Robust geospatial technologies in focus - towards sustainable development

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United Nations Expert Meeting on Space for Women
United Nations Office for Outer Space Affairs and UN Women
4 - 6 October, 2017, New York

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Agenda

- GNSS overview and applications
- Threats in GNSS
- Alternative positioning technologies
- Localization and remote sensing
  - geospatial data for sustainability

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Introduction (1)

- Satellite navigation has been one of the outstanding technical achievements of the late twentieth and early twenty-first centuries springing up predominately from space science
- The full capabilities of civilian Global Positioning System (GPS) were made public around 15 years ago
- Today, nearly every mobile app employs it

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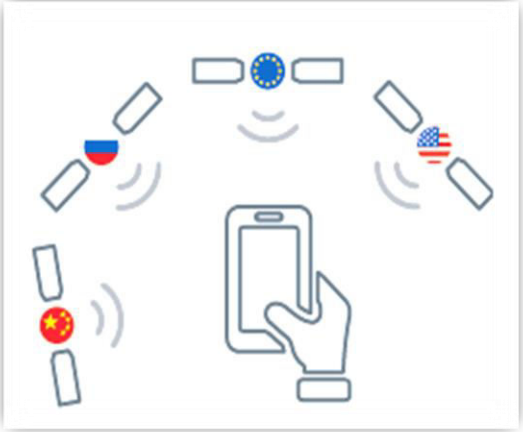
Introduction (2)



- The total number of Global Navigation Satellite System (GNSS) devices in use is about 5,8 billion units (GNSS Market Report 2017, GSA), and it is predicted to grow to almost 8 billion by 2020 - more than one device per person on the planet
- In parallel to governmental/public systems, commercial endeavors are foreseen even in the near future
  - in addition to satellite telecommunications, low earth orbiting (LEO) miniature satellites likely to provide users with some level of positioning service

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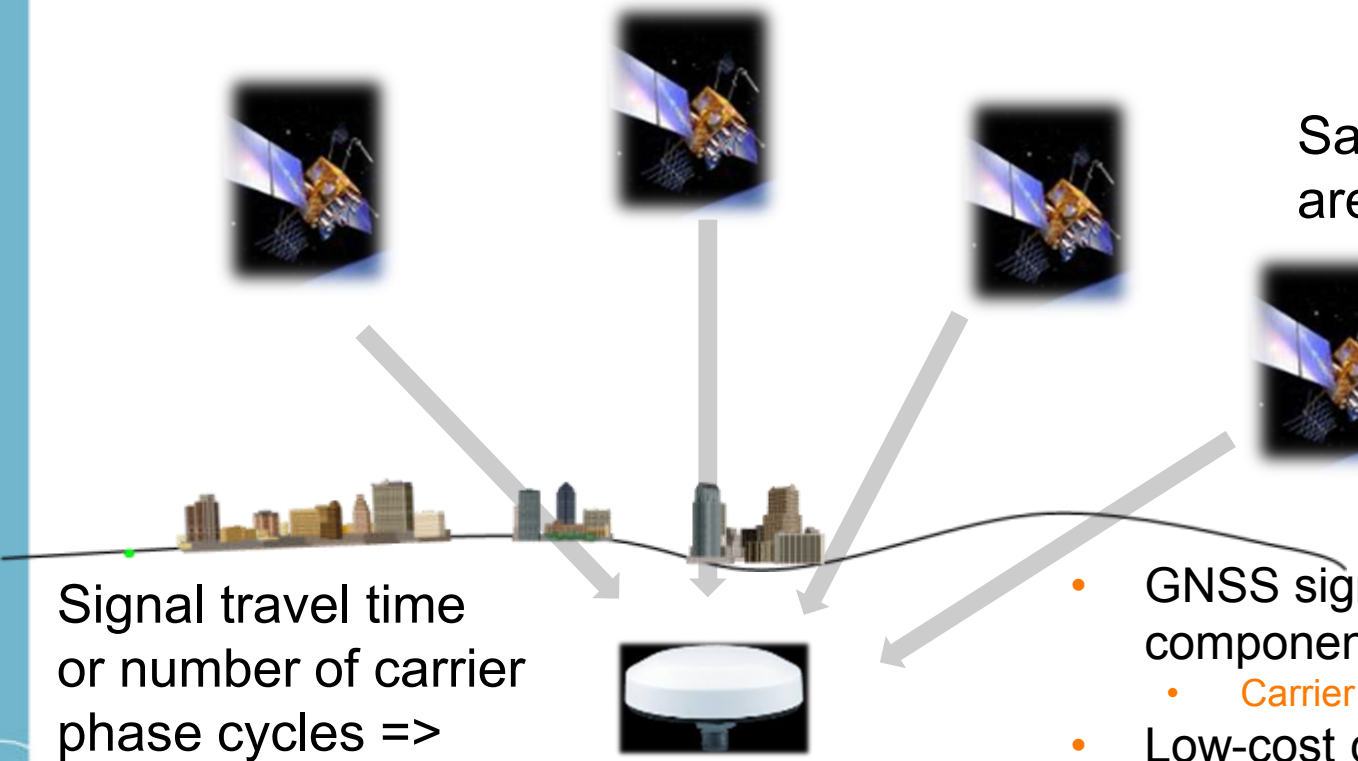
GNSS

Accuracy around 5 m with consumer-grade devices (code) and centimeter-level with professional devices and reference networks (phase)



Satellite locations are known

Signal travel time or number of carrier phase cycles => range

Position, Velocity, Time

- GNSS signal consist of multiple components
  - Carrier phase, code, data
- Low-cost consumer receivers use only code-based range for positioning
- Carrier phase observations and reference networks enable higher accuracy

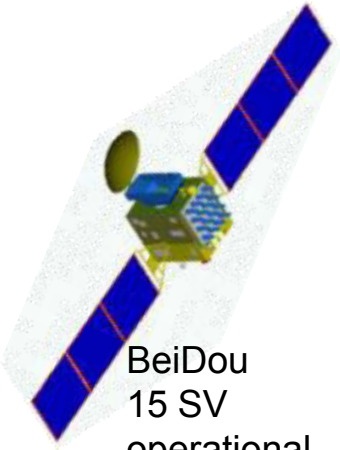
Next generation GNSS (1)

- The future European **Galileo**, the Russian **Glonass**, and the Chinese **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
Oct 2017: 31 SV
operational

Galileo
Oct 2017: 15 SV
operational

Glonass
Oct 2017: 23 SV
operational



BeiDou
15 SV
operational
in Oct 2017

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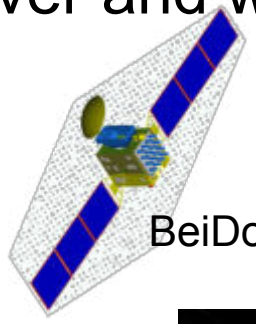
Benefits of using multiple GNSS

- More systems => **better accuracy**
  - more satellites with line-of-sight to the receiver and with better geometry

    => **better availability**

Galileo



BeiDou

  - more frequencies

    => **better resistance to interference**

GPS

  - unique features, e.g.
    - BeiDou has geosynchronous satellites

      => **better accuracy, especially height**

Glonass

    - Galileo includes authentication

      => **robustness to spoofing**

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Satellite navigation market segments

Source: European GNSS Agency's GNSS Market Report 2017

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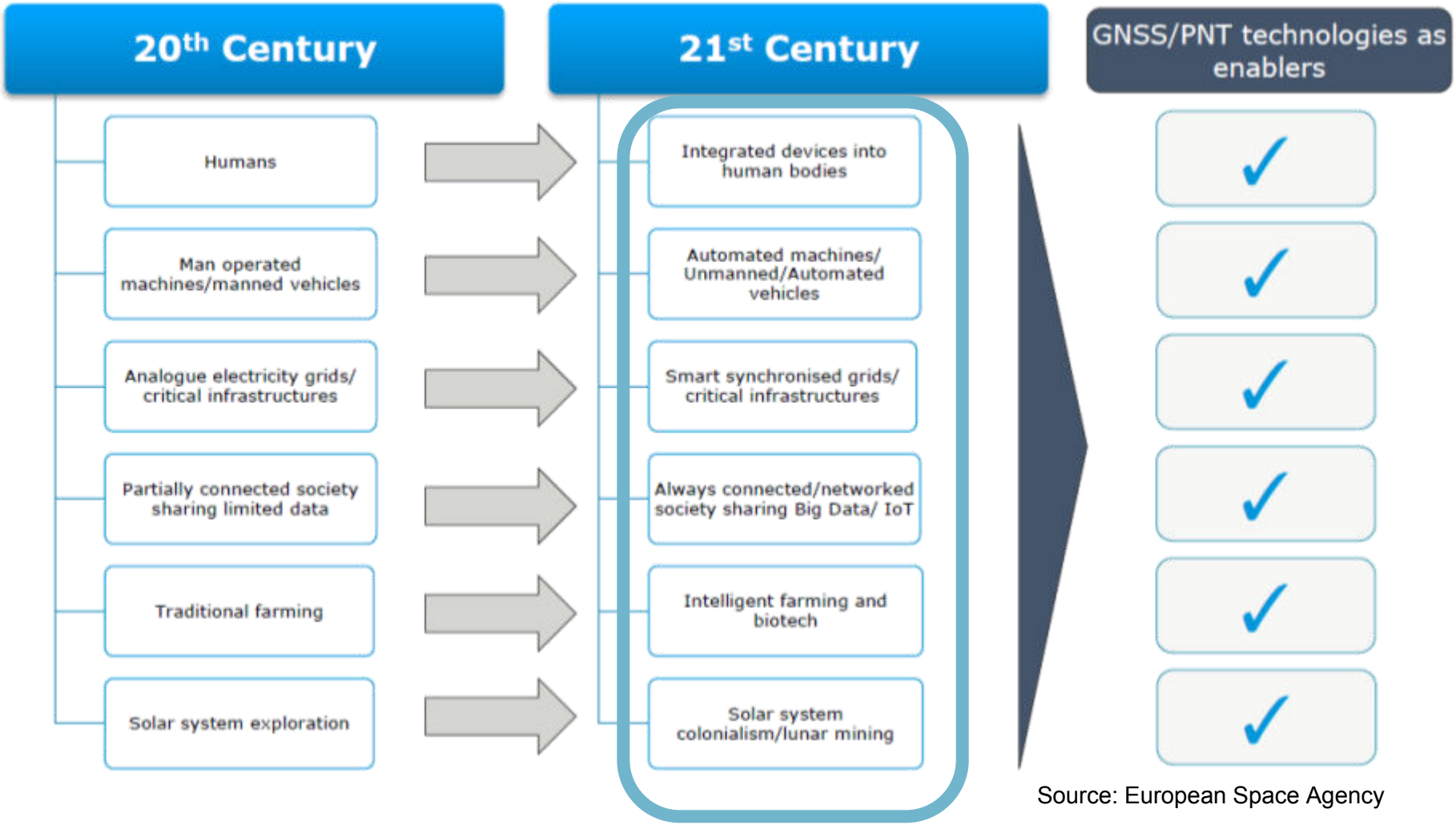
GNSS and PNT play a key role in several key trends



Source: European Space Agency

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

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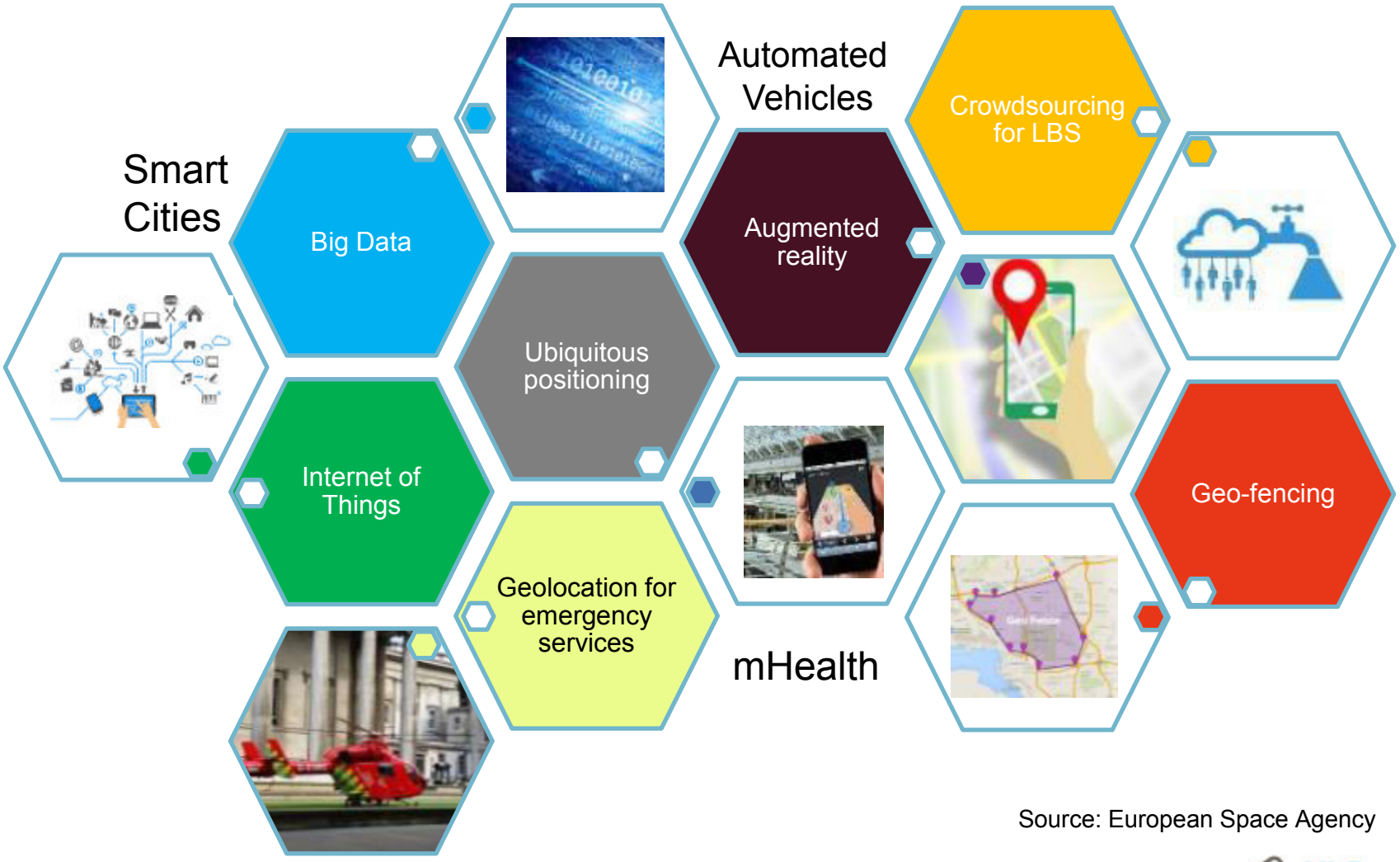
Positioning/timing play a key role in several broad technology trends



Source: European Space Agency

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

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New and emerging GNSS trends by market segment (1)

- **LBS**: More and more smartphones integrate multi-constellation GNSS
- **Road**: GNSS helps answers the need of Autonomous Driving (AD) for reliable and accurate positioning.

- **Aviation**: The aviation market continues to increasingly rely on GNSS, including rotocraft and unmanned vehicles
- **Search and Rescue (SAR)**: Beacon manufacturers are developing solutions for Aircraft Distress Tracking leveraging GNSS
- **Timing & Sync**: GNSS timing is at the core of many critical infrastructures, including telecoms, energy, finance

Source: European GNSS Agency

New and emerging GNSS trends by market segment (2)

- **Rail**: GNSS-enabled solutions can offer enhanced safety for lower cost, e.g. in railway signaling
- **Maritime**: GNSS has become the primary means of obtaining PNT information at sea
- **Agriculture**: GNSS applications represent a key enabler for the integrated farm management concept
- **Surveying**: Falling device prices drive the democratisation of mapping

Source: European GNSS Agency

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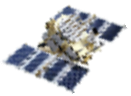
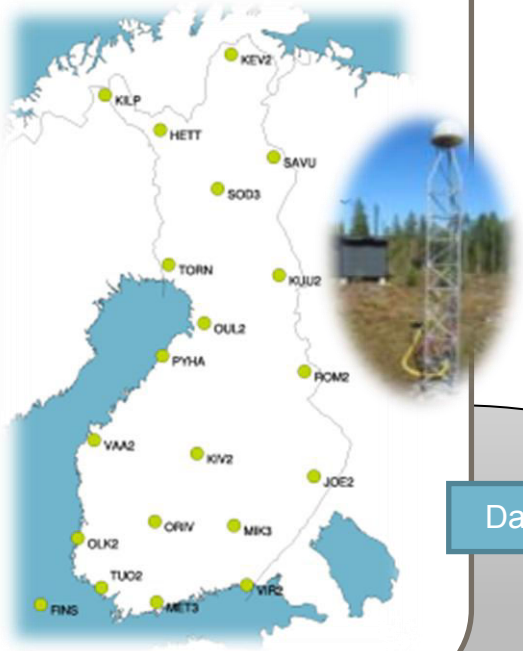
Finland's open GNSS positioning service



GNSS satellites

FinnRef-base stations

Satellite data collection

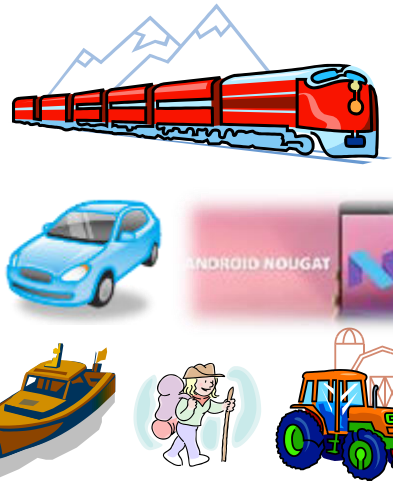


Errors

Data

Data

Users



Computing center

Real time error analysis

Data

Corrections to data

Data + correction = accurate position (< 0,5 m)

Internet

FGI's Department of Geodesy and Geodynamics

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Threats to GNSS

Intentional vulnerabilities

- Jamming: Broadcast of an interference signal

- Spoofing: Broadcast of synthetic GNSS signals to try to trick a GNSS receiver
- Meaconing: Re-broadcast of real satellite signals after a brief delay in order to create errors in the GNSS receiver
- Attacks on ground segment

Unintentional vulnerabilities

- Severe space weather: ionospheric storms may cause GNSS to loose lock

- Signal multipath/reflections: obstacles hinder the direct path from satellite to receiver antenna
- Orbital and clock failures
- Un-intended narrowband and wideband radio interferences

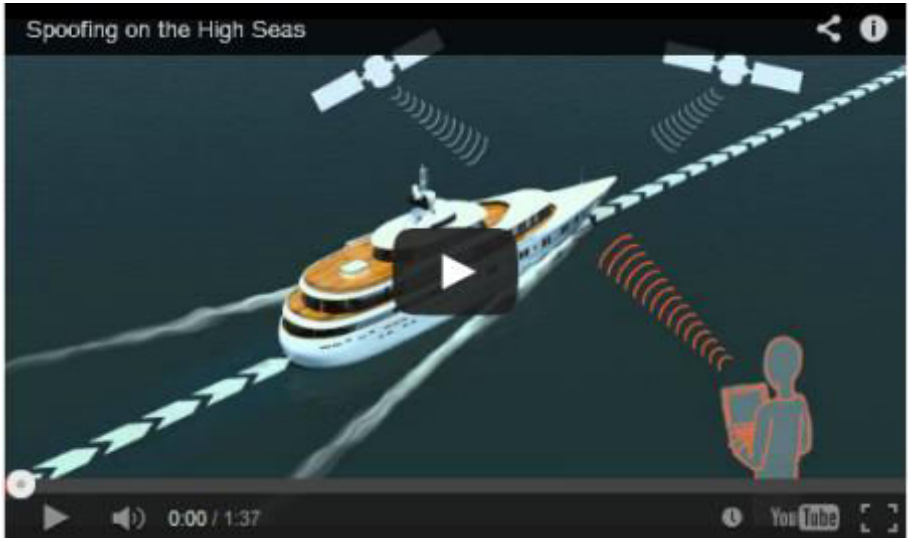
Reported interference cases

2009 Newark airport – reported daily outage in GPS signals

GPS jamming: No jam tomorrow", The Economist , 2011

University of Texas at Austin tested spoofing on an expensive private yacht

KVH Mobile World, 2014



- US port disruption due to interference
- Spoofing / interference of US border drones
- Recent Black Sea incidents of spoofing

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Towards robust GNSS technology

- **Interference resistant** GNSS receiver algorithms and GNSS authentication methods
- Different **backup systems** with non-GNSS technologies
- **Cryptographic techniques** for ensuring security and privacy of location
- Data protection regarding the **location privacy and security** in mobile devices and the mobile data **anonymization**

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Augmentation and backup to GNSS

Reliable positioning is needed despite the situation

- Dense forests, urban and indoor environments

- While exposed to jamming or spoofing

→ **Multi-sensor positioning**

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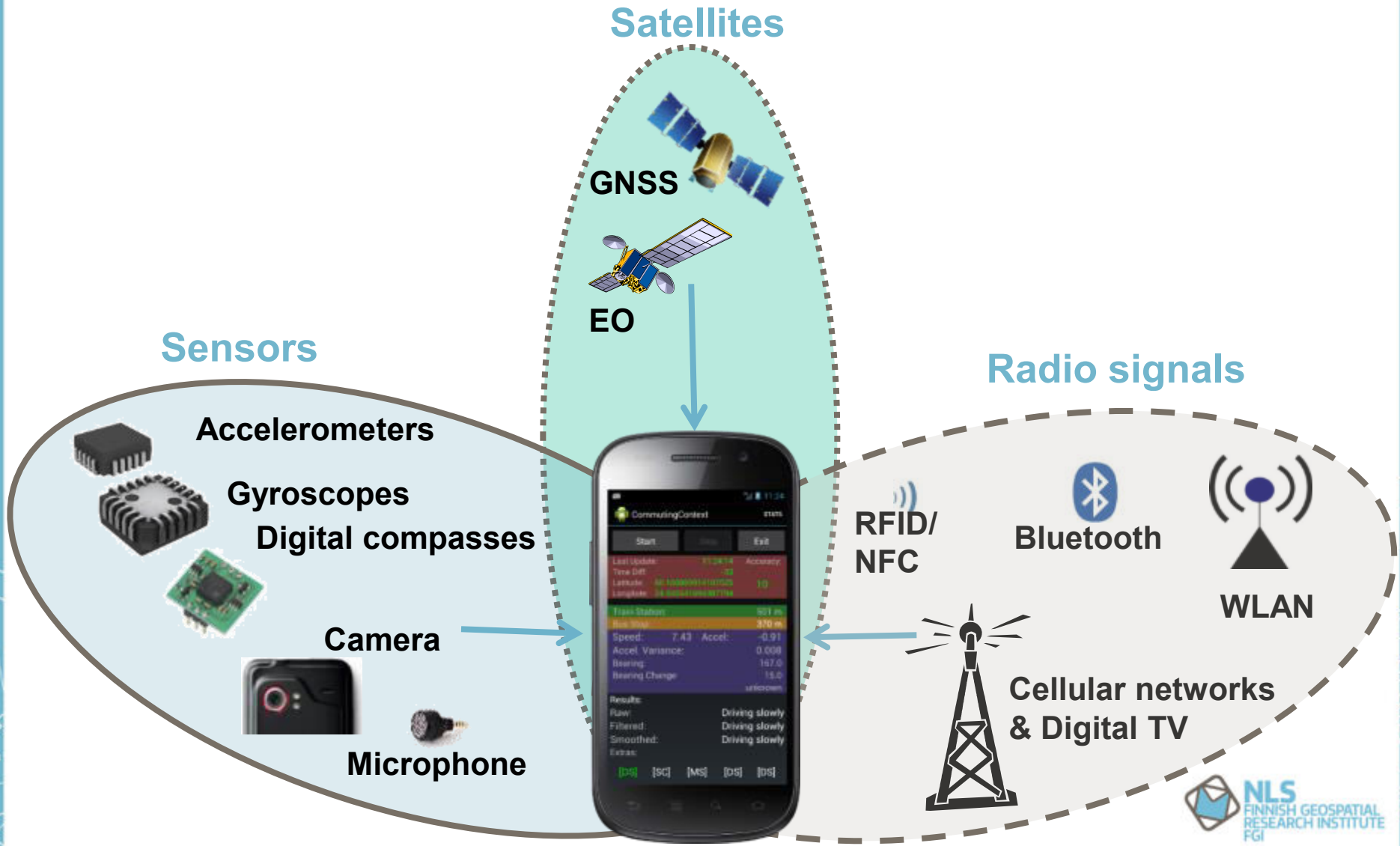
Seamless Positioning and Situational Awareness



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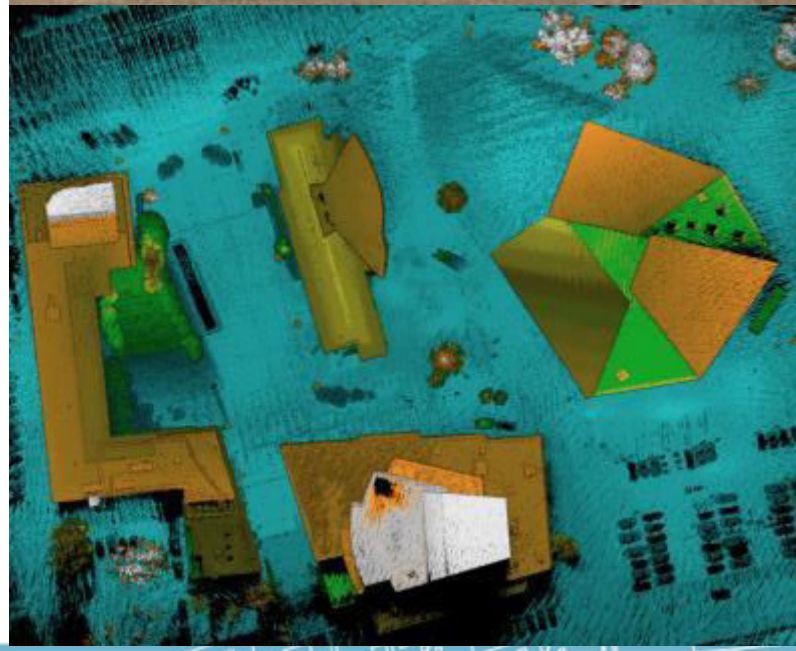
Geospatial data for sustainability (1)

- Geospatial solutions to monitor land use and urbanization
  - visualize, measure, and analyze Earth's features
    - GNSS, geographical information systems and remote sensing
      - E.g. forest and wastewater monitoring
      - Change monitoring of land use and vegetation
- Open access programs as drivers
  - Both GNSS as well as Earth observation (EO) data is highly accessible nowadays
  - Crowdsourcing feasible and enabling new opportunities



Geospatial data for sustainability (2)

- Robust geospatial technologies contribute to making the society take a sustainable and resilient path with its evident ability to help optimize and sustainably manage
  - natural resources
  - production and logistics

  leading to economic growth and increased welfare
- The technology transfer of geospatial solutions to market and growth is not a large leap with the existing accessible, open data
  - proper education and know-how building is necessary

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Thank you!