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# GNSS research and future trends

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# GNSS research

GNSS research influenced by 3 major factors:

- Changing trends in users' behavior and expectations
- Evolution of GNSS infrastructure, such as the appearance of new signals and frequencies
- Evolution of underlying technologies, largely driven by the IT & Communications industries

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# Changing trends in users' behavior and expectations

- Users needs and expects better accuracy and integrity in any (unfavorable) conditions
- They want it even with the low cost receivers
- Improved robustness is needed
- Any application: navigating, driving, sailing, parking, landing, etc.

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# Evolution of GNSS infrastructure

With the modernisation plans of GPS and GLONASS on one hand, and the deployment of Galileo and the Chinese BeiDou on the other, **users will soon have access to a wealth of open signals broadcasted on multiple frequencies**



| Signal status | Number of satellites (X) |
|---|---|
| | No service |
| | Initial services |
| | Full services |

| SYSTEM | PROVIDER | SIGNAL | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|
| GPS | | L1 | FOC (30) | | | | | |
| | | L1 C | | | (0-30) | | | |
| | | L2 | FOC (30) | | | | | |
| | | L2 C | IOC (19-30) | | | | | FOC (30) |
| | | L5 | (12-30) | | | | | |
| GALILEO | | E1 | IS (12-26) | | | ES (26-30) | | FOC (30) |
| | | E5 | IS (12-26) | | | ES (26-30) | | FOC (30) |
| | | E6 | IS (12-26) | | | ES (26-30) | | FOC (30) |
| GLONASS | | L1 FDMA | FOC (24) | | | | | |
| | | L1 CDMA | | | | | (0-24) | |
| | | L2 FDMA | FOC (24) | | | | | |
| | | L2 CDMA | | | | | (0-24) | |
| | | L3 CDMA | | | | | (0-24) | |
| | | L5 CDMA | | | | | (0-24) | |
| BEIDOU | | B1 | (12-35) | | | | | FOC (35) |
| | | B2 | (12-35) | | | | | FOC (35) |
| | | B3 | (12-35) | | | | | FOC (35) |

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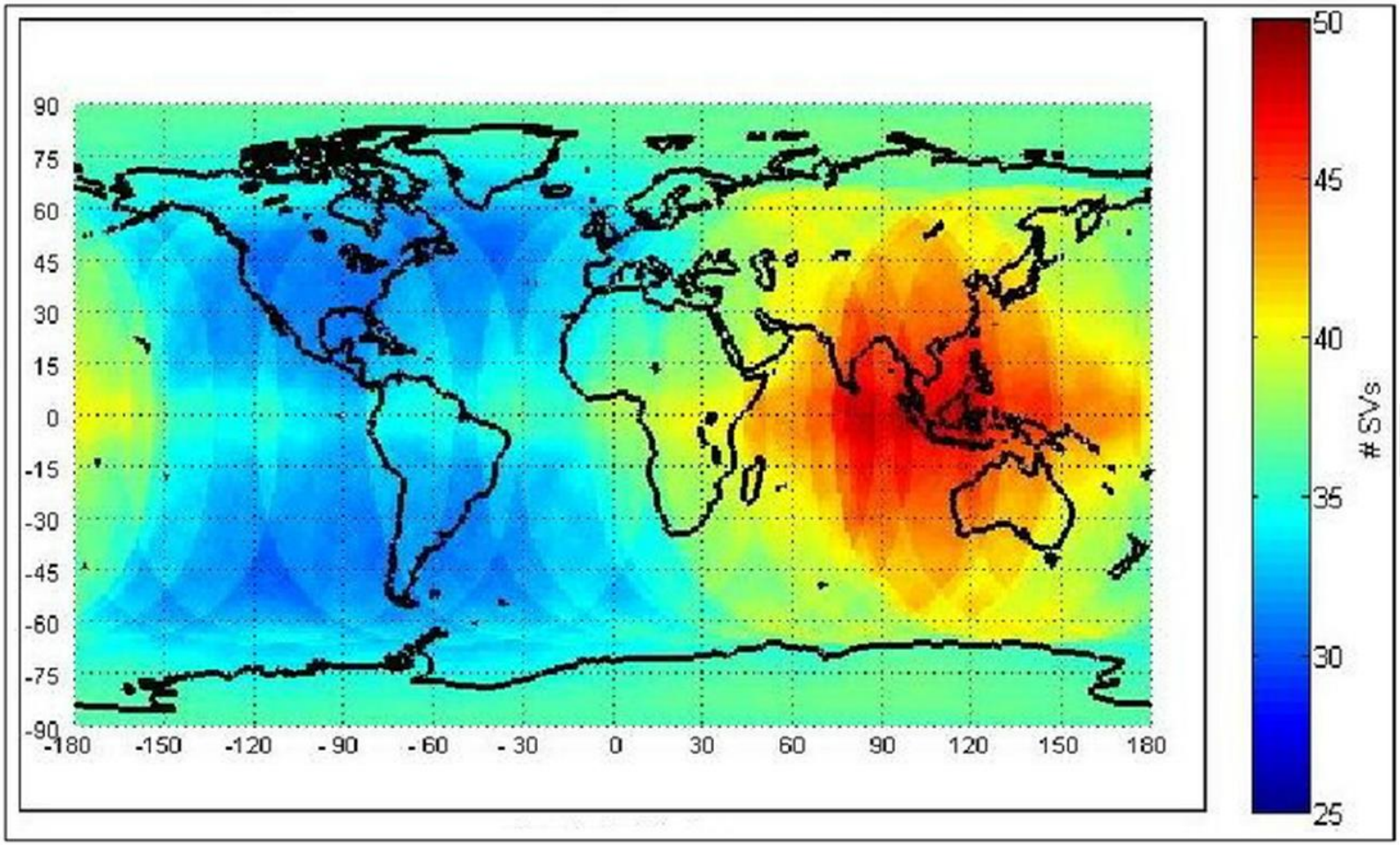
# Evolution of GNSS infrastructure 2

- GNSS 2020



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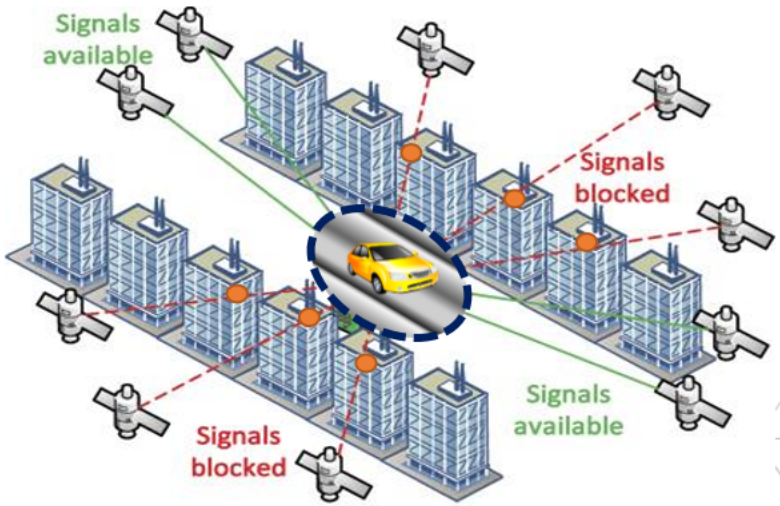
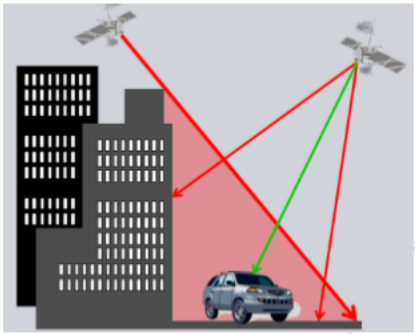
# Evolution of GNSS infrastructure 3

- ✓ *Multi-constellation*: When buildings block the signal and reduce the number of visible satellites, the availability of more constellations ensures a **much more accurate final position**

- ✓ *Multi-frequency* increases **robustness of the position against mass market jammers** because the interfering signal has a narrow bandwidth and the receiver can still calculate a correct position with the other GNSS signals.

- ✓ *Multipath:* the strength of Galileo signal, together with an **advanced code modulations**, makes Galileo better mitigating multipath effects



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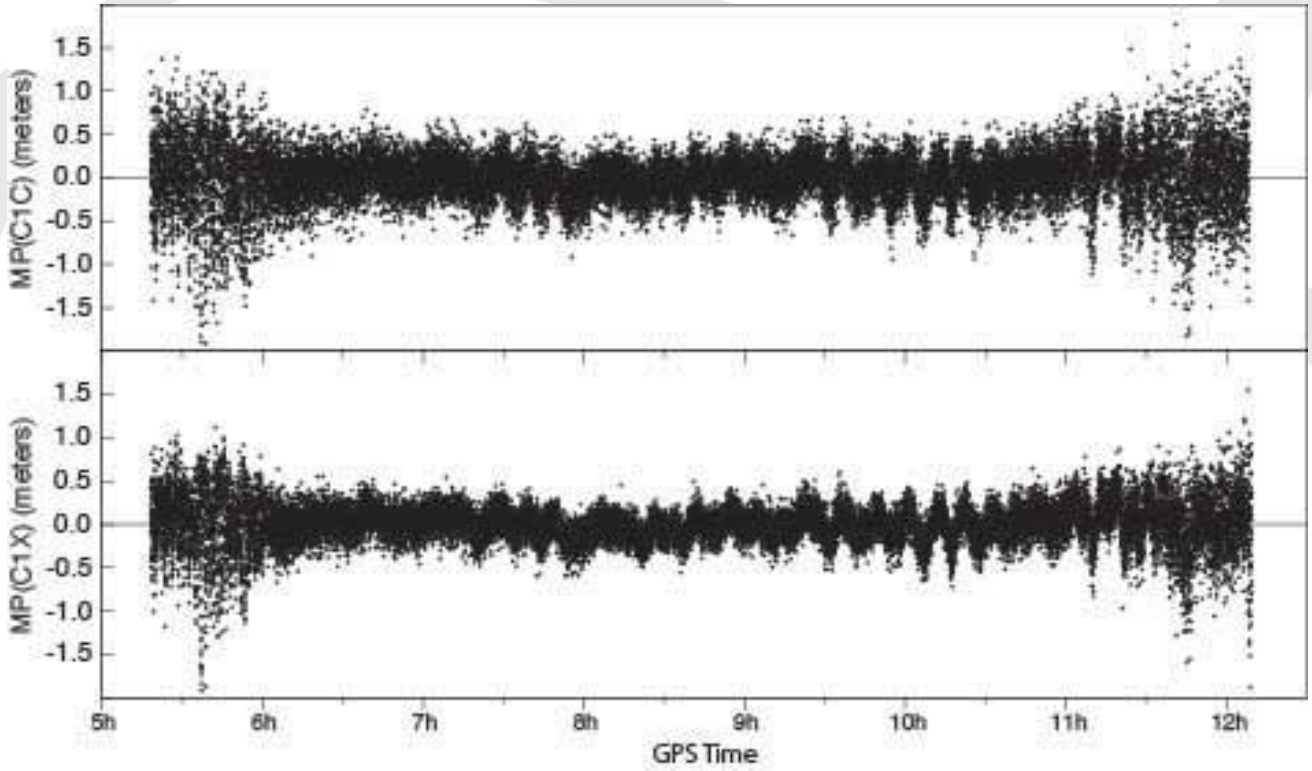
# New signals

- New GPS L1C




- Multipath linear combination (L1 pseudorange and L1 and L2 carrier phase) of the SVN74 L1 C/A-code (top) and L1C signal (bottom) from 1-Hz data of February 3, 2019, tracked with a Javad TRE-G3TH.

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# Classical research trends using multisystem multifrequency signals

- More accurate and reliable precise positioning
- More accurate atmospheric modelling (Zenith Total Delay, Precipitable Water, Slant Total Delay Gradients, Water Vapour Tomography, etc.
- More precise station velocities (tectonic movements, postglacial rebound, etc.)
- More accurate precise orbits (retroreflectors on satellites)

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# So future is bright?

- Is all infrastructure compatible with multisystem GNSS and new signals?
- Will GNSS units (low grade or survey grade) will be able to provide desired accuracy and robustness under any conditions?

**On July 11, 2019; A Notice Advisory for Galileo Users (NAGU) is issued, advising users that Galileo service is degraded on all satellites until further notice.**

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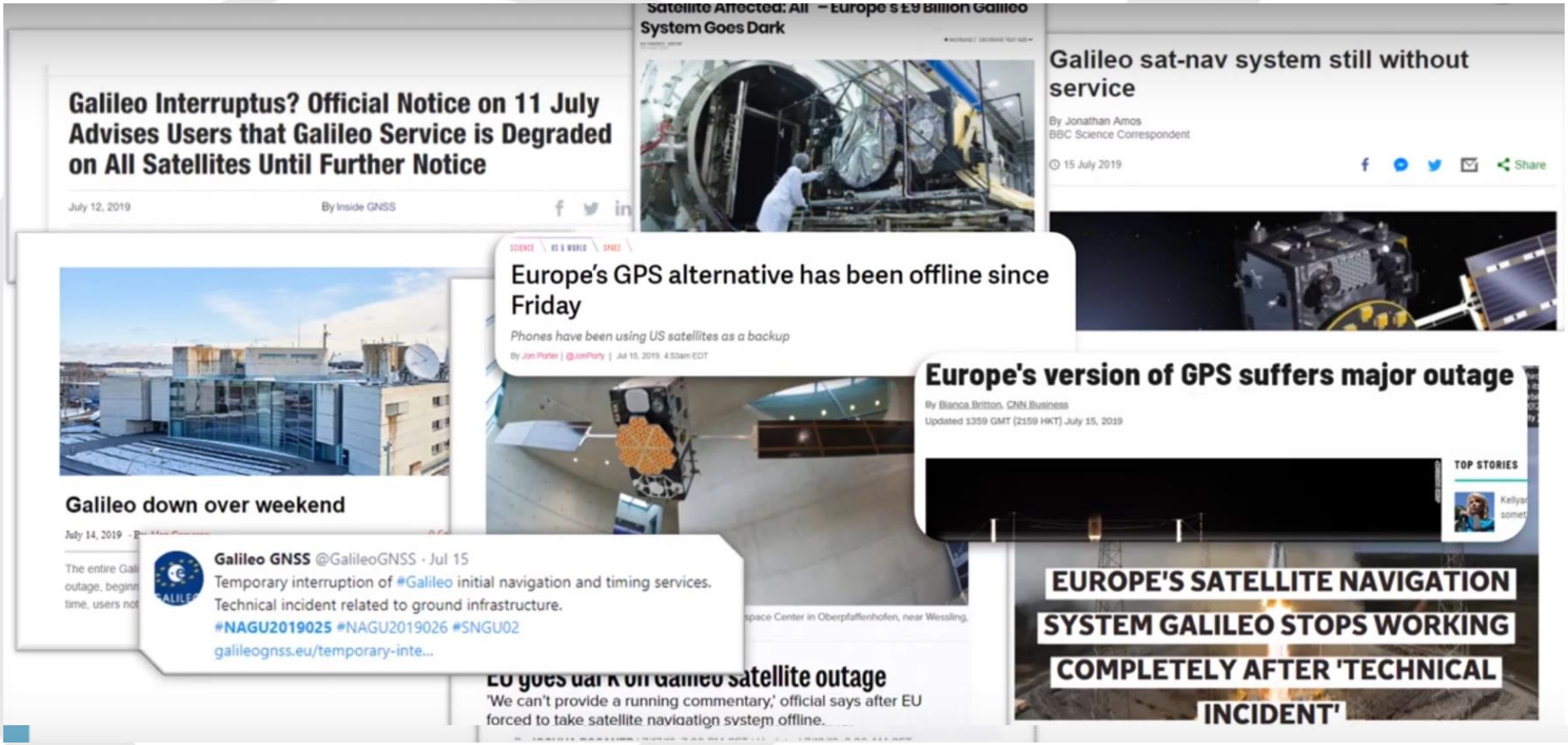
# Galileo incident

It breaks the news next day



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# Galileo incident

Navigation data for all satelites was not updated.

SIS status indicators creates confusion, since only 6 satellites report marginal SIS, while other 16 satellites report healthy SIS

Users around the world start to report **no Galileo satellites** on their screens and Galileo navigation **service unavailability**.

Indeed, this has been expected as most of the devices would detect that the navigation data have expired. With ephemeris data aging, any positioning estimation attempt is futile.

Here is what the Galileo OS SDD states:

The navigation solution is expected to meet the Minimum Performance Levels only if receivers do not use navigation parameters beyond their broadcast period.

The maximum nominal broadcast period of a healthy navigation message data set is currently 4 hours ?.

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# Galileo incident

Do the receivers work?

It was noticed, that some receivers actually try to use Galileo for positioning. The reason for this behavior was that the guidelines specified in the Galileo OS SDD were not strictly followed when determining the usability status of signals. (SISA flag)

Luckily many of the recivers have advanced algorithms for fault detection and consistency testing based on redundant observations(e.g. RAIM algorihms)

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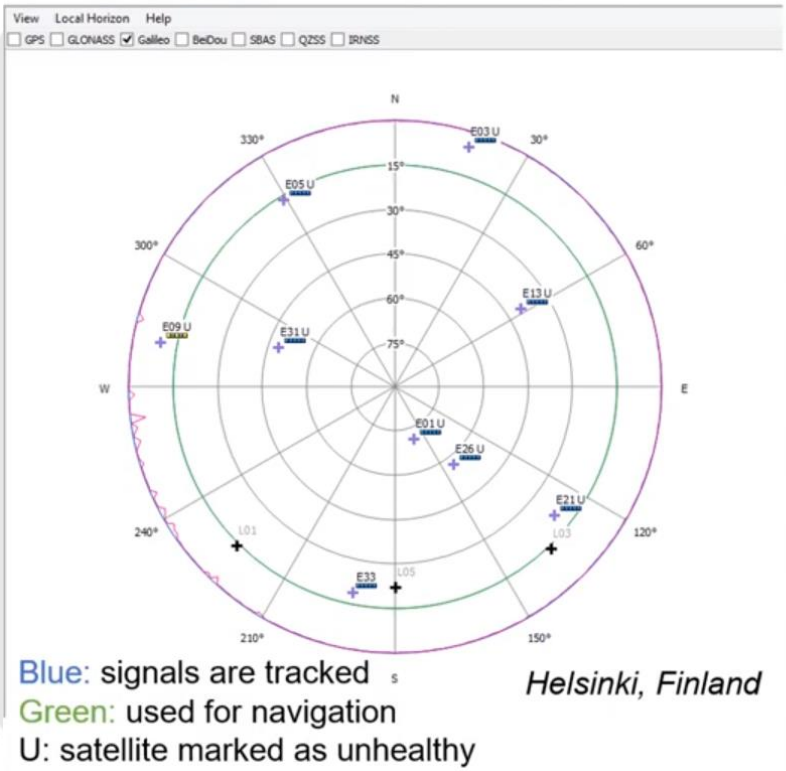
# Galileo incident

- Two geodetic grade receivers:

Galileo satellites are **tracked but not used** in the PVT solution




Blue: signals are tracked
Green: used for navigation
U: satellite marked as unhealthy

*Helsinki, Finland*

Galileo satellites are **tracked and used** in the PVT solution!

**Satellites Used:36**

GPS(12): 1, 2, 3, 6, 7, 9, 11, 17, 19, 22, 28, 30
GLONASS(8): 6, 7, 9, 10, 11, 20, 21, 22
Galileo(11): 2, 3, 7, 8, 13, 15, 18, 21, 26, 27, 30
QZSS(3): 193, 194, 195
SBAS(2): 127, 128

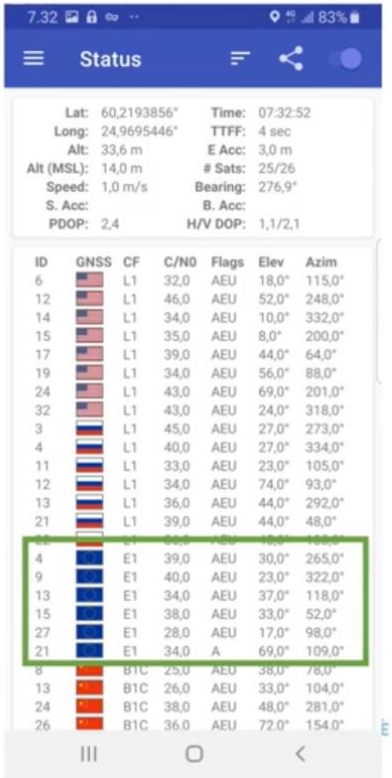
**Satellites Tracked:42**

GPS (13): 1, 2, 3, 6, 7, 9, 11, 13, 17, 19, 22, 28, 30
GLONASS (8): 6, 7, 9, 10, 11, 20, 21, 22
Galileo (11): 2, 3, 7, 8, 13, 15, 18, 21, 26, 27, 30
SBAS (6): 123, 127, 128, 129, 137, 140
QZSS (4): 193, 194, 195, 199

2019-07-17T03:48:09Z (UTC)

*Bangkok, Thailand*

Mobile phone uses Galileo too!



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# Galileo incident

- Lesons learned:

Galileo incident serves as a good example for some device manufacturers and application developers **to review how they comply with the Galileo SDD guidelines**.

In addition, the current event shows that operating a **resilient** satellite navigation system is an extremely challenging task.

Furthermore, the other global satellite navigation systems have had their **own challenges** in the recent years. US GPS encountered issues last time in January 2016, whereas Russian GLONASS faced difficulties in April 2014.

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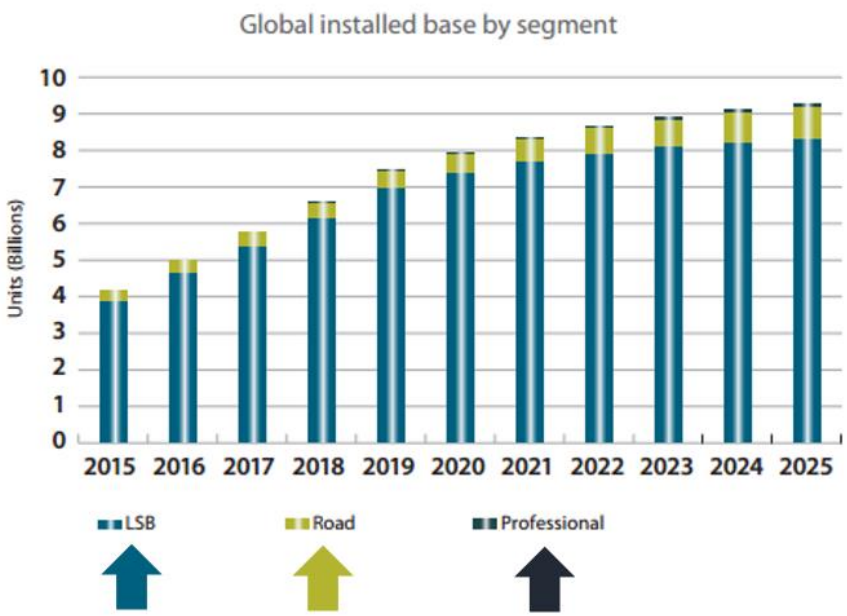
# GNSS will reach 8bln devices in 2020, meaning more opportunities




*Smartphones account for almost 80% of the global installed base of GNSS devices, being the most popular platform to support mobile "LBS"*

*Thanks to In-Vehicle System and eCall markets the number of devices used for "Road" applications is set to grow substantially, with a CAGR of 11.4%*

*Fostered by a maturing regulatory environment, drones market is set to account for over 70% of the installed base of "Professional" segments in 2025*

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# Multi frequency in smartphones

What it gives to a smart phone user?

- Improved accuracy
- Access to RTK and PPP techniques
- Improved robustness

In 2018 first dual frequency mobile phone (Xiaomi Mi8 with Broadcom GNSS chip) hit the market. You can record raw GNSS data, which allows user to create RINEX file (dual frequency including phase measurements)

Other brands starting offer similar options. Competitors promising triple frequency chips in near future

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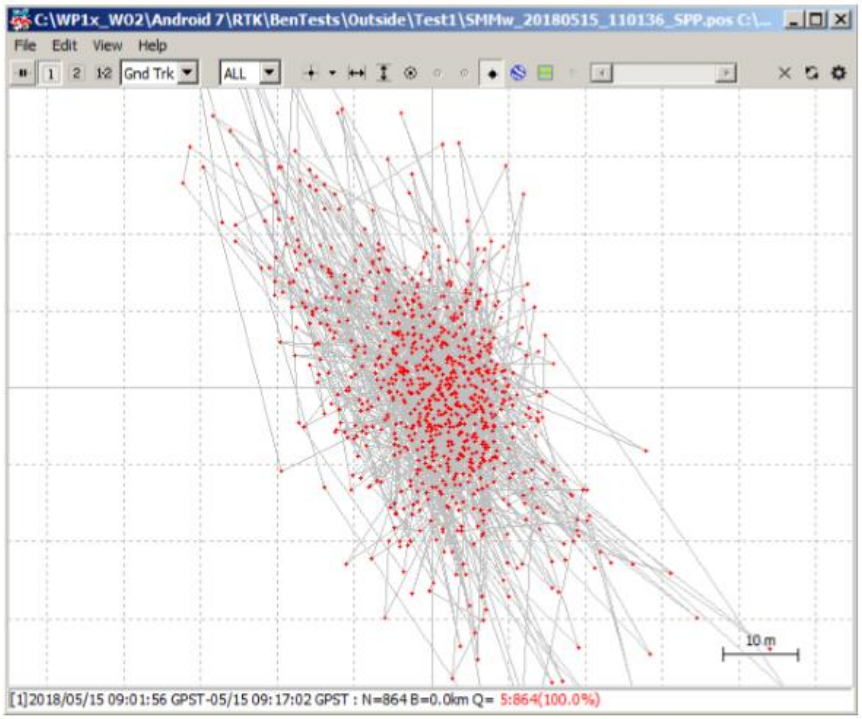
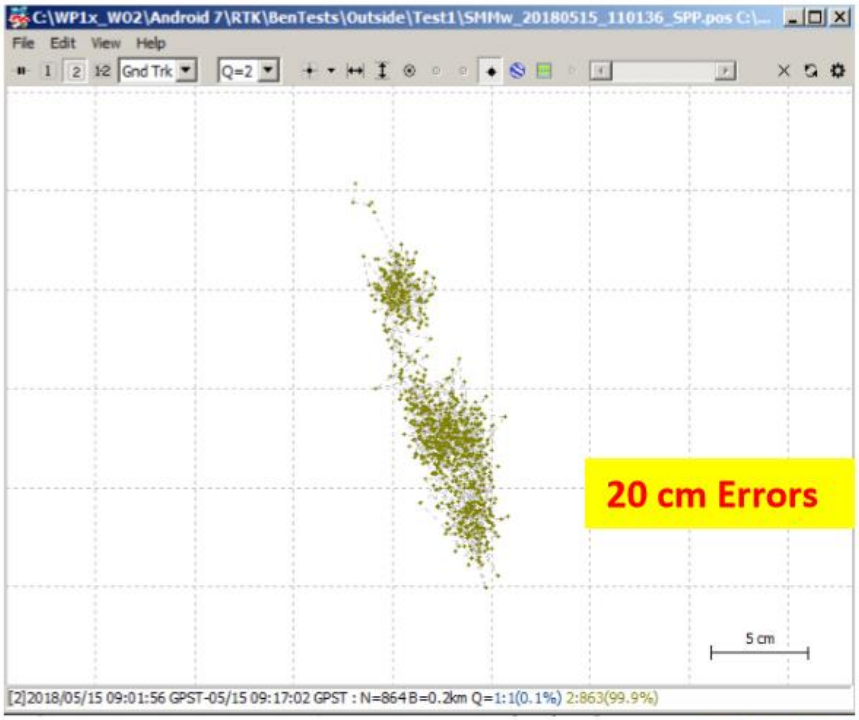
# Multi frequency in smartphones

**Single Point Positioning**




**RTK**



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# Future trends

- GNSS-sensor fusion

GNSS-INS, GNSS-5G, etc.

- Septentrio and CORE partner up to develop a GPS/GNSS receiver which will make use of Japan's Centimeter-Level Augmentation Service (CLAS). CLAS corrections are broadcast directly via QZSS constellation to enable high-accuracy positioning across Japan. This trend might appear in other augmentation systems (EGNOS, WAAS)

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# Future trends

- Big Data GNSS

(GNSS location data can be used in a myriad of ways to benefit the citizenry, including tracking someone, crowdsourced applications or vehicular traffic management via navigation apps)

- Cybersecurity and hacking

(GNSS receivers work on embedded operating systems such as VxWorks or Linux, and many support standard protocols such as TCP/IP and USB.This means that apart from jamming and spoofing through the RF channels, these systems are vulnerable to cyber attacks like manipulation of the application layer as well.)

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- Thank you!