Location, location, location –

Future trends in satellite positioning and radio navigation

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Agenda

- Introduction
- Next generation GNSS
  - Multi-GNSS
  - European GNSS benefits
  - GNSS enabler in key trends
- Different positioning technologies and accuracies
- The future for reliable navigation and mobility

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Definitions of navigation and positioning

- Positioning:

Determining the position of a target in a certain reference frame

- Navigation:

The method, process or activity of determining position, course, and distance traveled and following a route

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Introduction (1) - opportunities

- The full precision of the U.S. GPS (Global Positioning System) was made public only 15 years ago
- As recently as the early 2000s, GPS was considered a tool for sailors, hikers and other “outdoor enthusiasts“
- Today, nearly every mobile app employs it
- The actual global number of GNSS (Global Navigation Satellite System) devices in use is about 3,6 billion units (GNSS Market Report 2015, GSA) and it is predicted to grow to seven billion by 2019 - for an average of one device per person on the planet

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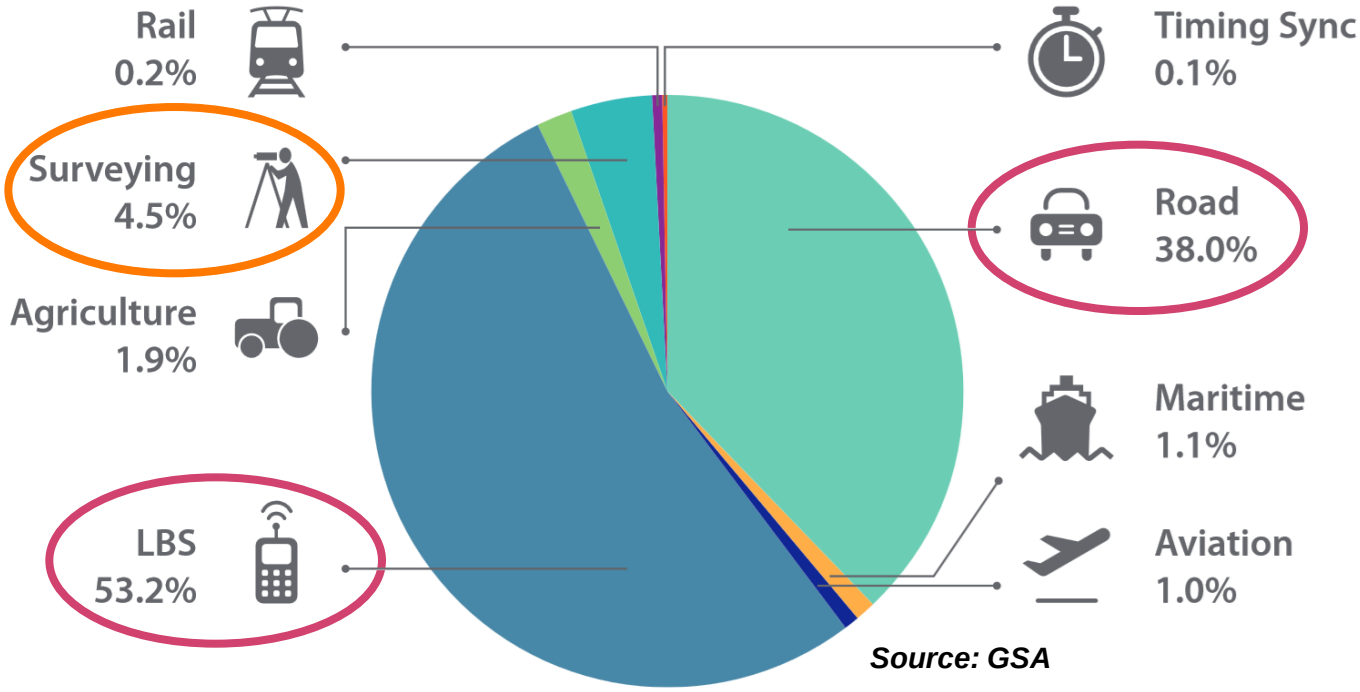
Introduction (2) - opportunities

- Global core GNSS market by segments (cumulated revenues 2013-2023)



- Different market segments have different operation environments and requirements for accuracy and reliability

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Next generation GNSS (1)

- The future European **Galileo**, the Russian **Glonass,** and the **Compass/BeiDou** are similar systems with the U.S. GPS
  - Glonass is however currently a frequency-divided (FDMA) system when GPS, Galileo and BeiDou are code-divided (CDMA)
    - Glonass to be modernized to CDMA
- Also **GPS** is being modernized: civil and military signals on new frequencies (L2 and L5)

GPS
October 2016: 31 SV operational

Galileo
October 2016: 9 SV operational

Glonass
October 2016: 24 SV operational

BeiDou2
20 SV operational in Oct 2016

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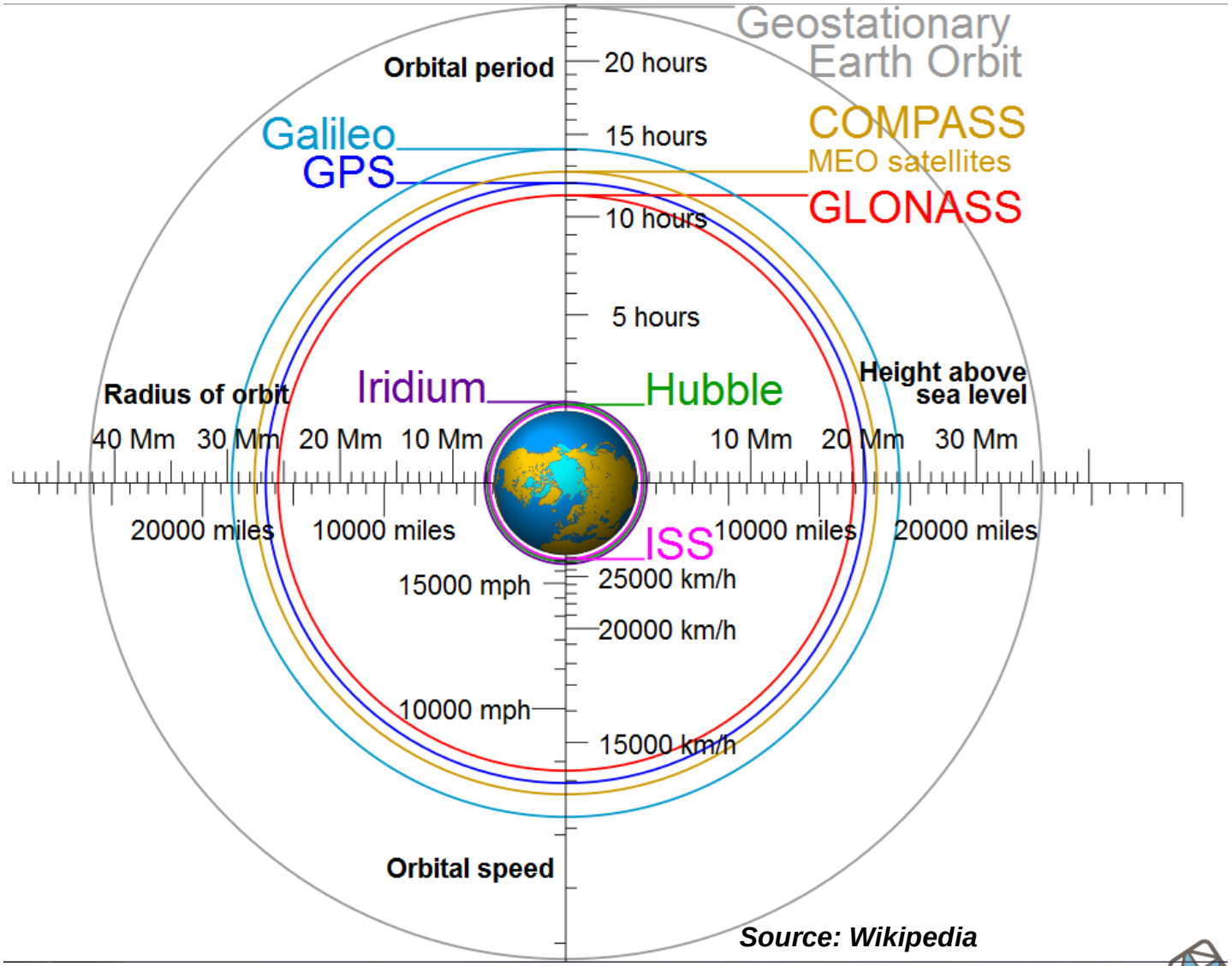
Next generation GNSS (2)



Source: Wikipedia

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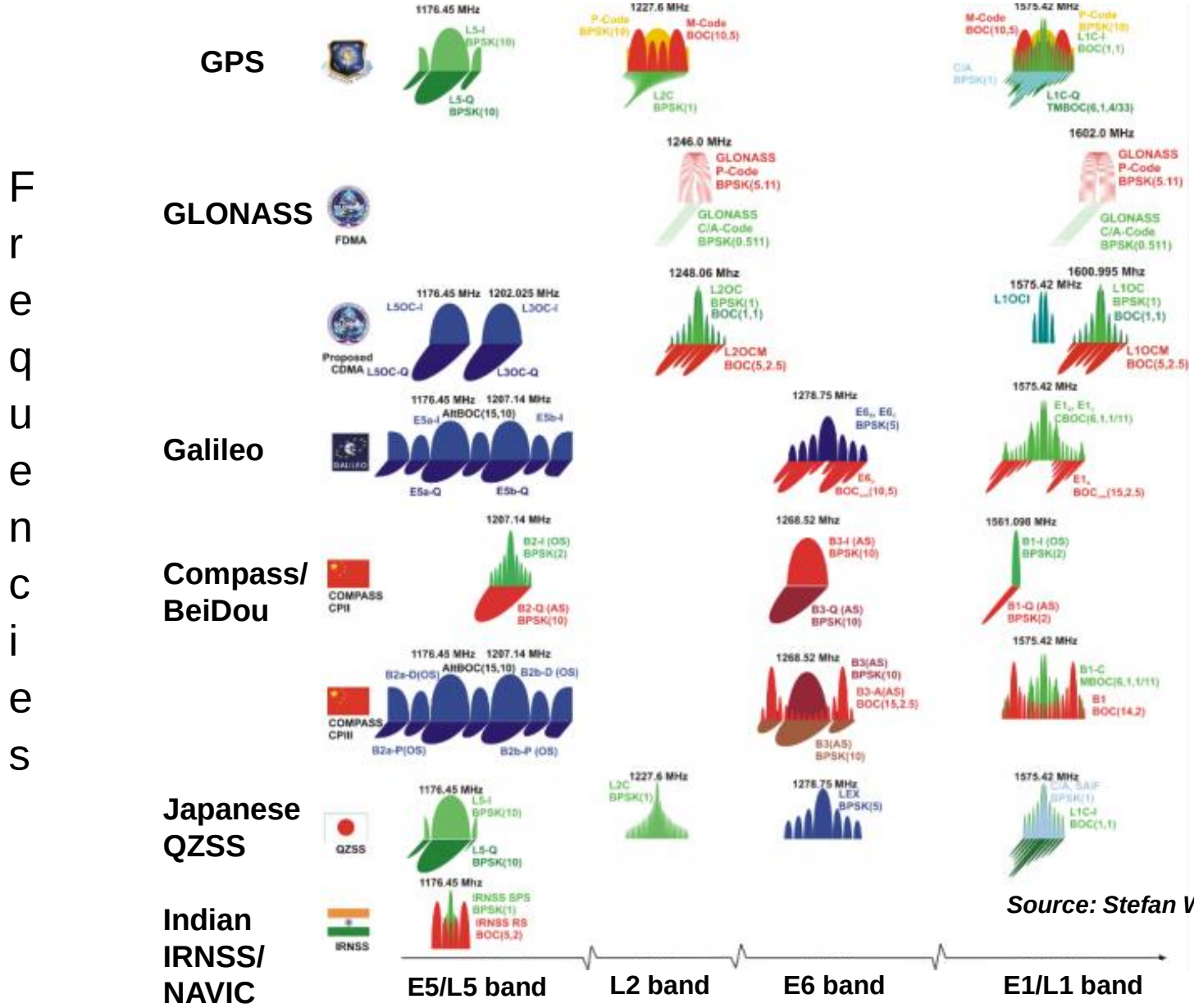
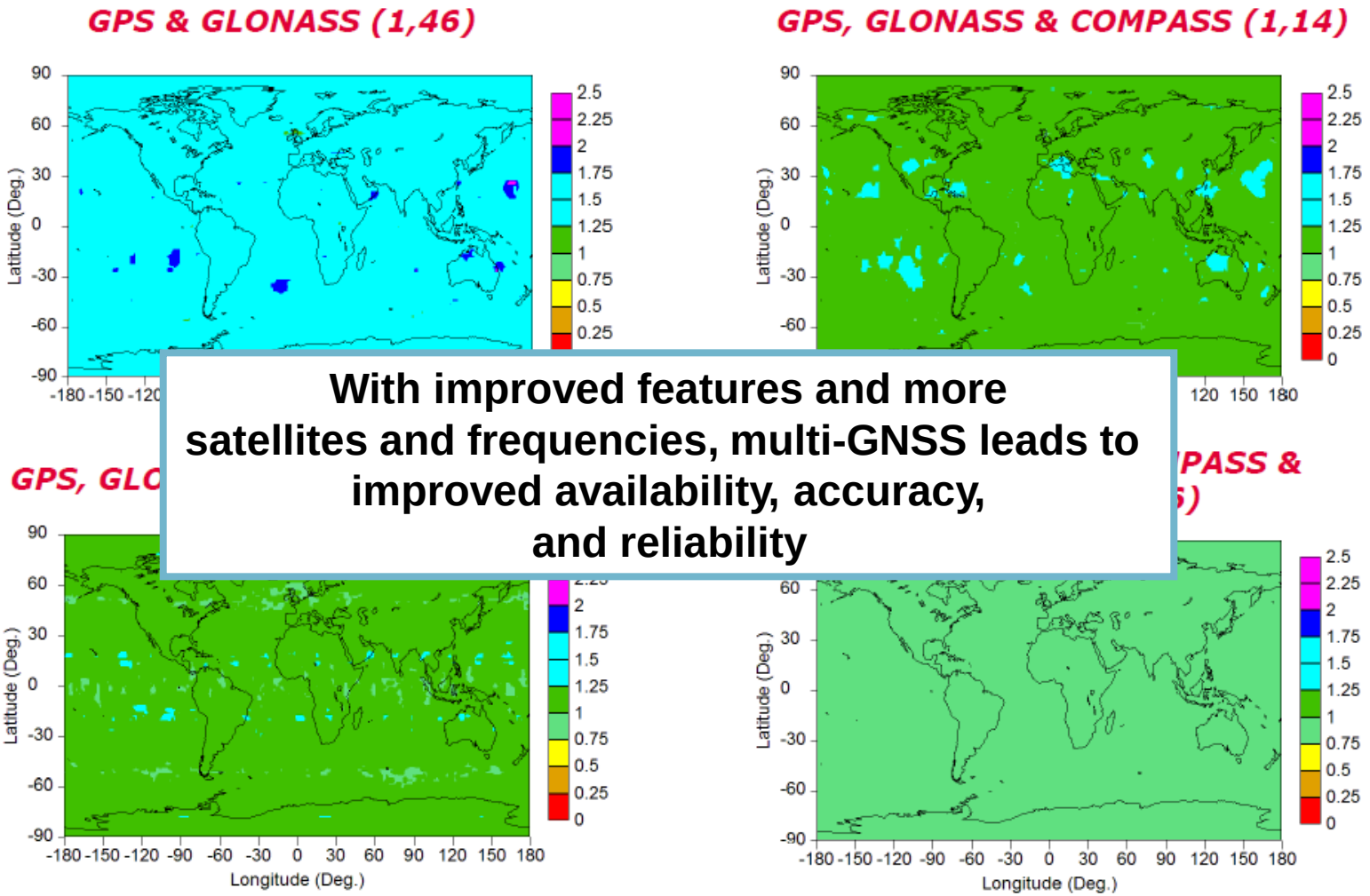
Next generation GNSS (3)



Source: Stefan Wallner

Next generation GNSS (4)

- Position dilution of precision with multi-GNSS, an example:



With improved features and more satellites and frequencies, multi-GNSS leads to improved availability, accuracy, and reliability

Source: Manuel Toledo Lopéz, GMV

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Benefits of the European GNSS - Galileo

- Galileo is the GNSS which will bring positioning and timing autonomy from GPS or GLONASS to Europe
- In addition to its strategic importance, Galileo brings other benefits:
  - **increasing accuracy and reliability**
  - **higher level of signal robustness**
  - **anti-spoofing capabilities with signal authentication**
  - **higher precision with Commercial Service and security with Public Regulated Service**
  - **civilian governance**

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Europe’s own Galileo - services

The Galileo system provides the following services:

1. **Open service (OS)** — Corresponds to current civil GPS
2. **Search and rescue service (S-A-R)** — Contribution of Europe to the international COSPAS-SARSAT
3. **Commercial service (CS)** — Corresponds to current commercial GPS RTK/VRS services etc
4. **Publicly regulated service (PRS)** — Position and timing restricted to government-authorised users

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PRS offers a robust and authenticated location and time

PRS = Galileo’s Public Regulated Service

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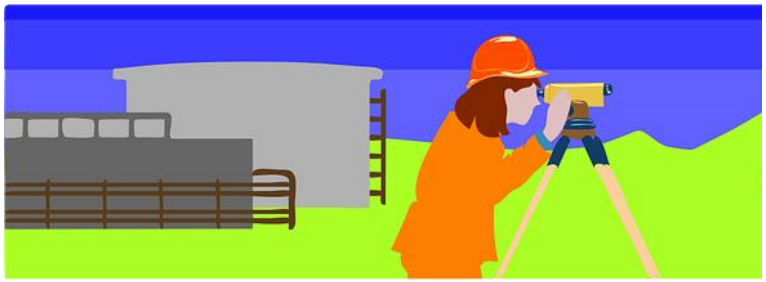
PRS applications

- PRS is meant for publicly authorized users only
  - **PRS is provided to authorities and safety-critical actors**
- The PRS service is strongly secured and encrypted - designed for applications that require special continuity in their operation
  - PRS usage is restricted to authorized users via encryption key arrangements

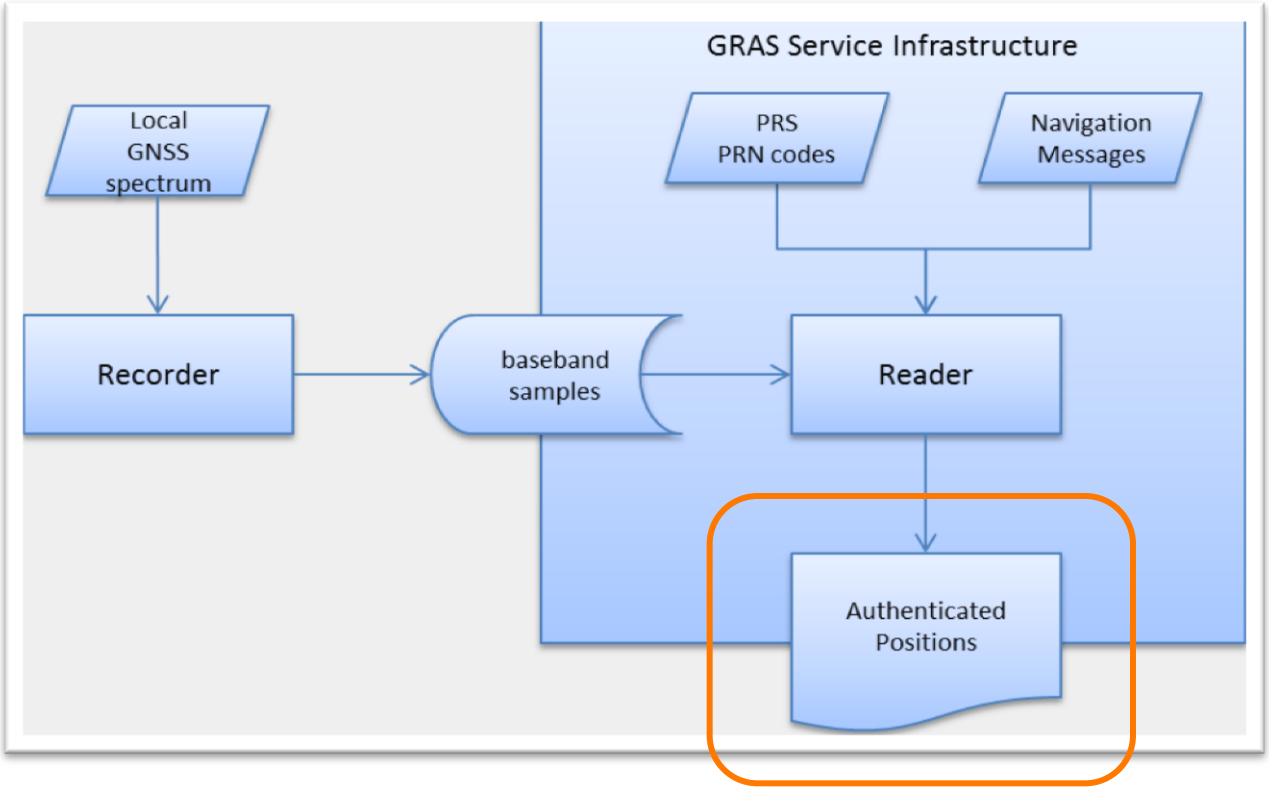
Galileo PRS for land surveying?



PRS = Galileo's Public Regulated Service

Authenticated geospatial information via PRS

PRS authentication in post-processing?



FGI's vision for a wider utilization of the PRS

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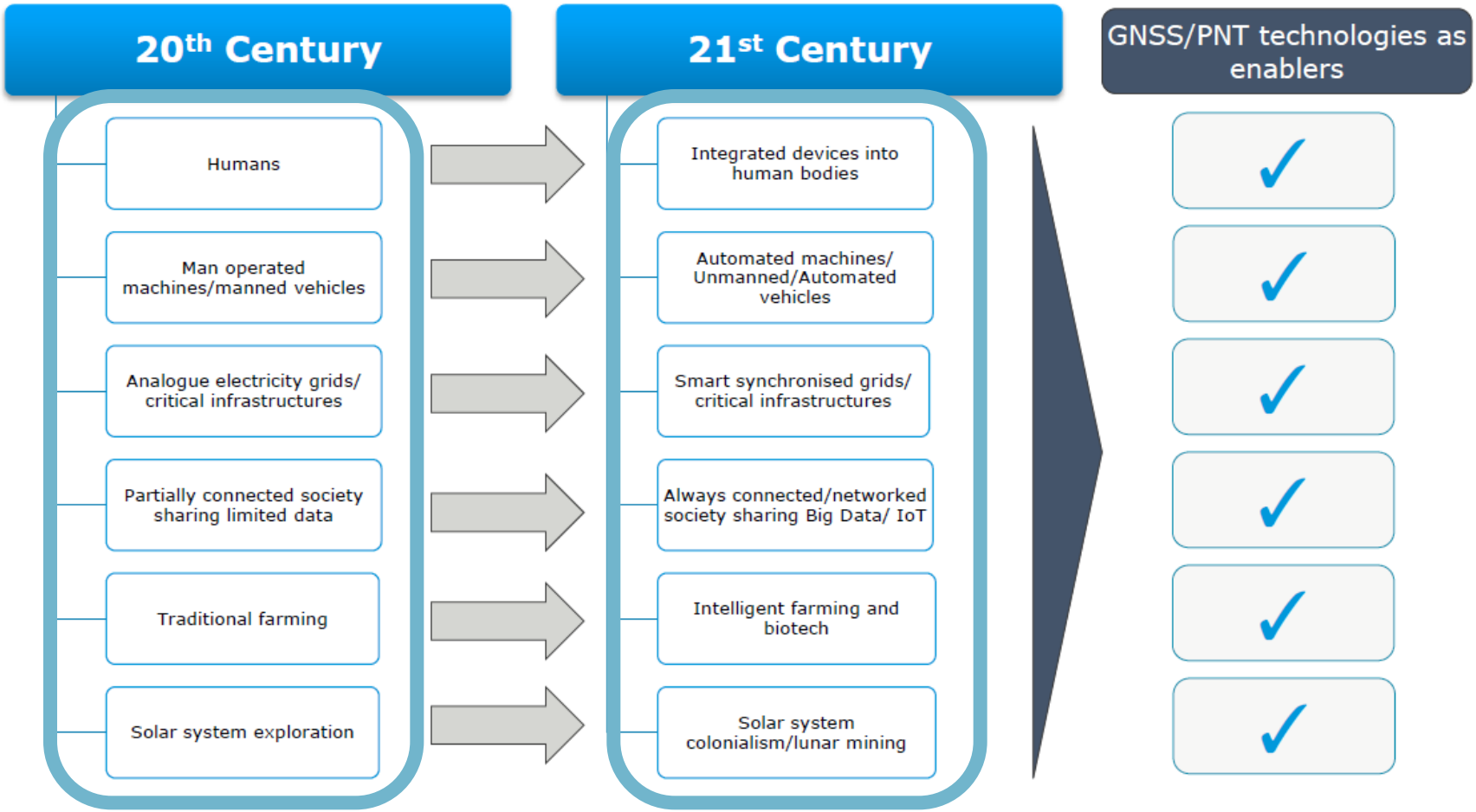
Source: ESA

In this ever changing world, GNSS and/or other PNT technologies will play an instrumental role on several key trends



GNSS = Global Navigation Satellite Systems
PNT = Position, Location, Time

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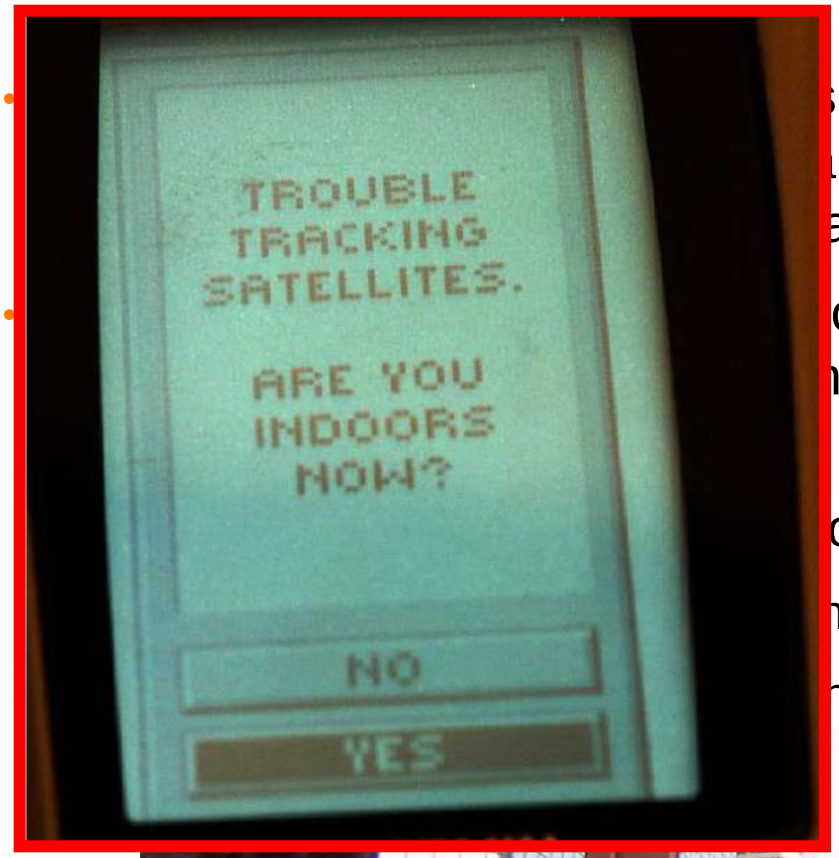
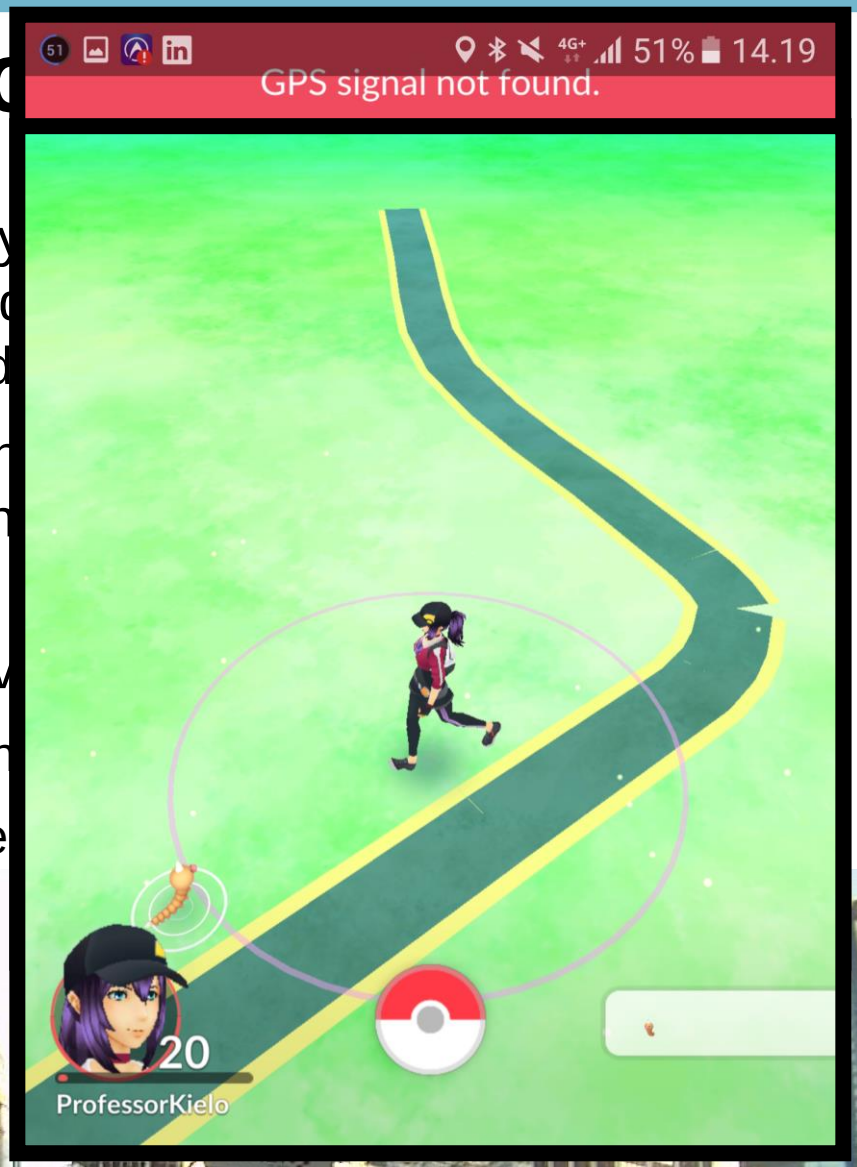
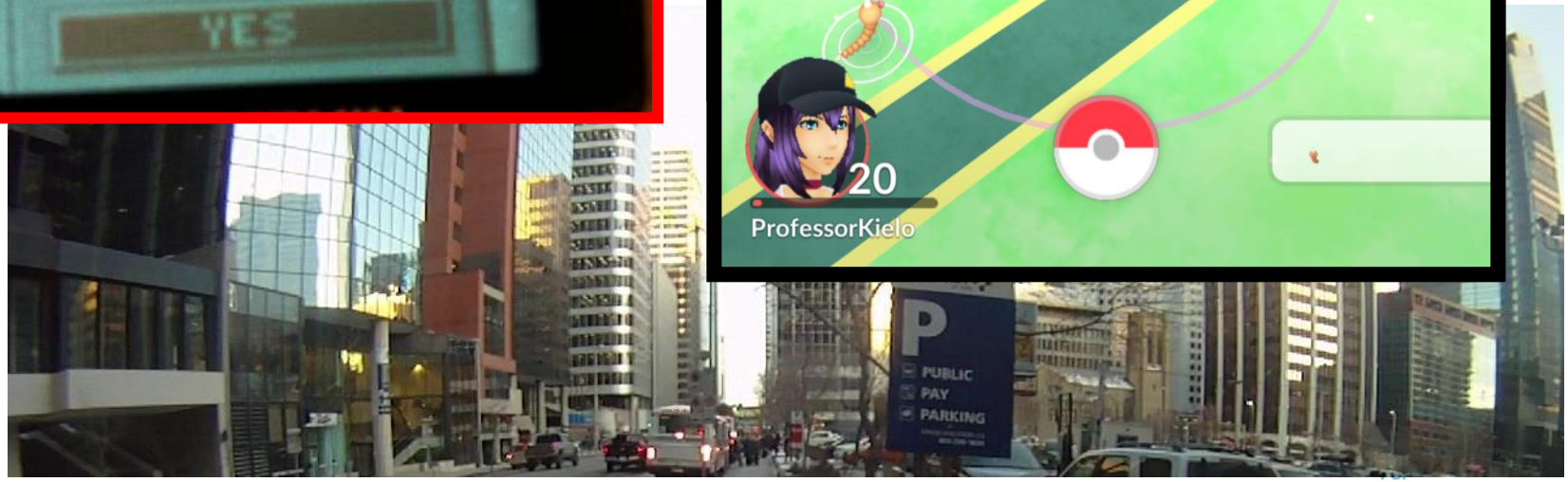
Positioning techno







Positioning technologies (2)

Reliable positioning is needed despite the situation

- Dense forests, urban and indoor environments




- While exposed to jamming or spoofing


→ **Multi-source positioning**

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Positioning technologies (3)

NON-RF SYSTEMS		
Technology	*Pros*	*Cons*
Inertial	Precise with expensive sensors Works in a variety of environments	Unusable without frequent corrections from external reference
Vision	High precision Works when instrumented	Limited range With database approach: extensive instrumentation
Ultrasound	Very inexpensive emitters and sensors High-precision	Limited range Very sensitive to surrounding noise
Infrared	Very inexpensive emitters and sensors High-precision	Limited range Very sensitive to surrounding noise

RF SYSTEMS		
Technology	*Pros*	*Cons*
Cellular	Wide coverage	Precision < 150 m typically Some instrumentation needed
Local area networks (e.g.WLAN)	Access points widespread	Somewhat limited range Instrumentation needed
RFID	Low-cost	Limited range Extensive instrumentation needed
GNSS	Worldwide coverage Free to use	Accuracy 10 m unaided Limited indoor use

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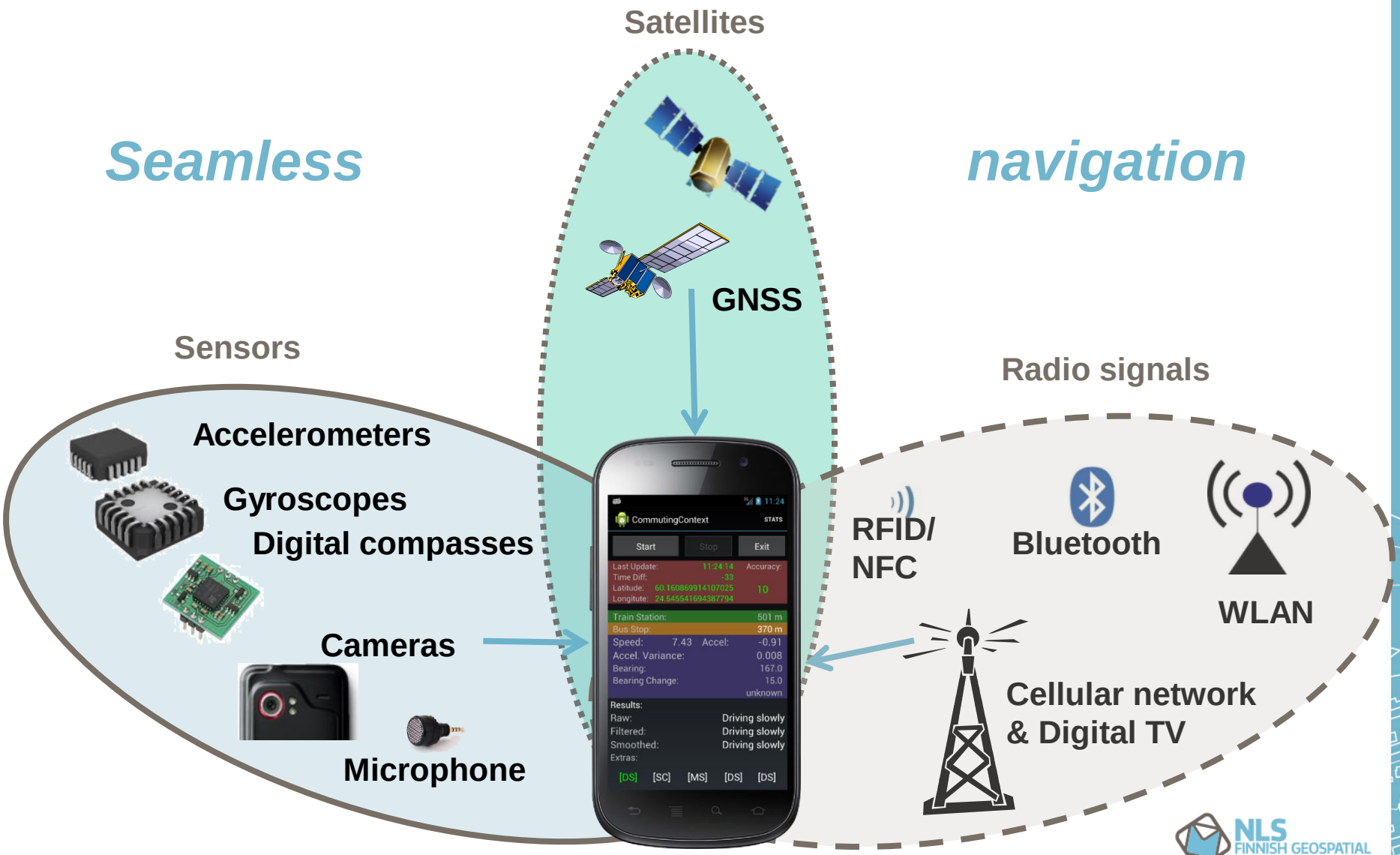
Positioning technologies (4)



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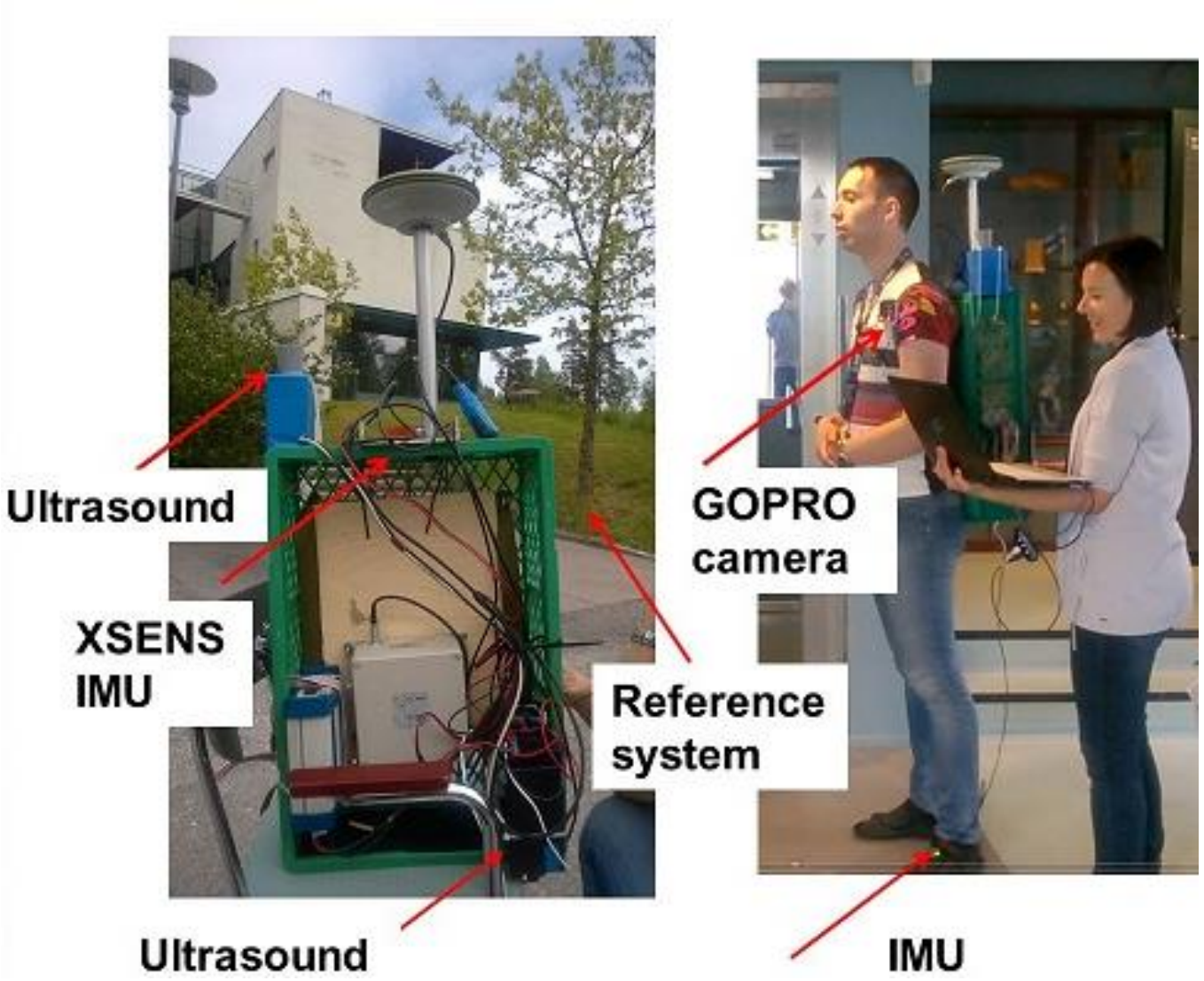
Infrastructure-free positioning at FGI



IMU = Inertial Measurement Unit

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Conclusions – reliable navigation in the future (1)

- Means for navigation and positioning:
  - Signals intended for navigation
    - Multi-GNSS
    - Dedicated radio navigation systems
      - Dedicated WLAN, Bluetooth, RFID tags and UWB emitters
    - Self-contained sensors
  - Signals of Opportunity
    - Not intended for positioning but freely available
      - WLAN, Bluetooth, Cellular, DTV, AM, FM, (5G)
  - Natural signals
    - Magnetic fields
    - Landmarks

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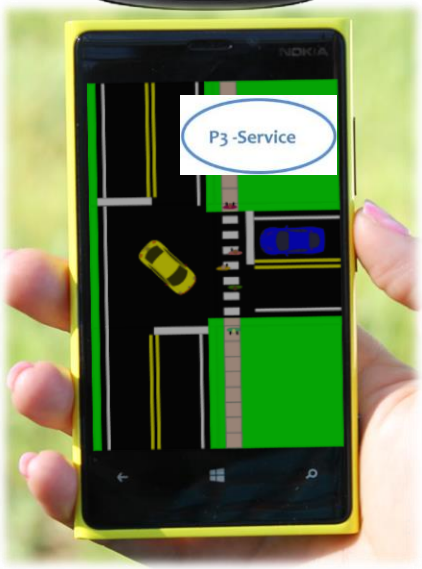
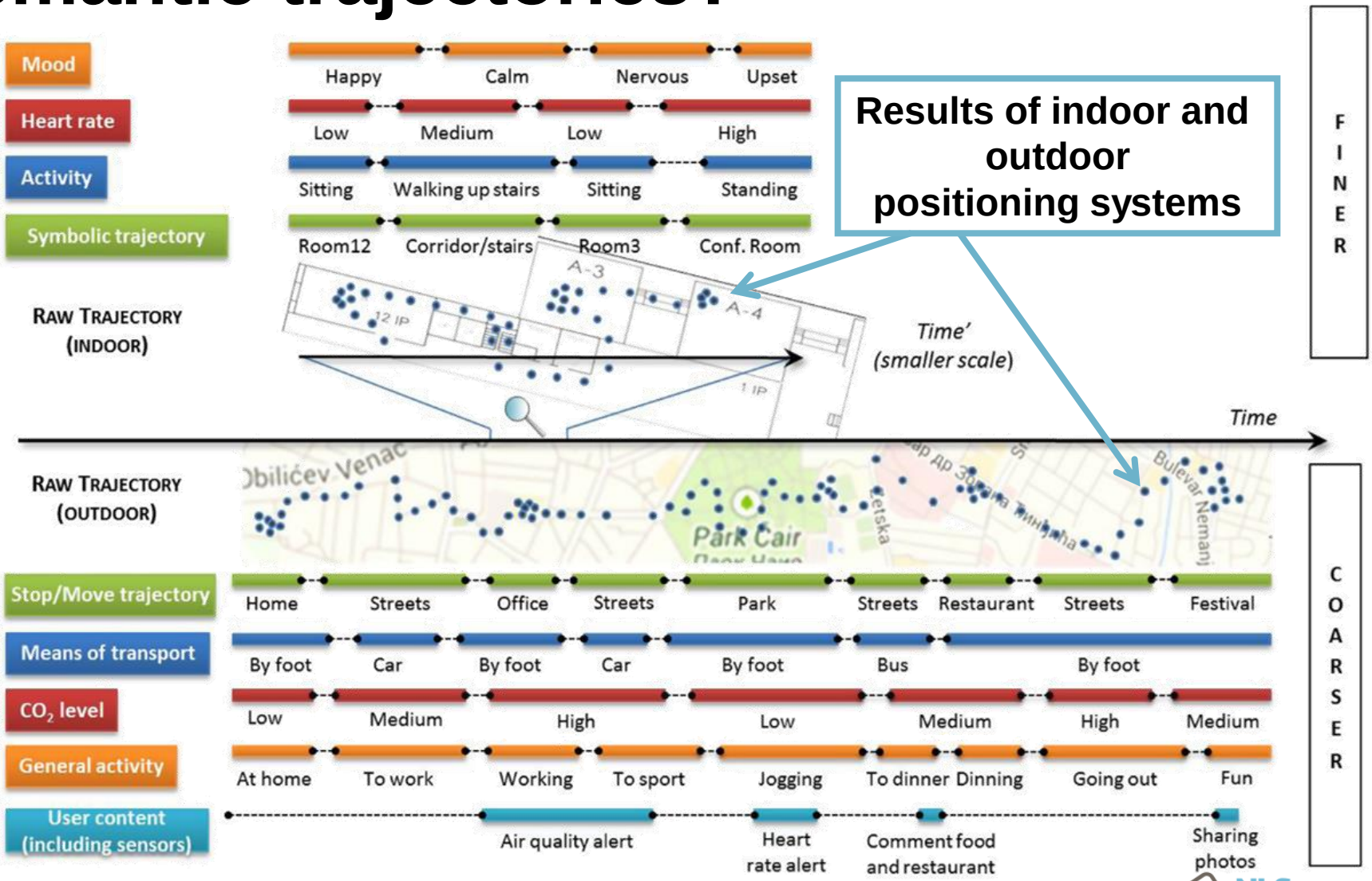
Conclusions – reliable navigation in the future (2)

- Accuracy, availability and reliability
  - Sufficient accuracy to e.g. autonomous vehicles (decimeter-level in real-time)
    - Carrier-phase utilization of GNSS
      - Professional and soon also mass-market (e.g. Android N)
    - Inertial measurement units
  - Interference resilience
    - Backup-systems
  - Seamless positioning from outdoors to indoors
- Interoperability among different location-based services and providers
- Protection of information security of localization



Future outlook – geographic vs. semantic trajectories?



S. Ilarri, D. Stojanovic, C. Ray (2015), "Semantic management of moving objects: A vision towards smart mobility", *Expert Systems with Applications*, Elsevier, 42:3, 2015, pp. 1418-1435.

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Thank you!

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