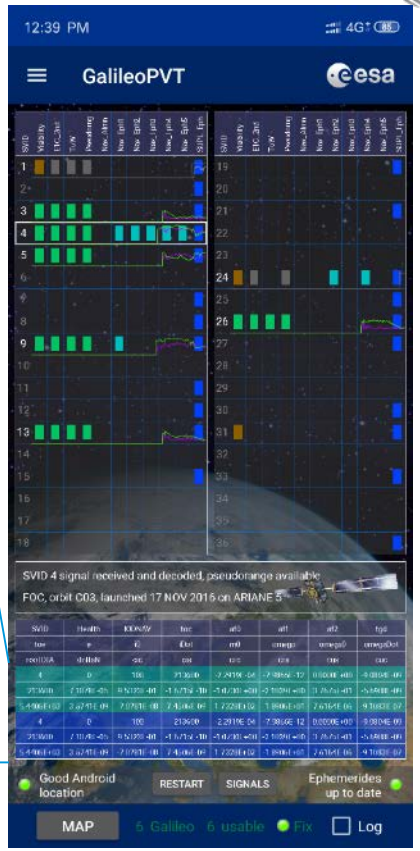
Broadcast real-time corrections for **precise** orbits and clock

SUPL SSL server connection and Navigation Data view of the Galileo PVT app





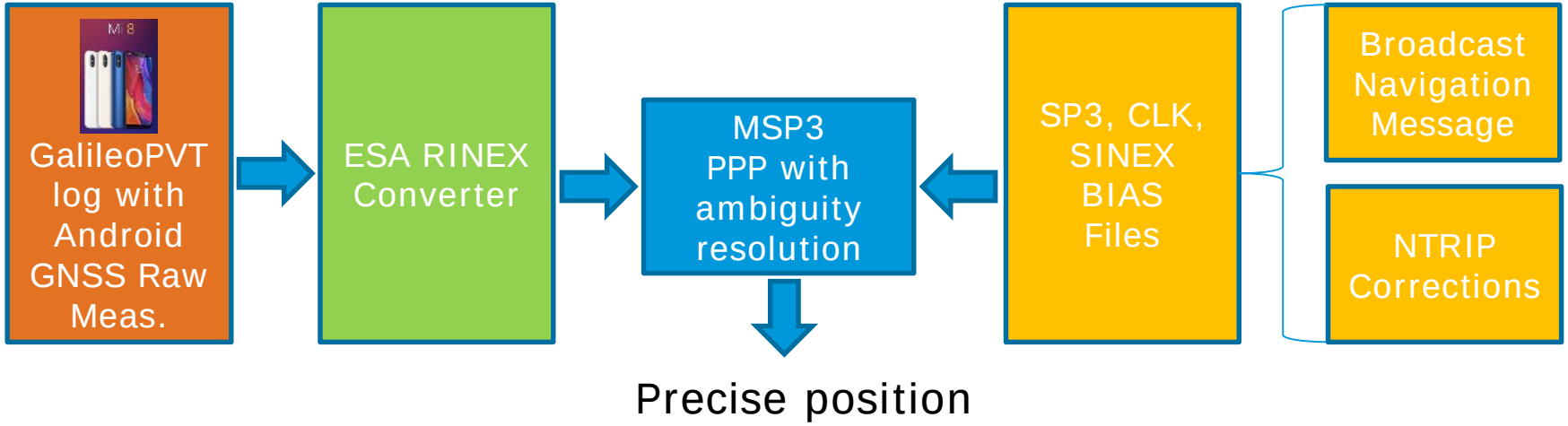
SVID	Health	IODNAV	toc	af0	af1	af2	tgd
toe	e	i0	iDot	m0	omega	omega0	omegaDot
rootOfA	deltaN	cic	cis	crc	crs	cus	cuc
4	0	100	213600	-2.2919E-04	-7.9865E-12	0.0000E+00	-9.0804E-09
213600	7.1078E-05	9.5323E-01	-1.6715E-10	-1.0730E+00	-2.1039E+00	3.7675E-01	-5.6988E-09
5.4406E+03	3.5741E-09	-7.0781E-08	7.4506E-09	1.7328E+02	-1.8906E+01	7.6164E-06	-9.1083E-07
4	0	100	213600	-2.2919E-04	-7.9865E-12	0.0000E+00	-9.0804E-09
213600	7.1078E-05	9.5323E-01	-1.6715E-10	-1.0730E+00	-2.1039E+00	3.7675E-01	-5.6988E-09
5.4406E+03	3.5741E-09	-7.0781E-08	7.4506E-09	1.7328E+02	-1.8906E+01	7.6164E-06	-9.1083E-07



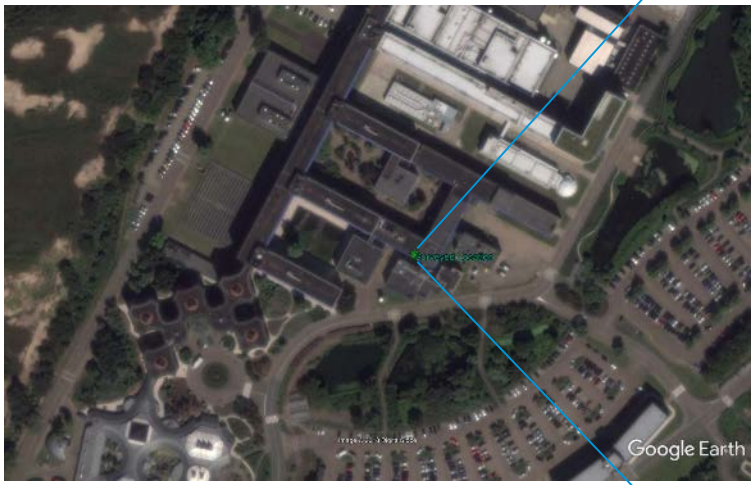
Matlab Toolbox

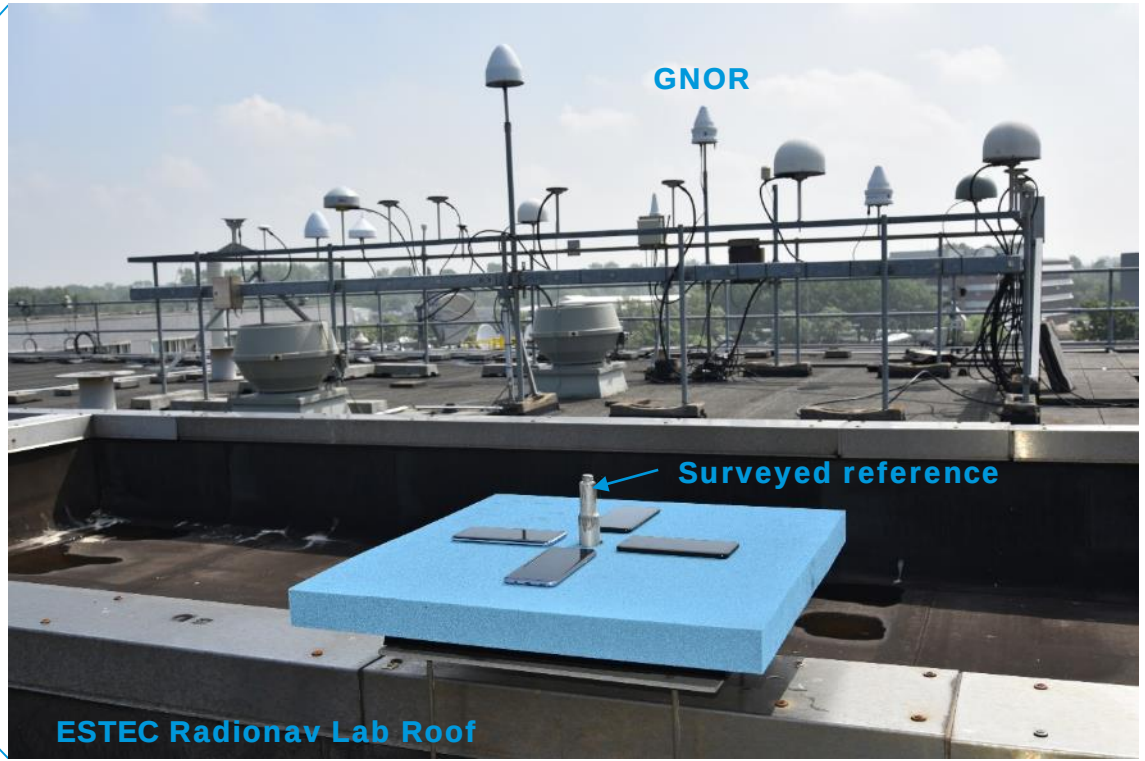
- **Common Log File** for:
  - Raw measurements (GNSSLogger format)
  - GPS and Galileo Ephemerids (from SUPL & live broadcast)
  - Ionospheric model parameters
  - INS measurements (acceleration + gyro) log at 10 Hz
  - Common time scale between INS and GNSS meas
- **Post-processing tool** for fast prototype of new GNSS algorithms
- **Loosely Coupled EKF with GNSS + INS**
- **Converter from Raw measurements to RINEX** (raw measurements screening, pseudo-range ms ambiguity resolution, multi-frequency, half/quarter cycle phase bias resolution)

Offline real-time PPP processing



Static test setup





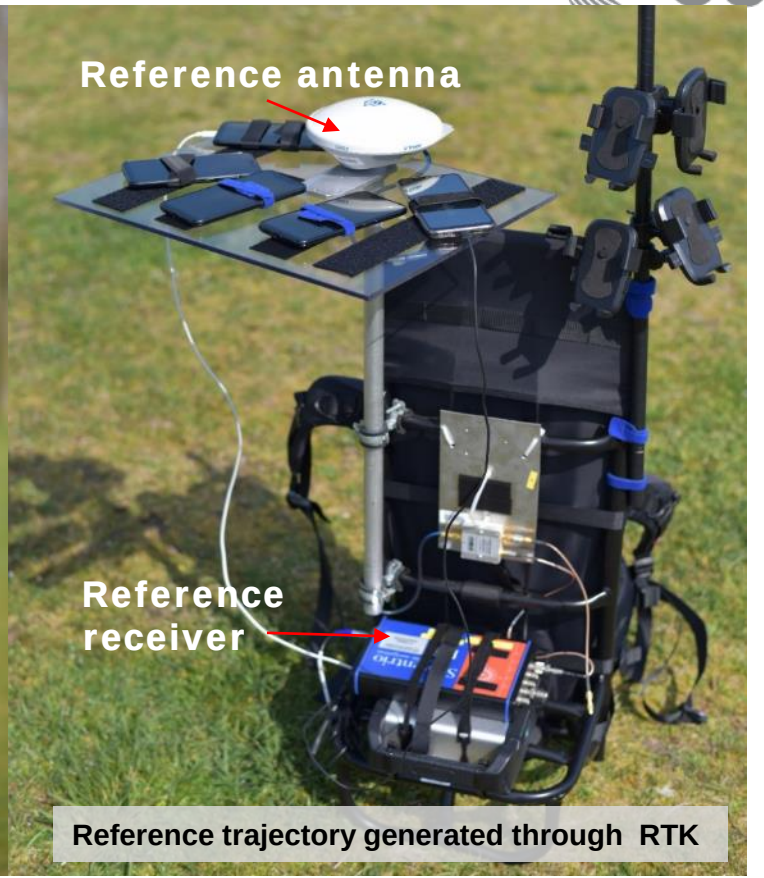
It can accommodate smartphones or chip evaluation kits + external antenna. Network connectivity is provided through WiFi hotspot or 4G

Pedestrian test setup

It can accommodate smartphones or chip evaluation kits + external antenna.

Network connectivity is provided through WiFi hotspot or 4G.

Single scenario duration limited to < 2e3 sec



Reference trajectory generated through RTK

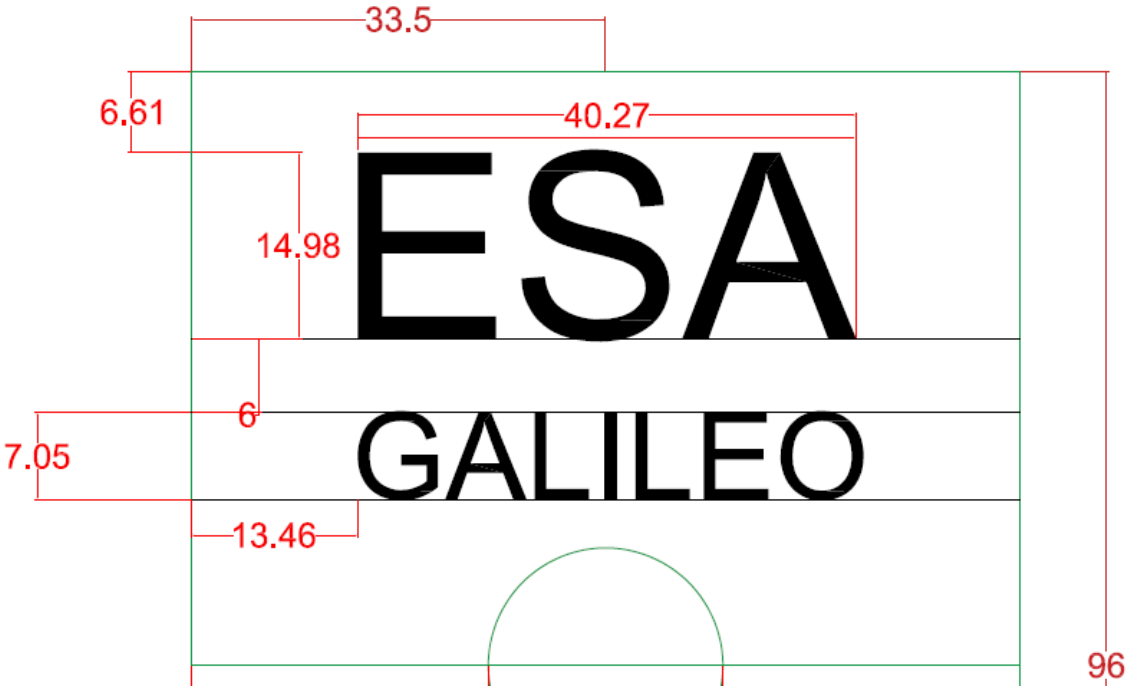
Vehicular test setup

→ Reference trajectory generated through RTK
→ SPAN® GNSS Inertial Navigation System

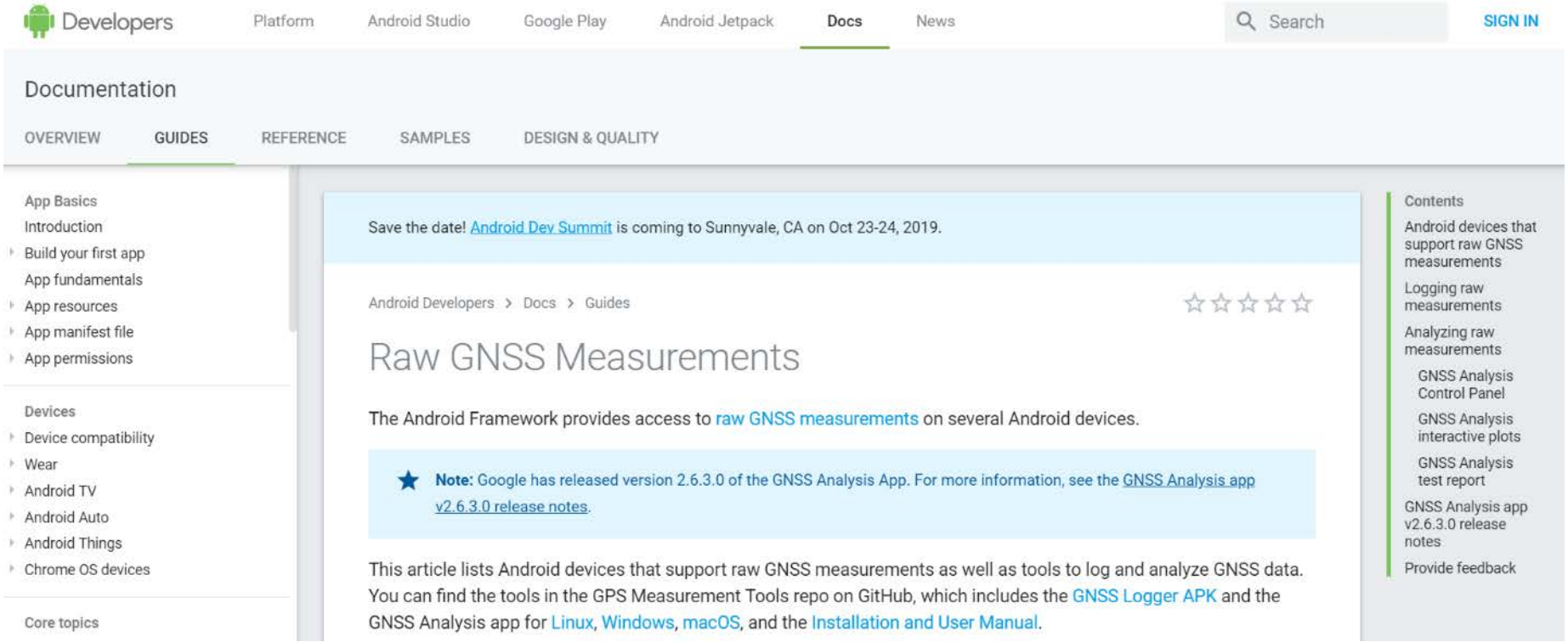
It can accommodate smartphones or chip evaluation kits + external antenna. Network connectivity is provided through WiFi hotspot or 4G. Scenario duration limited to < 12e3 s

Accuracy context during the pedestrian test…

- Write the two words ESA and Galileo on the football pitch
- **Level 1**: **ESA** with a font height of **15 m**
- **Level 2**: **GALILEO** with a font height of **7 m**



GNSS Analysis App @ g.co/gnsstools



GPS+Galileo, Raw PR and Carrier Smoothed PR

From GNSS Analysis App

GPS+Galileo, L1/E1+L5/E5a and L1 only

From GNSS Analysis App

GNSS is better with E5

PR smooth GPS+GAL L1/L5

E5a/L5 measurements boost PVT performances!

PR smooth GPS+GAL L1 only

From GNSS Analysis App

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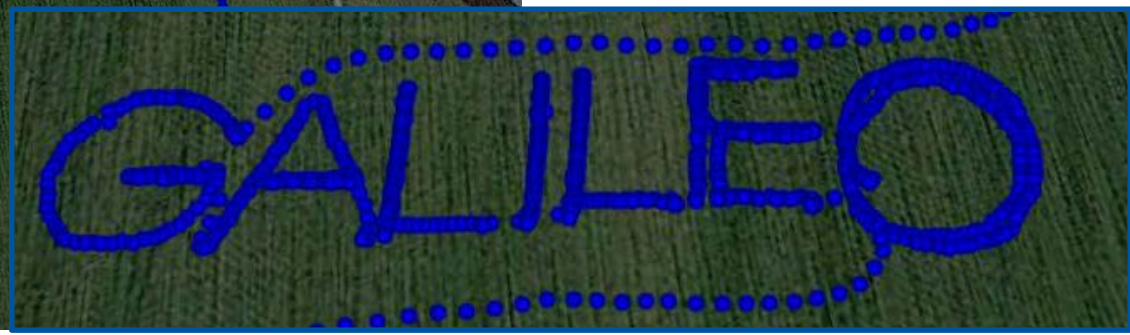
Results with MSP3 + GalileoPVT logs



MSP3 single vs dual frequency

GPS+GAL L1/L5

GPS+GAL L1 only

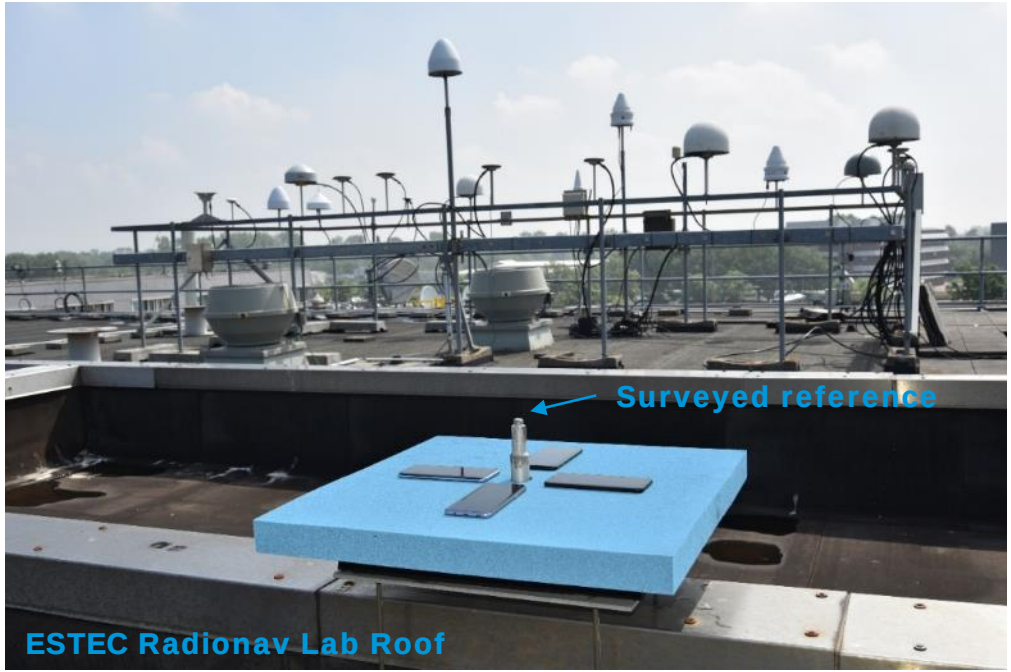
PPP with single and dual frequency measurements

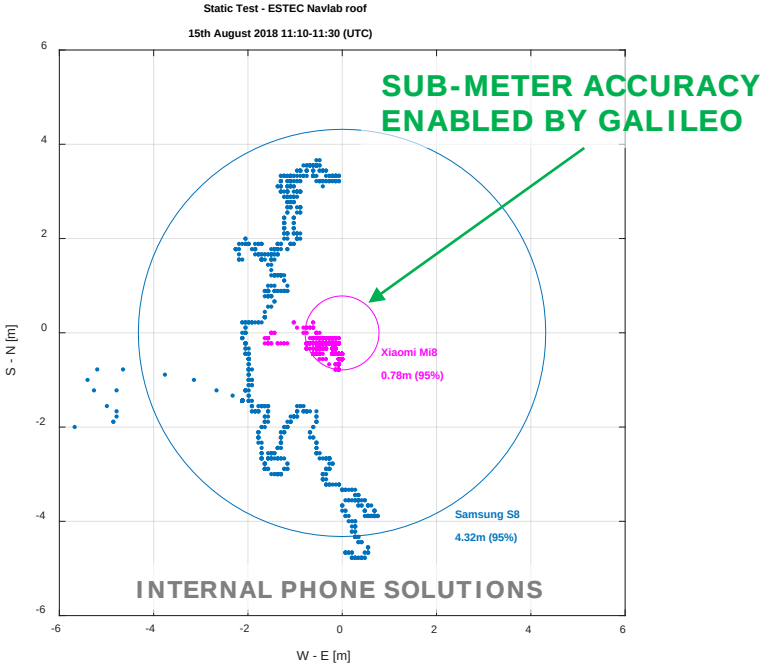
Horizontal Error [m]	MSP3 GAL+GPS E1/L1	MSP3 GAL+GPS E1/E5a+ L1/L5
Std. dev	1.82 m	0.89 m
50 %	3.01 m	1.80 m
68 %	3.78 m	2.44 m
95 %	6.19 m	3.85 m

E5a/L5 measurements boost PPP performance!

Availability 98.6%

Testing internal phone solutions - static





Multi-GNSS solution

5 GPS DF + 8 Galileo DF in view during this test

What's in the near future?

- **New chips** (Broadcom, Qualcomm, uBlox, Allystar,…) and smartphones with dual frequency GNSS (Xiaomi, Samsung, Lenovo, Huawei)
- **Convergence between professional and mass-market devices**
- Better **antennas**?
- Support to new constellations: **BDS-3**, **IRNSS supporting L5/E5a**
- **Android apps with PPP** (Gadip3, Galileo PVT, …)

Give
mE5
GALILEO