Future Users of GNSS Services for Positioning and Navigation

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Work done by AJ Geomatics for Lantmäteriet
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Outline of presentation

- GNSS – Global Navigation Satellite Systems
  - High accuracy GNSS positioning services
- Project on future users in Sweden
  - Background for the project
  - Future users internationally
    - EU reports and analyses
  - Future users in Sweden
    - Interviews with 19 stakeholders
    - Users and their requirements
  - Geodetic infrastructure

GNSS - Global Navigation Satellite Systems

The term covers the global systems:

- American GPS
- Russian GLONASS
- European Galileo
- Chinese BeiDou

and a number of regional augmentation systems

GPS and GLONASS were originally developed for military navigation, but today GNSS is used for a wide range of applications in the fields of positioning, navigation and timing

High accuracy GNSS positioning

- Based on observations of the carrier phase of the satellite signals
- Requires more advanced antenna and receiver than what is used with a smartphone or conventional car navigation system
- More advanced algorithms applied (math) in the software including models for atmospheric effects, more precise estimates of satellite positions and clock errors etc.

Position accuracies at the cm or mm level

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High accuracy GNSS postioining services

- High accuracy GNSS positioning services are in this presentation defined as:
  - Positioning services providing end user position uncertainty better than 20 cm in real time

- Divided into:
  - Global services
    - Based on global network of reference stations
  - National/local services
    - Based on national or local network of reference stations
  - Combinations do exist, but not discussed in this presentation

High accuracy GNSS positioning services (1)

Global service for Precise Point Positioning (PPP)

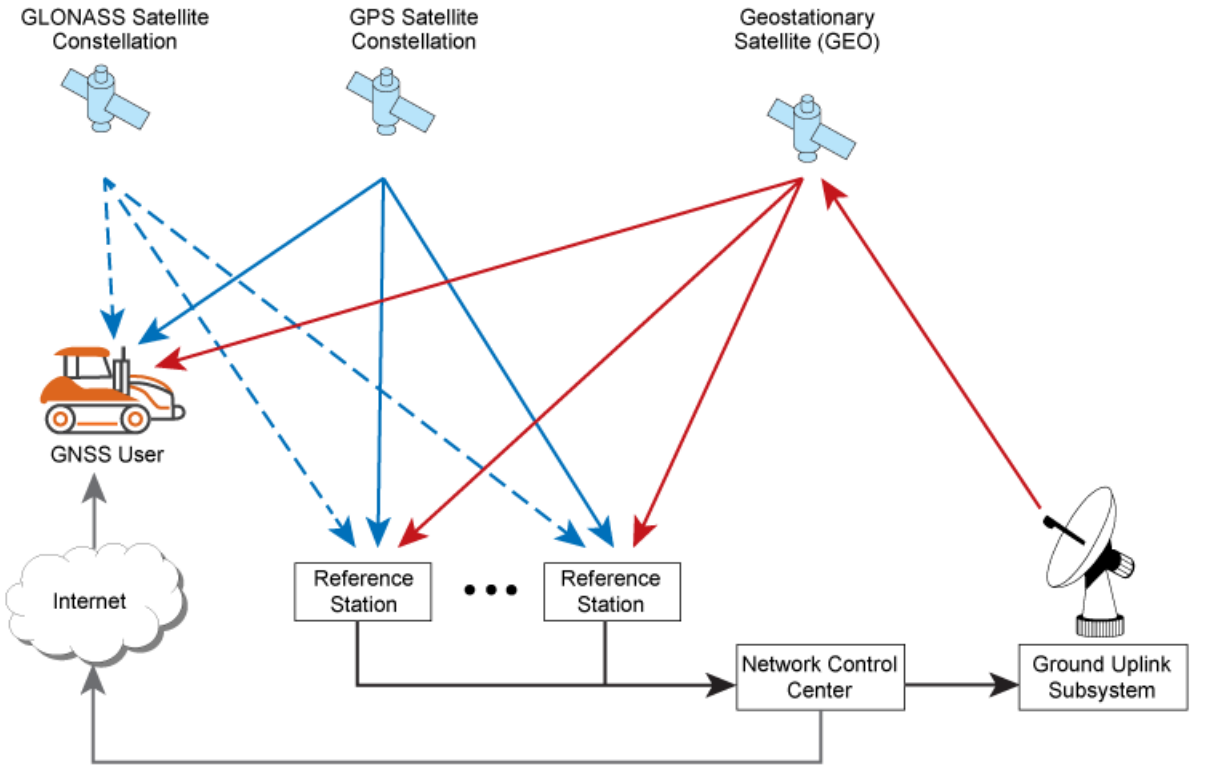
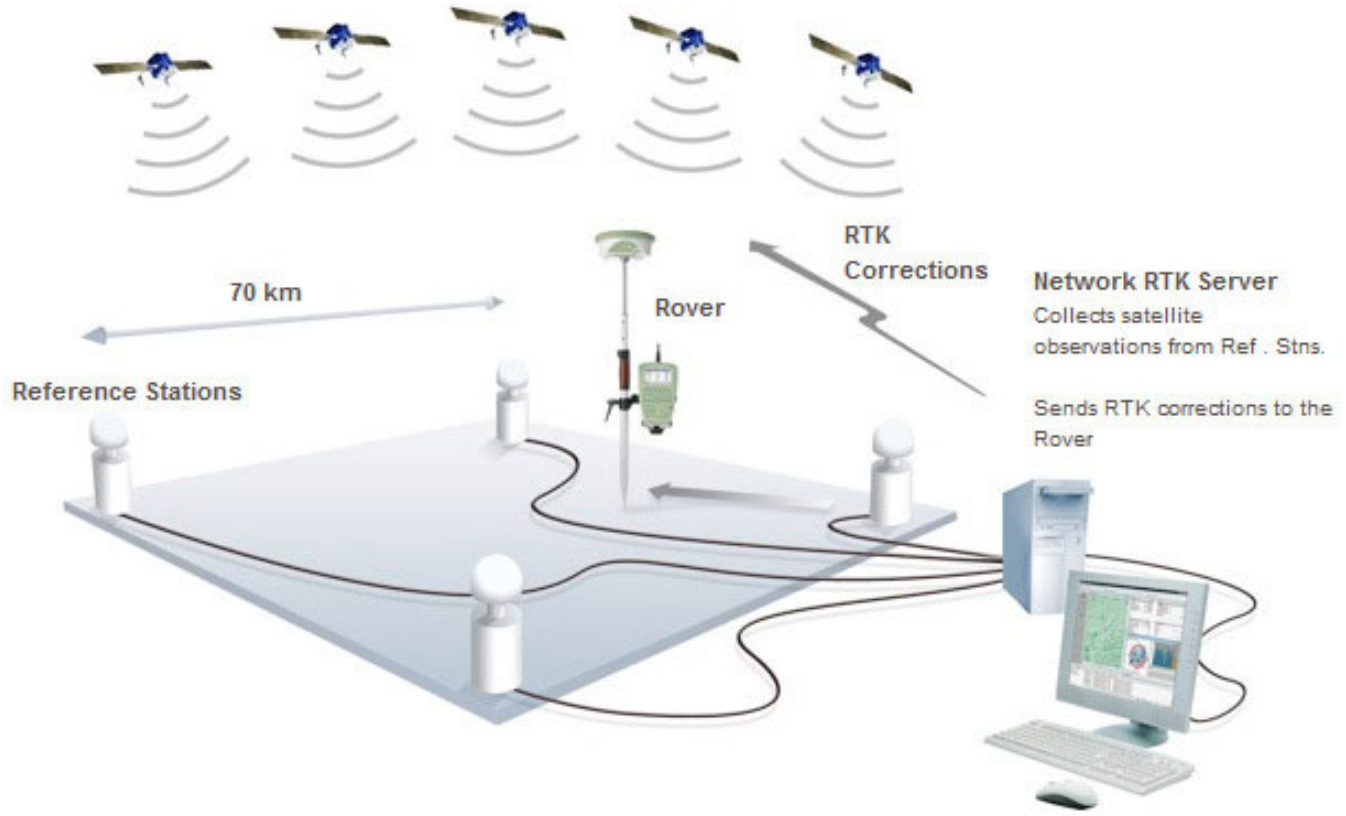


Figure 43 Precise Point Positioning (PPP) System Overview

- Illustration from Hexagon – Novatel (”An Introduction to GNSS”)

High accuracy GNSS positioning services (2)

National or local service for network Real Time Kinematic (RTK)



- lllustration from Hexagon Geosystems – HxGN SmartNet

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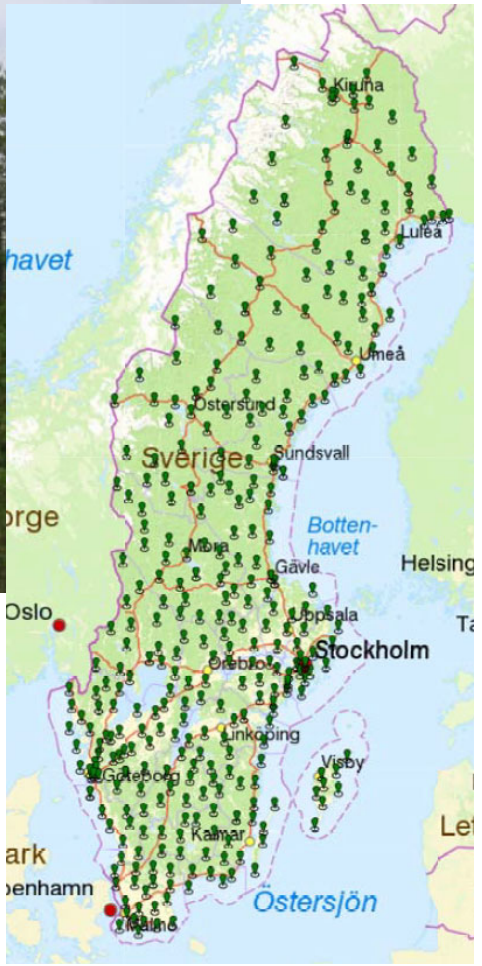
Future users of GNSS positioning services

- Lantmäteriet operates a nationwide RTK service and must prepare for the future.

- What can be expected:
  - Which user groups?
  - Which requirements from the users?
  - Need for alterations to the GNSS infrastructure?
  - Need for geodetic infrastructure?

GNSS infrastructure in Sweden



Illustrations from Lantmäteriet

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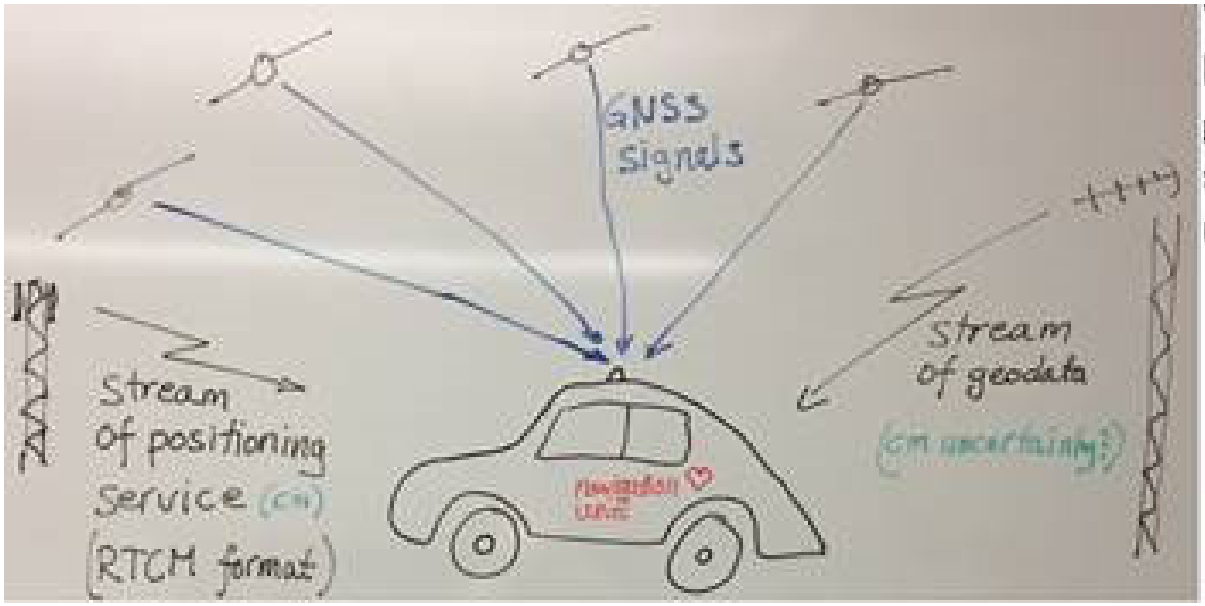
Autonomy



The navigation unit needs to be able to verify that geodata and positioning service use the same reference frame!

Drawing:
Martin Lidberg

- Geodata is used for navigation of autonomous vehicles for
  - Positioning relative to road signs or other objects
  - Route optimisation with digital terrain models
  - Navigation of drones with 3D city models
  - Etc.

Current development of GNSS applications

- GNSS – Global Navigation Satellite Systems
  - Soon four fully operational global systems
  - Development of many new applications right now

- Development of new applications driven by:
  - Personal applications e.g. in smart phones
  - Autonomy – self driving and autonomous vehicles, drones, vessels etc.
  - *Smart cities, Internet of Things (IoT), Big Data, Augmented reality* etc.
  - Many new professional users in Asia and Africa

Current development in positioining services

- A consequence of the development in applications is a related development in positioning services
- More companies want to make a business in providing positioning services e.g. for the car industry
- Positioning uncertainty at the dm-level for mass market users
  - Global service providers
- Further, many professionals need position uncertainty at the cm level
  - National / local service providers

=> Development towards integration of different techniques (e.g. PPP and RTK)

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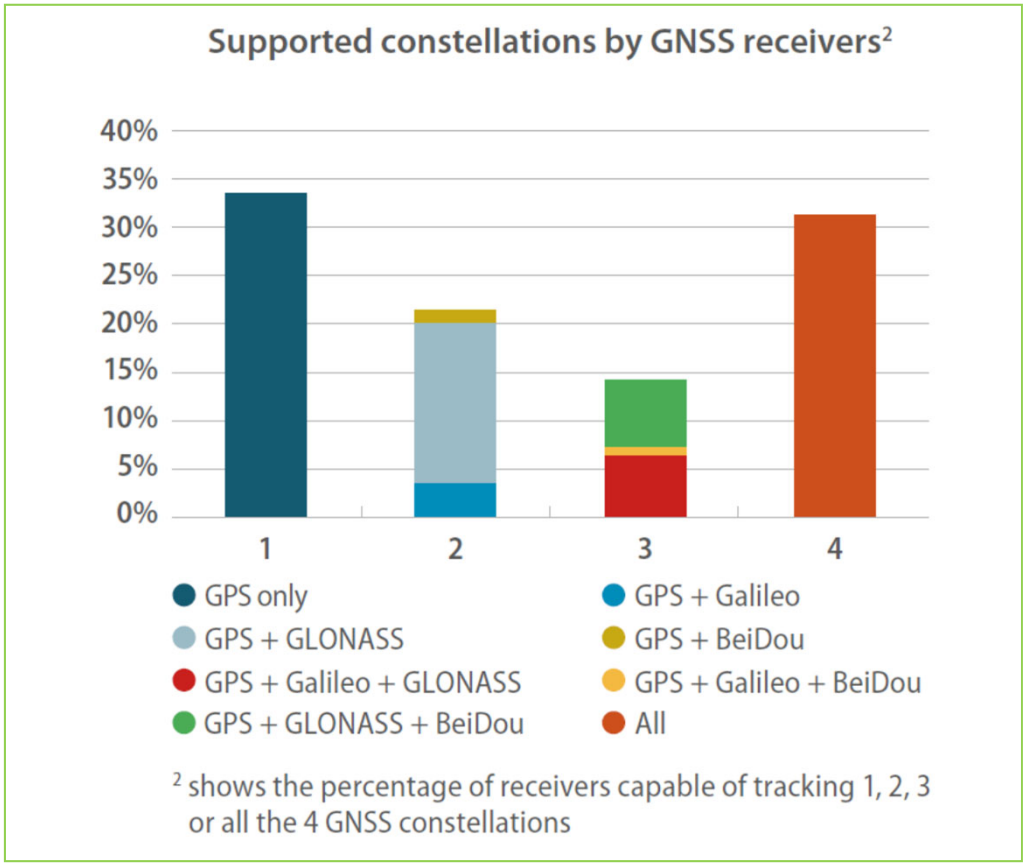
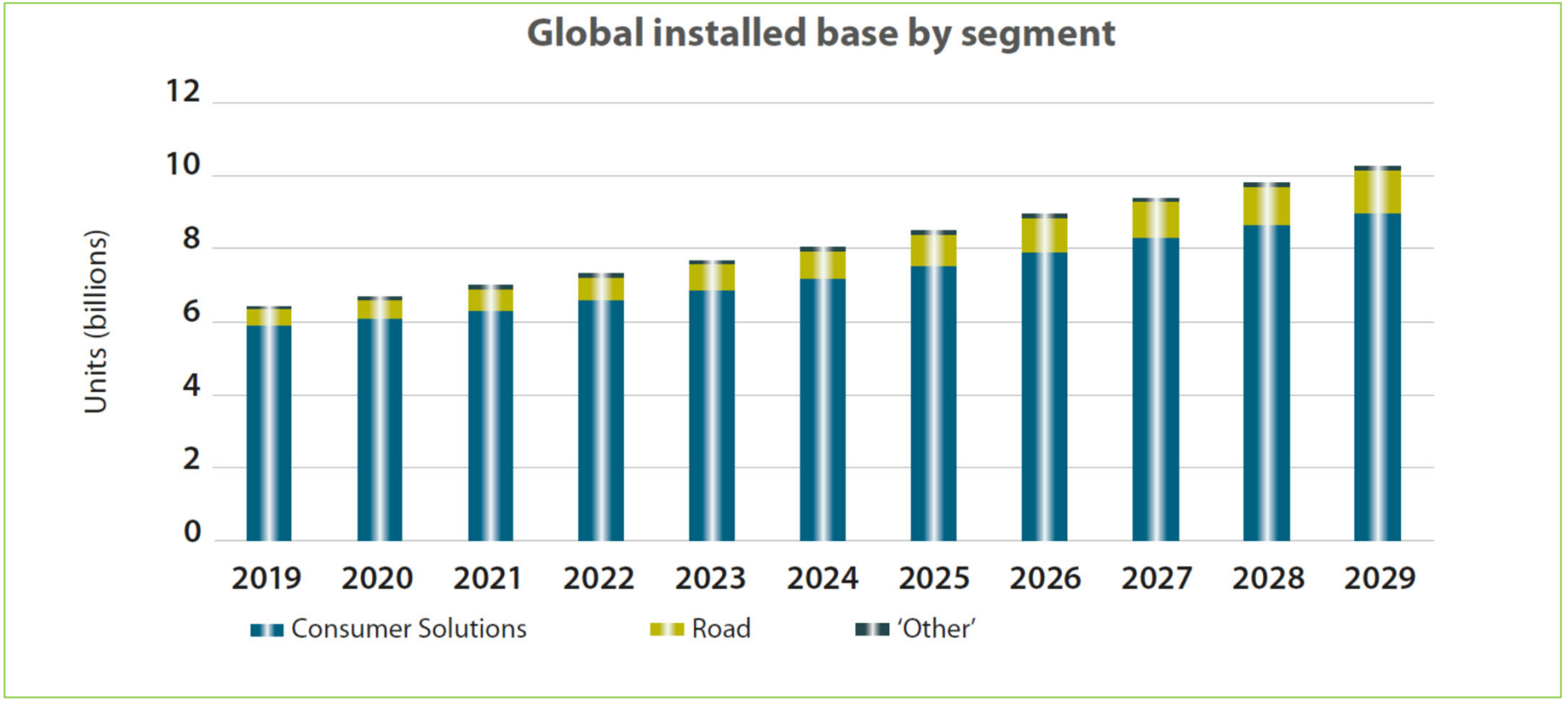
EU User Technology Report 2018



EU Market Report 2019



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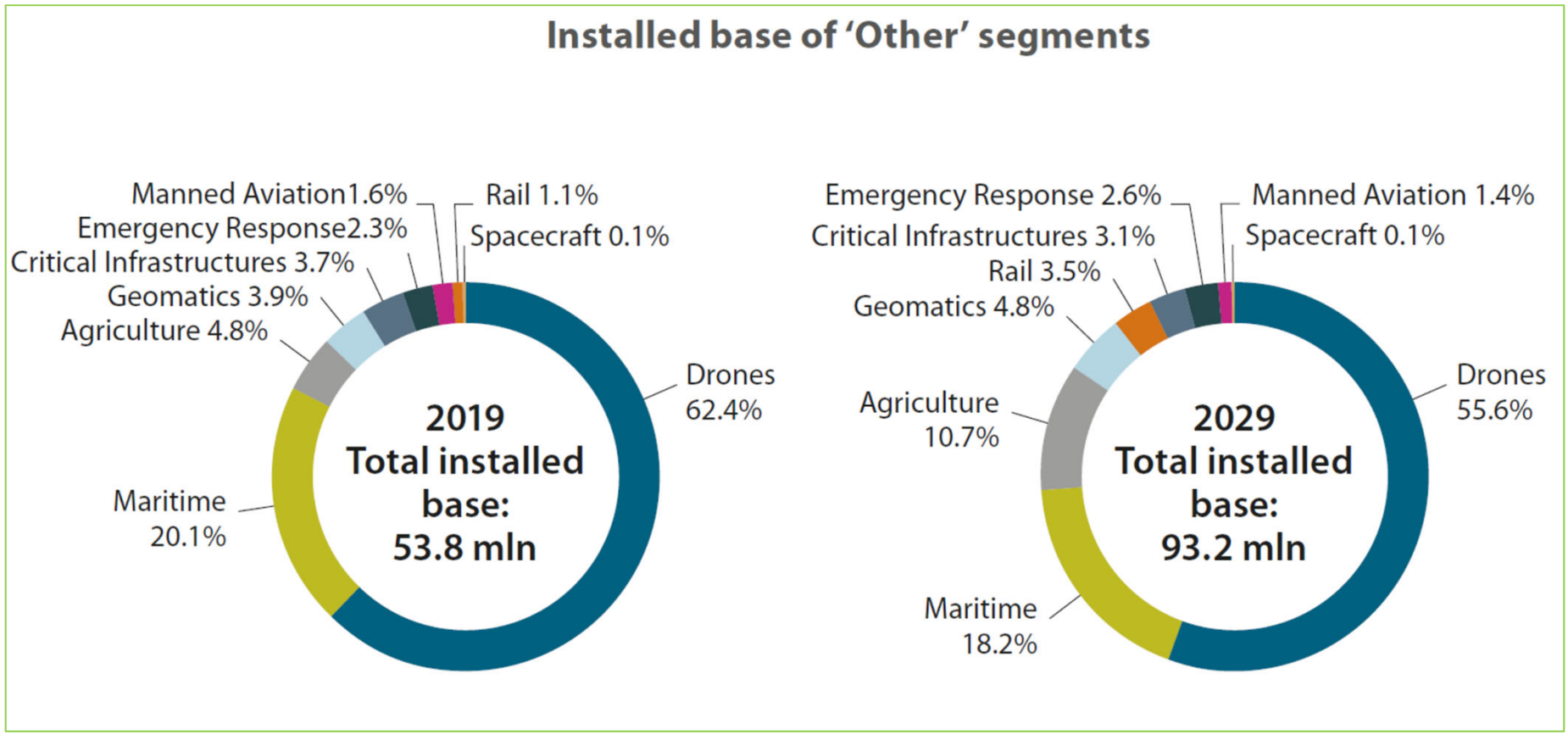
EU Market Report 2019

- *LBS – Location Based Services*
  - Towards 7,5 bill. GNSS receivers for LBS in 2025
  - Personal and private users, mostly smart phones
  - Development driven by e.g. multi-GNSS, *mHealth* and *wearables*
  - Integration with other sensors (wifi, cell-ID etc.)
  - Battery capacity is a limiting factor

- *Road applications*
  - Towards 1 bill. GNSS receivers for road applications in 2025
  - Mainly personal and private applications
  - Development driven by autonomy, *eCall, smart tachographs* etc.
  - Integrity is very important for autonomy

EU Market Report 2019



EU Market Report - summary

- Summary of EU *Market Report 2019:*
  - Largest user groups today and in 2029 are LBS and road applications (private cars and trucks)

- Professional users towards 2029:
  - Largest increase in percentage of users expected for agricultural, rail and geomatics applications
  - In terms of number of users, maritime applications is expected to be the largest user group

- Largest increase in **high accuracy** users expected in farming, land surveying and construction work
- Also large increase expected in use of **drones** for farming, construction work, land surveying etc.

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Interview with stakeholders from:

- Construction companies
- Municipalities
- Land survey companies
- Farming
- Autonomous mobility
- Car industry
- Drone navigation developer
- Swedish maritime administration (Sjöfartsverket)
- Swedish transport administration (Trafikverkt)
- Ericsson
- Leica Geosystems (in Switzerland)

- Totally 19 persons

The interviews showed …

- Use of GNSS is expected to increase within all fields of application
- Everybody talks about autonomy – will become very important in construction, for mobility at land and sea, and for farming

- New techniques for positioning; multi-GNSS and GNSS integrated with other sensors
- New platforms, e.g. high accuracy in smart phones

- Ericsson points to new techniques for transmission of GNSS correction data
- Leica notes that the GNSS service providers become bigger
  - Local -> national and national -> global services

The interviews showed …

Most important quality parameters for the future:

- **Integrity** - a measure of how much you can rely on the position solution
  - For safety and security in autonomous applications
  - For quality and documentation in land surveying
- **Availability** – services must be available for use at any time
  - Especially for machine control and autonomous applications
- **Positioning uncertainty** (also for the height component)
  - Especally important for machine control, land surveying, marine appliations and some applications of drones

The interviews showed …

Less important (but still important) quality parameters in the future:

- **Time to first fix**
  - For some, but most find it works well as it does today
- **Authentication**
  - To reduce risk of spoofing especially for drones, marine applications and autonomous vehicles
- **Robustness**
  - To reduce risk of interference and jamming, especially for machine control, drones, municipalities etc.
  - Solution is expected to be integration with other sensors

Global or national positioning services

- Most of the people interviewed use local/national positioning services today

- They find global services are interesting and attractive, but prefer benefits of the local services (lower uncertainty in positioning and local support)

- Despite the advent of more global services in the future, Leica Geosystems still see a need for local or national services for many years into the future
  - Because of the need for support and knowledge about national conditions, rules, regulations etc.

National or privatised positioning services

- Those interviewed, who make used of the Swedish SWEPOS service today, expressed satisfaction with the service

- There are requests for improvements and expectations for the future, but there is also a general support towards having a national service, operated by a government organisation

- A high accuracy positioning service is seen as being part of the basic national infrastructure in Sweden in the future

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Interviews showed .... geodetic infrastructure

- Need for a national reference frame (like ETRF), so all users apply the same coordinate system
- Estimation of heights with GNSS must be improved
- Coordinate transformations must be available and easy to use
- Need for education and information for users who do not know geodesy, in order to reduce the risk of errors with precise coordinates

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Geodetic infrastructure needed (1)

- GNSS reference stations
  - Distance between stations depending on performance of the positioning service

- Geodetic reference frame
  - National frame (like ETRF) needed for best compliance with reality
  - International frame (like ITRF) needed for best compliance with satellite positions in space

=> Need for accurate coordinate transformation between the reference frames

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Geodetic infrastructure needed (2)

- Geoid model for estimation of heights with GNSS
- Height system in relation to mean sea level
- Geodyamic models for best possible coordinate transformations
- Safety and security aspects around GNSS installations (*jamming* and *spoofing*), cyber security etc.

Infrastucture for autonomy

For autonomy even more infrastructure is needed:

- Digital 3D terrain models
- Digital 3D city models
- Database with road centre lines
- Database with objects along roads for navigation of vehicles e.g. with radar, lidar or vision (e.g. road signs, road barriers etc.)
- Database with objects along inland water ways for navigation of vessels (as above)
- Etc.

NB: All geodata must have **low uncertainty** in positions

Concluding remarks (1)

- The future users of high accuracy positioning services in Sweden towards 2025 will be the **same as today**:
  - Land surveying, contrcution, farming and marine applications
  - All user groups will increase

- Further, there will be a **large increase** in autonomous applications:
  - For machine control and drones in farming, construction work and land surveying/mapping
  - Autnomous vehicles and vessels

Concluding remarks (2)

- **National GNSS positioning services** will be used mainly for land surveying / mapping, construction work and marine applications in inland waterways
  - Correct geodetic basis and low uncertainty in positioning in both horizontal and vertical position is important for these users

- Autonomous vehicles and farming does also rely on high accuracy positioning, but these user groups are more likely to make use of **global positioning services**

For an introduction to the future of GNSS positioning services:

”White paper on Future Positioning Services”

by

Nordic Geodetic Commission, 2019

http://www.nordicgeodeticcommission.com/wp-content/uploads/2019/12/NKG-White-Paper-on-Future-Positioning-Services-2019.pdf