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GNSS-Signal Quality Evaluation in Finland

Preliminary Study

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Author(s)
Sarang Thombre, Giorgia Ferrara, Salomon Honkala, Laura Eskelinen, Pia Isojärvi, Martti Kirkko-Jaakkola, Stefan Söderholm, Heidi Kuusniemi.
Department of Navigation and Positioning, Finnish Geospatial Research Institute, National Land Survey of Finland.

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Contact person
Dr. Sarang Thombre
(sarang.thombre@nls.fi)

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Other information
Other contact person(s): Prof. Heidi Kuusniemi, Director, Department of Navigation and Positioning, Finnish Geospatial Research Institute (heidi.kuusniemi@nls.fi).

Abstract

This is the Final Report describing the *GNSS-Signal Quality Evaluation in Finland (GLAS) – Preliminary Study* project implementation. The project duration was from 1st October, 2016 – 28th February, 2017 and included identification of end-users, user requirements, initial service definition, and proof-of-concept demonstrator. This report also briefly describes the project structure and the future project plan.

Section 1, 2, and 3 are an introduction to this document and the GLAS project. It describes the project scope and schedule for the first phase of activity, including a brief discussion about future phases of the project. Section 4 presents an executive summary of the report covering the most significant conclusions from this study. Section 5 lists the end-user groups and example end-users identified in the stakeholder analysis. This list was essential for inviting respondents to the project web-survey. Section 6 describes the results and conclusions of this web-survey – indicating the expectations and requirements of end-users. The complete web-survey results are provided in Appendix 3.

Section 7 describes the conclusions from the detailed in-person interviews conducted with 4 (expert) end-users to know better their expectations and opinions. The detailed transcripts of the interviews are presented in Appendix 1. Section 8 presents conclusions from the comparative study of state-of-the-art services similar to GLAS-service available globally. The comparative table is provided in Appendix 2. Section 9 describes the FinnRef reference GNSS network and its capabilities, because that is envisaged as one of the data sources for the proposed service. Section 10 compiles all the information from previous Sections to offer an initial service definition for the GLAS-service based on which the first roll-out version of the service will be implemented. Finally, Section 11 describes briefly the proof-of-concept demonstrator service implemented as a prototype of the proposed GLAS-service.

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1. Introduction

Satellite navigation together with wireless data transformation and geographic information enables many applications enhancing safer, more cost-effective and more environmentally friendly transportation. Global Navigation Satellite Systems (GNSS) like GPS, Galileo, GLONASS and BeiDou are providing more comprehensive and precise positioning and timing services, and also new services for regulated use.

Europe is currently making a great effort to the development of the satellite navigation infrastructure and services through Galileo and EGNOS, which corrects GPS signals. However, GNSS signals and measurements are very vulnerable to both unintended (atmosphere errors and on-earth radio traffic) and intended (e.g. jamming and spoofing) errors. Also general system errors are a threat for several industries relying on position, navigation and timing.

This preliminary study aims to build an information service about the usability of satellite navigation. The service will be giving information about the current and forecasted quality, availability and other information of satellite navigation systems and signals over Finland. It will be accessible via a web interface where information will be displayed graphically using maps, color codes, time series plots and statistical tools. The service is meant to be a useful tool for all industries and individual actors using satellite navigation in their work or other activities, benefiting therefore numerous market segments such as surveying, transportation, banking, agriculture, energy distribution, and location-based services.

The quality-monitoring services for GNSS signals provide crucial information about the reliability of the global positioning service (the quality of GNSS signals) especially for critical applications relying on satellite navigation and its reliable functioning. This applies also for the larger audiences using navigation and positioning services. At the moment there is no service available in Finland that monitors the quality of GNSS signals and covers the whole country. There are foreign services available (for example in Sweden and Norway) which do not cover Finland and in which the information about the quality is restricted. This project aimed to build a service that could utilize open information from FinnRef stations. The information from the service would be available for everyone for free via human and machine readable interfaces.

2. GLAS Project in Brief

GNSS-Signal Quality Evaluation in Finland – Preliminary Study is a project to implement an internet-based application which will indicate to the public the current and forecasted status of satellite navigation signals over Finland.

Therefore, GLAS-service will develop a continuous GNSS/EGNOS monitoring service to analyze the performance of Global Navigation Satellite Systems (GPS, GLONASS, Galileo, and BeiDou) and the European GNSS Navigation Overlay Service in all the GNSS reference stations of the Finnish public reference network (FinnRef) 24/7 in order to clarify that these system performance reaches its target, also in Finland. FGI is the only public entity in Finland that has both the necessary infrastructure and knowledge for monitoring the EGNOS/GNSS performance.

An EGNOS performance monitoring service would provide an opportunity to identify weaknesses in EGNOS system performance, especially at high northern latitudes. This would facilitate also investigation of the timeliness of EGNOS parameters and usability of the low elevation SBAS signals. The outcome of this project would contribute to the future improvements of EGNOS, especially if we think of the expected performance and planned upgrades to EGNOS in the North and North-East European area, including the EGNOS RIMS to Kuusamo, Finland.

It is believed that knowledge of the quality of satellite navigation signals over Finland will benefit the public to plan their position, navigation, and timing (PNT) related operations more efficiently, and handle unexpected errors more robustly. It will provide estimates of errors that can be expected in positioning and navigation results at present or in the immediate future. Furthermore, it will provide notifications and alerts to registered end-users in case an ongoing or an upcoming signal disruption event is detected.

The goal is to make this service beneficial to all market segments and application domains: surveying, transportation, banking, energy distribution. Even end-user driven sectors such as location-based services, leisure boating, and personal navigation can potentially benefit from this service.

The GLAS project was not conceived in isolation, but is based on sound knowledge gained at FGI during previous similar project efforts. The EU H2020 project STRIKE3 (Standardisation of GNSS Threat reporting and Receiver testing through International Knowledge Exchange, Experimentation and Exploitation) aims to deploy a network of GNSS receiver based modules to monitor signal jamming events at critical locations such as airports and harbors. The project FEGNOS (Performance of EGNOS in Finland) aims to measure the performance of EGNOS in all FinnRef GNSS stations during a one-year time frame (2015-2016) as a precursor to possible continuous monitoring of EGNOS performance in Finland. Project FinCOMPASS implemented a BeiDou capable receiver to study the performance and usability of the Chinese GNSS in Finland. The European GNSS Agency (GSA) has previously expressed interest for a Europe wide network of receivers to collect standardized radio frequency GNSS data for monitoring and research purposes. Lessons learnt during these projects will definitely benefit FGI during the implementation of GLAS-service. This experience also makes FGI a capable entity to implement the proposed service with a high probability of success.

3. Structure of the Project

The project is led by the Department of Navigation and Positioning, Finnish Geospatial Research Institute (FGI) of the National Land Survey. The Satellite and Radio Navigation research group within this Department is responsible for the project activity.

Project Plan: Phase 1

- Identification of end-user groups and example end-users.
- Preparing the contact method – web-survey & personal interview questionnaire.
- Conducting the web-survey and personal interviews.
- Compiling the results and analyzing them to form conclusions => end-user requirements.
- Literature survey of existing services/ portals/tools around the world.
- Integrating all the above information to form the initial service definition.
- Implementing a proof-of-concept demonstrator of the future service.
- Duration of this phase: October 1, 2016 – February 28, 2017 (5 months).

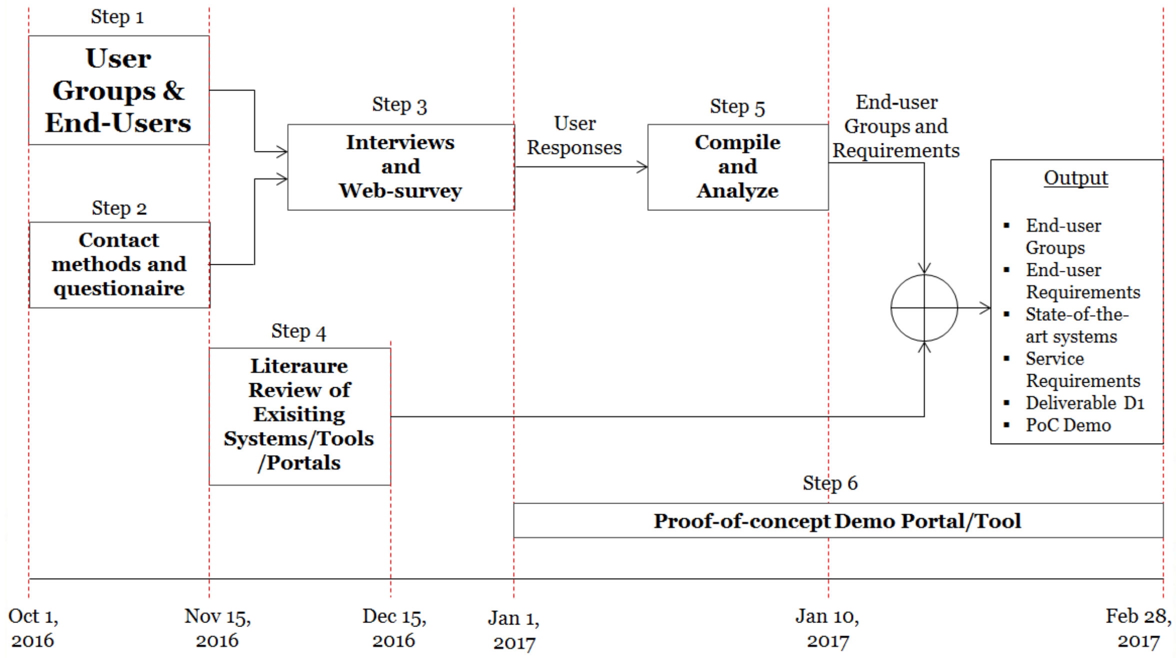


Fig. 1 GLAS project plan for Phase 1 and time schedule

Plan for Future Phases of the Project

With regards to roadmap for service provision, the GLAS-service Phase 1 activity involved identification of end-user categories (market domains) in Finland, a background literature survey of existing similar services in other regions of the World, and ultimately, end-user expectations and requirements for the proposed service. Based on these inputs Phase 1 concluded with a proof-of-concept demonstrator web-service showing a preliminary version of the future service offering. The next paragraphs describe how the project road-map towards full technology implementation.

Phase 2 of the project will use the end-user requirements identified in Phase 1 as the basis. The first task in Phase 2 will be to perform a detailed mapping between the end-user requirements and corresponding technical requirements. The goal is to identify system requirements and to organize them in order of priority – those which will be targeted for implementation within Phase 2 and those which will be implemented in phase 3. Another objective of this task is also to identify those user requirements which cannot be fulfilled as part of this project activity. The next task within Phase 2 includes a detailed system and service architecture design, including a list of hardware, software, inter-modular communication, and system integration needs. This will be followed by the development and deployment of the Initial Operational Capability (IOC) GLAS-service. It is expected that Phase 2 activity will be of 12 months duration.

Phase 3 of the project will include continuous maintenance of the IOC service, accepting end-user feedback and recommendations, planning and executing change requests, and implementing the rest of the user requirements which were deferred for implementation to Phase 3. The result of Phase 3 activity will be the Final Operational Capability, wherein all the identified service and system requirements (including latest end-user feedback on the IOC) will be implemented. It is expected that Phase 3 activity will be of 12 months duration.

The FOC GLAS-service is planned to be hosted by the Finnish Geospatial Research Institute Department of Navigation and Positioning – as the official service provider. This includes the day-to-day maintenance and ensuring the availability of the operational capability. The FGI's Department of Geodesy will be to continue in their role of maintaining the FinnRef stations, which will be the primary source of GNSS information to the proposed GLAS-service. Other stakeholders and end-users identified in Phase 1 will contribute towards raising awareness about the service launch. FGI has previous experience in collaborating with the local news (print, radio, and television) and social media for disseminating most recent developments regarding EGNSS to a wide audience in Finland.

GLAS-service is envisaged as a public service provided by Finnish Governmental agencies to the general public in order to encourage the uptake of EGNSS, foster business in this domain, and provide predictability of GNSS (especially EGNSS) services over Finland. When fully operational, this service will act as a National information infrastructure as well as an enabler for business expansion and consolidation among the diverse companies and applications dependent on GNSS within Finland. Therefore, at the moment we do not foresee any direct paying customers for the service within Finland. However, outside Finland the service is expected to generate interest in Finnish know-how regarding GNSS status monitoring and provision of the service to the general public. We foresee that this expertise can be exported to other countries who wish to establish a similar service, particularly in East Europe, Middle East, South Asia, and South East Asia. Consequently, we foresee foreign national governments or their respective GNSS/communications authorities as paying customers as a result of successful implementation of the GLAS-service in Finland.

4. Executive Summary

As a first step towards this goal, FGI conducted a survey within the Finnish geospatial and navigation community regarding the viability and level of interest towards such an initiative. A web-survey and in-person interview questionnaire was designed to gauge the respondents current work responsibilities, level of EGNOS/GNSS usage, work environment, and need for and expectations from the proposed GLAS-service. In all, 400 persons responded to the web-survey and 4 in-person interviews with experts were conducted. The respondents represented diverse professions dealing with EGNOS/GNSS-enabled PNT regularly in their work, e.g. from land surveying (including National Land Survey of Finland), reference GNSS network stations, weather monitoring, location-based services, transport - maritime, transport – leisure maritime, transport – aviation (including the Finnish National Civil Aviation Authority - Finavia), transport – road (including Aurora SnowBox), transport - rail, system integrators and equipment vendors, machine guidance and agriculture, UAV operators, timing and synchronization, and security. The results showed that a significant majority of the respondents would benefit or definitely benefit from knowing the current and forecasted status of EGNOS/GNSS over Finland. The primary benefits as cited by the respondents were:

- It would provide users a cost-efficient and reliable source of information,
- It would help users to plan the most optimum time and place to perform their GNSS-enabled field operations, by avoiding expected signal degradation or disruption time windows,
- It would help users build new applications and services based on this information,
- It would help users to notify their own customers of upcoming or ongoing disruptions,
- It would help users to effectively compute the errors in the measurements already taken,
- It would help users to identify areas affected by intentional signal jamming, and

- Potential for outreach to uninformed users, thus helping to increase the uptake of GNSS-enabled solutions (especially Galileo and EGNOS) into their products and services.

We acknowledge that EGNOS status information is currently monitored using the reference station in Lappeenranta and available to end-users via the EGNOS User Support webpages maintained by ESSP. The benefits of the proposed GLAS-service are that:

- It will provide an independent assessment of the current and forecasted near-future status of the GNSS systems in addition to EGNOS over Finland.
- The spatial resolution of GNSS/EGNOS status monitoring will improve due to the use of 20 monitoring stations of the FinnRef network.
- The service will provide more local, and hence a more realistic representation of GNSS/EGNOS performance over the entire territory of Finland.
- More sensitivity and freedom in generating alerts to end-users in case of signal degradations.

Opinions were recorded regarding the signals and frequency bands to be monitored, update rate of the information, spatial resolution of the data, and performance parameters as well as performance levels of interest to be monitored.

Following this exercise, a background study was conducted about existing state-of-the-art services similar to the proposed GLAS-service. In all 17 services were identified from throughout the world and compared based on 7 factors: purpose and structure of the service, data source, file/data format, communication protocols, user interface and alerts, monitored parameters, and any other (special) features. The conclusions from this study helped identify some of the common aspects which were observed between the various identified reference services. Based on these conclusions and on the findings from end-user discussions, we have compiled an initial service definition for the proposed GLAS-service. A proof-of-concept demonstrator based on this service definition was implemented as a final step of Phase 1.

5. Identification of End-users

Potential end-users of the proposed GLAS-service were identified in this task. First, broad user groups who are associated with positioning, navigation, and timing were listed. Thus, these user-groups make use of GNSS-enabled PNT in varying degrees in their day-to-day work/activities. Subsequently, example end-users were identified for each of the user groups. These example end-users were categorized into Public/Government agencies/NGOs, Private/industry, and academic/research users.

This list of end-users was used as a basis for contacts to advertise the GLAS-service user web-survey and to request for their feedback and suggestions on the most optimum design for the service. Four of the end-users were selected for in-person and detailed interviews to understand their requirements and viewpoints in more detail. Please note that the end-users listed in Table 1 are only a subset of those contacted during the web-survey. In total, over 2000 persons were sent the request to complete the web-survey.

Table 1. Potential end-user groups and example end-users for the proposed GLAS-palvelu

User Group	Public/Government Agencies/NGOs	Private/Industry	Academic/Research
Land surveying	▪ Maanmittauslaitos ▪ Destia Oy ▪ VR Track Oy ▪ Municipalities ▪ RIL – Finnish Association of Civil Engineers ▪ Geological Survey of Finland (GTK) (http://www.gtk.fi/)	▪ FINNMAP ▪ SKM Gisair Oy (www.skmgisair.fi/en/) ▪ Sito Group (www.sito.fi/en/) ▪ Road Consulting (www.roadconsulting.fi/ ▪ Ramboll Oy (www.ramboll.fi/ ▪ JT-MITTAUS Oy ▪ Terratec ▪ Finnish Consulting Group Oy	▪ Metropolia University of Applied Sciences (www.metropolia.fi/en/academics/degree-programmes-in-finnish/land-surveying/) ▪ Lapland University of Applied Sciences ▪ Aalto University, Dept of Real Estate, Planning and Geoinformatics
Reference networks	▪ FinnRef	▪ Geotrim ▪ Leica Geosystems/ SmartNet Finland ▪ Indagon, Digita	-
Weather monitoring	▪ FMI ▪ Sodankylä Geophysical Observatory	▪ Vaisala	-
Location-based services	-	▪ Suunto ▪ Here ▪ SportsTracker ▪ Polar ▪ Semel – Taksi ▪ Geocaching community- www.geocache.fi ▪ Pokemon-Go! users	▪ Tampere University of Technology, University of Oulu, Aalto University research units on GNSS, indoor positioning, etc.
Transport – Maritime	▪ Port of Helsinki ▪ Finnish Navy ▪ LiVi (and VTS), Trafi, Vesitieverkosto, Finnpilot, Shipowners association LiikenneVirasto ▪ Meriteollisuus ▪ Finnish Marine Directory (Meridiem)	▪ Shipping, e.g. Viking Line Silja Line, Eckero Line ▪ Infrastructure, e.g. Cargotec, Meritaito ▪ Arctia ▪ ESL Shipping, Neste shipping	-

	▪ Finnish Maritime Cluster ▪ HELCOM ▪ PA SAFE ▪ Project VORIC ▪ Finnish Maritime Pilots' Association – forum ▪ Finnish Sailing and Boating Federation		
Transport – leisure maritime	▪ Finnboat ry ▪ Suomen navigointiyhdistys ▪ Saimaan purret ry	-	-
Transport – aviation	▪ Finavia ▪ Suomen Lentäjäliitto – Finnish Pilots' Association ▪ Suomen ilmailuliitto ▪ Finnair	-	-
Transport – road	▪ LVM (Ministry of Transportation) ▪ HSL ▪ ITS Finland ▪ Aurora network	▪ Logistics companies e.g. Matkahuolto. DHL, Posti	▪ Research groups on transportation in Universities
Transport – rail	▪ VR ▪ HSL – raitiovaunut	-	-
System integrators	-	▪ Navdata ▪ Smart Integration Oy ▪ Roger GNSS Oy ▪ uBlox Finland Oy ▪ Space Systems Finland ▪ Exafore ▪ Digia Oyj	-
Machine guidance and agriculture	▪ Destia Oy	▪ John Deere Oy ▪ Ponsse ▪ Sisu ▪ Novatron Oy ▪ Cargotec Oy	-
UAV operators	-	▪ Sharper Shape ▪ Insta Airhow ▪ Pohjonen Group	-

Timing and synchronization	-	▪ Telecom providers (Nokia, Ericsson, DNA, Sonera, Elisa, Digita, FiCom) ▪ Electric power grids (Fingrid) ▪ Banks and stock exchange	▪ VTT MIKES
Security	▪ Poliisi ▪ Rajavartiolaitos/ Border Guard ▪ Defense forces ▪ Huoltovarmuuskeskus/NESA ▪ Hätäkeskuslaitos – Emergency Response Centre Administration	▪ Securitas	-

6. Results from the End-User Web-Survey

This Section describes the conclusions from the web-survey (complete results in Appendix 3) sent to the identified potential end-users of the proposed GLAS-service. As mentioned earlier, invitations to the web-survey were sent to over 2500 email addresses. The web-survey was prepared in both Finnish and English. A large majority of the contacted end-users were from Maanmittauslaitos (National Land Survey of Finland). Approximately, 100-200 email addresses were out of date and hence were discarded.

These results combined with the conclusions from the in-person interviews conducted with four end-users (Section 7) help define the user requirements. These are then combined with the conclusions from literature study of state-of-the-art services similar to GLAS-service (Section 8) to form the initial service definition, as listed in Section 10.

Each of the results listed in this Section is followed with a percentage figure of the respondents who voted for the result. (F) refers to the respondents of the Finnish version of the survey, while (E) refers to the English respondents.

Response Statistics

1. Total responses were 398 (356 for Finnish (F) and 42 for English (E)), of which 196 were complete responses (181 (F), 15 (E)).
2. On average every question was answered by 180 (F) and 20 (E).

Background of Respondents

3. Respondents work location (in descending order):
   - Uusimaa (29.3% (F), 74% (E))
   - Pirkanmaa (12.7% (F), 15.8% (E))
   - Keski-Suomi (6.7% (F))
   - Pohjois-Pohjanmaa (5.7%(F))
   - Varsinais-Suomi (4.9% (F))

- Etelä-Pohjanmaa (4.9% (F))

4. Professional background and work position:
   - Finnish respondents:
     - Asiantuntija (expert/specialist) – 55.4%
     - Päällikkö (leader) – 11.2%
     - Johtaja (senior management) – 7%
   - English respondents:
     - Researchers – 35%
     - Senior management – 25%
     - Project managers – 15%
     - Specialists/Experts – 15%

5. Market segment and application domain:
   - Finnish respondents:
     - Maanmittaus (land survey) – 62.6%
     - Paikannuspalvelut (location-based services LBS) – 8.4%
     - Meriliikenne (transport – maritime) – 6.3%
   - English respondents
     - PNT research – 30%
     - LBS – 25%
     - Maritime transport – 10%

6. Majority of respondents use GNSS-enabled positioning, navigation or timing solutions frequently or very frequently during a week (69.3% (F), 60% (E)). Respondents using GNSS-enabled PNT very rarely or never in their work were (16.9% (F), 15% (E)).

7. An analysis of the primary work environment shows the wide gap between the Finnish and English respondents – Finnish respondents being primarily from the field operations background work mostly in outdoors, rural locations with very good satellite visibility. A significant portion of their work is also in hilly, forested or snow-clad terrain. English respondents being primarily from the research and academic background, their work is mostly in urban, semi-urban, or indoor locations with poorer satellite visibility. They are less likely to experience hilly, forested, or snow-clad terrain. Both groups of respondents work mainly in terrestrial (on-ground) static locations.

Technical Details

8. GNSS signals <u>used by respondents</u> for PNT (descending order):
   - GPS: 95.1% (F), 80% (E)
   - GLONASS: 72.3% (F), 55% (E)
   - Galileo: 19% (F), 30% (E)
   - SBAS/EGNOS: 9.8% (F), 30% (E)
   - BeiDou: 9.2% (F), 40% (E)
   - Signals of opportunity (WiFi, Bluetooth, etc.): 32.6% (F), 45% (E)

   Therefore, by covering the primary GNSS and SBAS signals, the proposed GLAS-palvelu service can cover almost the entire end-user base. A significant minority use signals of opportunity. However, the proposed service is not slated to cover the status monitoring of these signals.

9. GNSS signals which <u>should be monitored</u> over Finland (descending order):
   - GPS: 90.9% (F), 86.7% (E)
   - GLONASS: 77.3% (F), 73.3% (E)
   - Galileo: 64.2% (F), 58.3% (E)
   - BeiDou: 18.8% (F), 33.3% (E)
   - SBAS/EGNOS: 11.9% (F), 33.3% (E)

Please note that the position of BeiDou and SBAS/EGNOS have interchanged as compared to Question 8.

10. GNSS signal frequency bands used by respondents for PNT (descending order):
    - GPS/Galileo/EGNOS L1 (1575.42 MHz): 38.3% (F), 60% (E)
    - GLONASS L1 (1602.0 MHz): 30.1% (F), 45% (E)
    - GPS/Galileo/GLONASS L5 (1176.45 MHz): 27.9% (F), 45% (E)
    - GPS L2 (1227.6 MHz): 30.1% (F), 15% (E)
    - GLONASS L2 (1246.0m MHz): 26.2% (F), 15% (E)

    A minority of respondents use BeiDou L1 (1561.098 MHz) (8.2% (F), 35% (E)), and Galileo E6 (1278.75 MHz) (6.6% (F), 5% (E).

    A significant number (56.3% (F), 40% (E)) of respondents are unaware of the frequency bands under use in their devices during PNT operations.

11. GNSS signal frequency bands which should be monitored over Finland (descending order):
    - GPS/Galileo/EGNOS L1 (1575.42 MHz): 44.4% (F), 78.6% (E)
    - GLONASS L1 (1602.0 MHz): 36.9% (F), 78.6% (E)
    - GPS/Galileo/GLONASS L5 (1176.45 MHz): 38.1% (F), 64.3% (E)
    - GPS L2 (1227.6 MHz): 35% (F), 35.7% (E)
    - GLONASS L2 (1246.0m MHz): 33.1% (F), 42.9% (E)
    - Galileo E6 (1278.75 MHz): 21.9% (F), 35.7% (E)
    - BeiDou L1 (1561.098 MHz): 16.3% (F), 50% (E)

    Please note the larger percentage of respondents requesting the monitoring of Galileo E6 and BeiDou L1, and their interchanged positions as compared to Question 10.

12. PNT receiver equipment used by the respondents (descending order):
    - Finnish respondents:
      - Professional grade multi-GNSS, multi-frequency receiver – 52.5%
      - Professional grade GPS-only receiver – 19.7%
    - English respondents:
      - Smartphone-based or PNA device-based receivers – 42.1%
      - Software/hardware research receiver – 26.3%

    These results once again reflect the broad fact that Finnish respondents were heavily derived from the land survey application area (thus the preference for professional high-accuracy receivers), while English respondents were from the research/academic domain.

13. Most important performance parameter of the GNSS receiver used by the respondents (descending order):
    - Finnish respondents:
      - Paikka- tai aikaratkaisun tarkkuus (accuracy) – 37.2%
      - Laitteen toimintavarmuus/tekniikan luotettavuus (reliability) – 25.6%
      - Vastaanottimen antaman paikka- tai aikaratkaisun sekä tämän virhearvion luotettavuus (integrity) – 22.2%
      - Paikka- tai aikaratkaisun saatavuus (availability of signals & PNT solution) – 9.4%
    - English respondents
      - Accuracy – 42.1%
      - Availability of signals and PNT solution – 26.3%
      - Robustness to errors – 15.8%
      - Sensitivity – 10.5%

14. Performance parameter of the GNSS systems which should be monitored over Finland (descending order):
    - Number of visible satellites of every constellation – 64.2% (F), 84.6% (E).
    - Expected accuracy from the GNSS/EGNOS signals – 64.2% (F), 76.9% (E).
    - Monitoring unexpected failure of the entire GNSS system – option not included in Finnish survey, 76.9% (E).
    - Presence of RF interference – 46.1% (F), 69.2% (E).
    - Monitoring the atmospheric activity (ionosphere scintillation, troposphere, TEC values, etc.) 45.5% (F), 69.2% (E).
    - Number of unhealthy satellites of each constellation – 34.5% (F), 61.5% (E).
    - Monitoring the quality of data products provided by FinnRef network – 19.4% (F), 30.8% (E).

15. FinnRef reference network products used by the respondents (descending order):
    - Real-time differential corrections (DGNSS) – 62.1%
    - Real-time GNSS raw data – 32.9%

    Due to very few (6) English respondents answering this question, results from the Finnish respondents only (140) is provided here.

16. Majority (54.9% (F), 58.3% (E)) respondents agree that knowing the operational status of the various GNSS systems over Finland will definitely benefit end-users to conduct their PNT related work more effectively. However, a significant number (42.2% (F), 46.7% (E)) also feel that though this information would be beneficial, it is not absolutely necessary for their work.

17. Majority (50% (F), 53.3% (E)) respondents agree that knowing the current status of atmospheric effects (ionosphere and troposphere) over Finland will definitely benefit end-users to conduct their PNT related work more effectively. However, a significant number (42.5% (F), 46.7% (E)) also feel that though this information would be beneficial, it is not absolutely necessary for their work. 7.5% (F) respondents feel that this information will not be beneficial to their work.

    Results of Q16. and Q17. show that there is a majority population who will most likely use (and benefit from) the proposed GLAS-service. A significant minority is open to the idea of such a service, although not fully convinced of its overwhelming need. This group of potential users would need to be actively motivated and attracted to use the service through efforts such as a great user-interface, timely notifications and alerts, and provision of non-intuitive information which brings some practical, real-life, and positive change in their PNT related work.

18. Primary benefit of the proposed GLAS-service (descending order):
    - Finnish respondents:
        - Se auttaisi valitsemaan parhaan ajankohdan ja paikan GNSS-pohjaisten mittausten (It would help to choose the best time and place for GNSS based measurements) – 43.1%
        - Mittauksen suunnittelussa voisi paremmin varautua GNSS-signaalin häiriöihin (it will help me be prepared with a back-up solution in case of any disruptions) – 24.0%
        - Sen avulla voisi paremmin tiedottaa asiakkaille mahdollisista häiriöistä ja laadun (I would be able to better inform my customers about possible disturbances and expected quality of GNSS signals) – 13.2%
        - Sen avulla voisi kehittää sovelluksia ja palveluita (It will help me build new applications and services based on this information) – 8.4%
    - English respondents

- It will help me effectively compute the errors in the measurements (E) have taken – 27.7%
- It will help me build new applications and services based on this information – 26.7%
- It will help me estimate the performance of my position-based products and services – 20.0%
- It will help me be prepared with a back-up solution in case of any disruptions – 13.3%

The difference in the Finnish and English respondents is a reflection of their primary work environments and tasks. As the Finnish respondents were primarily from land surveying/industrial/field operations background, their interest in GLAS-service was in its benefits towards optimum planning of the time and place of making their outdoor measurements and field work. Secondly, the service would benefit in planning a back-up solution in case of an upcoming signal degradation or disruption.

English respondents were primarily from the research/academic domain and hence preferred the service to help in computing the errors in the PNT measurements and solutions. Secondly, the service (and its information) may prove valuable as a possible platform to develop new applications and services.

In conclusion, for persons who depend on PNT for their day-to-day operations the primary benefit of the proposed service is in the <u>planning stage</u> of their work. Therefore, the users in this group would prefer <u>forecasted status information</u> on a constellation level.

For persons who use PNT in research or academic domain the primary benefit is in the <u>computation and implementation stages</u> of their work. The users of this group would prefer more <u>detailed and accurate historical or current information</u> on a signal level.

19. Majority of respondents would like to be notified of major events (ongoing or predicted disruptions/degradation in GNSS performance) over Finland via traditional channels such as SMS and email, rather than over social media such as Facebook or Twitter etc.

20. Level of GNSS signal quality degradation at which respondents would like to be notified (descending order):
    - In case of large measurement errors – 42.9% (F), 50% (E)
    - Complete denial or unavailability of a GNSS system – 22.9% (F), 7.1% (E)
    - In case of degraded signal power (RF interference) – 17.6% (F), 21.4% (E)
    - Respondents would like to specify the notification criteria themselves – 15.9% (F), 14.3% (E)

21. Majority of respondents (69% (F), 78.6% (E)) would like the notification to be sent to end-users either immediately or within a few minutes of realization of an upcoming or ongoing event.

22. Majority of respondents (75% (F), 64% (E)) would prefer a map-based user interface to display the service information. The next popular choice was a visual interface with x-y plots, scatter plots, statistical distribution diagrams, etc. A minority of respondents were interested in a machine and human readable text-based information format – (*possibly to be able to automatically source information from the service to external applications?)*.

23. Update frequency of information on the service web-page (descending order):
    - At least once every minute – 35.1% (F), 71.4% (E)
    - Once every 10 minutes (more relaxed update rate) – 31% (F)

24. Acceptable spatial resolution of the information provided by the service (descending order):
    - Better than 20 km radius – 43% (F), 38.5% (E)
    - An area of 100 km radius – 40% (F), 38.5% (E)
    - An area of 200 km radius – 16% (F), 15.4% (E)
    - An area of 400 km radius – 1% (F), 7.7% (E)

    This result indicates that the respondents would prefer to have very local (immediate surrounding) information.

25. Other significant comments from respondents:
    - A number of end-users use data provided by commercial virtual reference station networks such as TrimNet from GeoTrim, SmartNet from Leica, etc. (*The information and service provided by GLAS-service will be based on data provided by the FinnRef reference network, which is a public network of 20 reference stations over Finland*).
    - Suggestions about which existing standards should be used in the proposed service include: Ntrip, RTCM3, XML, JSON, and Earth Observing System (EOS).
    - Generally, end-users would not prefer to work with a new data or communication format, protocol, or standard. Existing and open standards should be used as much as possible.
    - Additional information or data products may be provided via a web link rather than crowding on the front page.
    - Service should be provided as a smartphone application in addition to computer-based web service.
    - Construction/earth excavation, emergency/security services, and timing are also potential end-user domains for the proposed service.
    - It would be useful to have very simple information, such as the expected error (in meters) in position computation under good conditions using a mobile phone receiver.
    - Traffic light interface with a corresponding rating of the situation on a scale of between 0 and 1.
    - A number of users were concerned about the reliability of the proposed GLAS-service itself. There should be some guarantee of its reliability and notification if the service will be temporarily out of function. One way to guarantee continued (24/7, 99.9%) availability is to host the service on multiple servers, perhaps a few outside Finland, if necessary.

Short Conclusion

As a first step towards this goal, FGI conducted a survey within the Finnish geospatial and navigation community regarding the viability and level of interest towards such an initiative. A web-survey and in-person interview questionnaire was designed to gauge the respondents current work responsibilities, level of EGNOS/GNSS usage, work environment, and need for and expectations from the proposed GLAS-service. In all, 400 persons responded to the web-survey. The respondents represented diverse professions dealing with EGNOS/GNSS-enabled PNT regularly in their work, e.g. from land surveying, reference GNSS network stations, weather monitoring, location-based services, transport – maritime, transport – leisure maritime, transport – aviation, transport – road, transport – rail, system integrators and equipment vendors, machine guidance and agriculture, UAV operators, timing and synchronization, and security. The results showed that a significant majority of the respondents would benefit or definitely benefit from knowing the current and forecasted status of EGNOS/GNSS over Finland. The <u>primary benefits</u> as cited by the respondents were:

- It would provide users a cost-efficient and reliable source of information,

- It would help users to plan the most optimum time and place to perform their GNSS-enabled field operations, by avoiding expected signal degradation or disruption time windows,
- It would help users build new applications and services based on this information,
- It would help users to notify their own customers of upcoming or ongoing disruptions,
- It would help users to effectively compute the errors in the measurements already taken,
- It would help users to identify areas affected by intentional signal jamming, and
- Potential for outreach to uninformed users, thus helping to increase the uptake of GNSS-enabled solutions (especially Galileo and EGNOS) into their products and services.

Opinions were recorded regarding the signals and frequency bands to be monitored, update rate of the information, spatial resolution of the data, and performance parameters as well as performance levels of interest to be monitored.

7. Conclusions from the End-user In-person Interviews

In-person interviews were conducted with 4 end-users to understand more clearly expectations from the proposed service. The details of the interviews are provided in Appendix 1. This Section is a summary of the most significant conclusions from this exercise.

- By basing GLAS-service on data sourced from the FinnRef network will help to accord a degree of credibility and reliability to the service.
- The service should provide real-time updates about the GNSS status, predictions of upcoming disruptions or degradations, and historical trends.
- Forecasting should be provided few hours to 2-3 days in advance.
- Significant GNSS status parameters to monitor depend upon the application domain of the end-users. However, the most important are:
  - Availability of healthy visible satellites (and Dilution of Precision), signals, and the entire GNSS system.
  - Total expected error on every satellite measurement.
  - Expected PNT accuracy or degradation in accuracy.

  In general, all parameters which can be derived from data provided by FinnRef should be eventually monitored.
- User interface: the service should be internet-based and available on a computer as well as smartphone platform. This will help access to the service from remote locations as well.
- The UI should be easy to use, with concise information, graphical display of the data (including heat maps, traffic light interface, etc.), and possibility to download or view additional data and information via links on front page.
- The service should use existing data standards and formats.
- Alerts and notifications should be used to inform users of upcoming or ongoing events. Notifications should be sent via SMS or email in real-time (i.e. as soon as the event has been realized). Notifications to aviation personnel regarding status of navigation systems are standardized to the Notification to Airmen (NOTAM) format.
- Update rate of the data on the service: 15 minutes to 1 hr update rate is sufficient in most cases. Ideally it would be beneficial if the frequency is adaptable based on user preference, or on changes in the prevailing GNSS conditions, or in parallel with the update of ephemeris (to be informed of unhealthy satellites).
- Historical data can be available on a per-day basis.

Future requirements from the service:

- The service should use and display more local data, for example from additional receivers installed at critical locations – which could help monitor radio frequency interference and disruption areas.
- Make the service more flexible by allowing the users to configure the different service parameters such as: frequency of data update, thresholds to send alerts and notifications, thresholds to configure the traffic light interface, etc.
- Density of the reference data should be as good as few kms in radius.
- GNSS status information at altitudes of 10-40 km to cater to aviation and weather monitoring end-users.
- The heat map interface can provide additional information by superimposing multiple maps on top of each other – for example laser scanning data or meteorological data over GNSS status data will help identify effect of heavily forested areas or uneven weather.
- Raw GNSS data from FinnRef can be used to in Geodesy applications to show deformation in co-ordinate systems or motion of the Earth's crust.
- The GLAS-service should be designed so that it provides some benefits directly to registered GNSS receivers (e.g. differential corrections?) in case of an ongoing degradation event.

8. Conclusions from Literature Survey of State-of-the-art Services similar to GLAS-service

17 state-of-the-art services similar to the proposed GLAS-service were identified and analyzed (please refer to Appendix 2). These 'references' were compared based on 7 factors: purpose and structure of the service, data source, file/data format, communication protocols, user interface and alerts, monitored parameters, and other (special) features. The following points list briefly the conclusions from this study. They state the **common aspects which were observed between the various identified reference services**. This study is expected to provide input for the initial service definition of the proposed GLAS-service.

- **Purpose of the services:**
    - Performance monitoring of GNSS and SBAS systems and associated services.
    - Monitoring the performance of reference stations.
    - Monitoring space weather and Earth's atmosphere.
    - Special geo-physical measurements of the Earth.
- **Structure of the services:**
    - Modular – independent processing modules and an ability to add or remove modules as necessary.
    - Scalable – ability to expand the scope and functionality of the service through the addition of reference stations.
    - Physical structure – consists of a core central data processing and management engine with auxiliary modules for specialized functions.
    - Flexible – the services and their structures are to an extent customizable or configurable to user requirements.
    - User interface – most of the services are offered as software, either as a dedicated computer-based tool or an internet-based application.
- **Data sources for the services:**
    - Reference stations, both private and public, and using Ntrip casters.

    - Satellite transmissions, external sensors, camera, and the GNSS system's own ground control station.

- **Frequency of data update** is around once every second to once every 5 seconds for raw data, and once every hour to once every 24 hours for processed information.
- **File/data formats** supported by the services: RTCM (2.x, 3.x), RINEX (2.x, 3.x), IONEX, SINEX, NMEA, and text-based. The most frequently used database platform was MySQL.
- **Communication protocols** supported by the services were TCP/IP and Ntrip.
- **User interface and alert notifications:**
    - Graphical user interface options include traffic light and color coded visuals based on the different grades of errors and events.
    - Statistical tools, scatter plots, sky plots, time series graphs, interactive and heat maps, etc.
    - Text-based interpretation of the data also provided in certain scenarios.
    - Internet-based access, available as a webpage or computer-based application.
    - Maps are divided into geo-regions for better resolution of the data.
    - The webpages are designed so that separate regions of the page are dedicated to one GNSS or one satellite. This makes the information easy to read and interpret.
    - The services compile monthly and yearly performance reports which are archived and available on the webpages.
    - Alert notifications are sent in NANU (notice advisory to navigation users) format via SMS or email. These alerts are also archived on the service webpage.
- **Monitored parameters by the services:**
    - Performance of GNSS and SBAS systems and associated services:
        - accuracy estimates (user equivalent and differential range errors UERE, UDREI, etc.).
        - Availability.
        - Satellite status, visibility, outage, DOP, range errors, elevation.
        - Signal to noise ratio SNR.
        - Integrity.
    - Performance of DGNSS, network RTK, and PPP data.
    - Integrity of reference station data.
    - Geo-physical parameters of the Earth: Geo-deformation/displacement, seismic activity, stability of co-ordinate reference frames, Earth's magnetic field.
    - Space weather, cosmic radiations.
    - Ionosphere thickness and scintillation (S4), Total Electron Content (TEC), Rate of TEC Index (ROTI), Grid Ionospheric Vertical Error (GIVE), plasma content (VTEC), etc. (It can be observed that the Troposphere is not monitored by any of the reference services).
    - GNSS interference, local multipath environment, cycle slips, etc.
    - Receiver Autonomous Integrity Monitoring (RAIM) availability.
    - External sensor performance.
- **Special features of the services:**
    - Capability to compile and export performance reports and event logs in different (PDF, CSV, etc.) file formats. They are archived on the webpages.
    - Raw data and historical data archived on webpages and available for download.
    - Real-time services, forecasted predictions.
    - Email help-desk facility.
    - End-user registration to avail additional benefits, such as notifications, alerts, and data download permissions.

9. Description of the FinnRef Network

The previous Sections of this document described the expectations and requirements from the various stakeholders and end-users of the proposed GLAS-service. This Section describes FinnRef – one of the possible sources of GNSS data which will be used by the proposed service in the initial phase of technology development. Please note that this does not restrict the use of other publicly available GNSS data sources, such as International GNSS Service (IGS), etc. in future updates to GLAS-service.

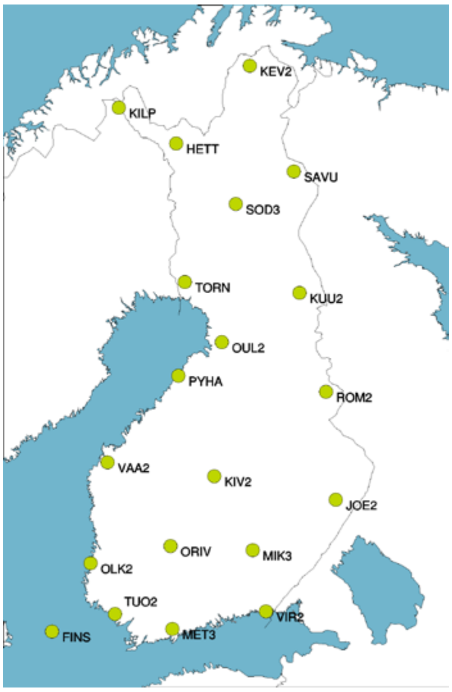


Fig. 2 FinnRef stations and their location in Finland

It is important to list the data products and other technical capabilities of the FinnRef network here, before proceeding to developing the initial service definition for GLAS-service.

The FinnRef network has been renewed in 2012-2013. The renewed FinnRef network consists of 20 GNSS reference stations distributed over the territory of the country (Fig. 2). All stations receive signals from all the presently available global satellite navigation systems. More information can be obtained from the homepage of FinnRef (http://euref-fin.fgi.fi/fgi/en/positioning-service/finnref-stations).

FinnRef network is part of a Nordic GNSS network, which was established on the initiative of the Nordic Geodetic Commission and the Director Generals of the Nordic Mapping Authorities in 1990's. Some of the stations belong to the global IGS network and to the European Permanent Network (EPN).

One of the main tasks of the FGI is to carry out national geodetic base measurements and tie them to the respective measurements of neighboring countries and international systems. Observations of the FinnRef network enable this connection and the frame for the national EUREF-FIN coordinate system.

Data products provided by FinnRef are described here (as discussed in the in-person interview with Geodesy specialists):

- Data provided by the public interface of the FinnRef stations include differential corrections, both in RTCM (2.x, 3.x) format over Ntrip and with 1 Hz rate.
- Raw multi-GNSS multi-frequency data is currently available through the research interface. This data will soon be available through the public interface via EUREF's casters (stations applied to the EUREF permanent GNSS network.
- These data can be accessed using the Ntrip client on any platform.
- The reference station receivers support GPS, Galileo, GLONASS, BeiDou, and EGNOS systems. Although the GNSMART software supports at the moment only GPS, and GLONASS.
- The post processing data is collected in hourly files from each station separately and pushed to one common data server.
- Error modelling from the captured GNSS signals (e.g. tropospheric and ionospheric errors) is performed by the GNSMART software platform, and the errors are parametrized using the state-space representation (SSR) model.
- The differential corrections provided by the DGNSS service indicate the lump-sum error encountered in the GNSS signals at the reference stations.

10. Initial Service Definition for GLAS-service

Table 2 lists the initial service definition for the GLAS-service based on the conclusions from the stakeholder (and end-user) analysis, state-of-the-art services study, and possible data sources. These requirements are divided into those which will be implemented in the first roll-out of the service, and those which will be implemented in future when the relevant data sources and computational resources may be available. Accordingly, the future requirements are specified separately in each row.

Please note that the planned proof-of-concept demonstrator at the conclusion of this phase of project activity will show a subset of these functionalities!

Table 2. GLAS-service Initial Service Definition

Service Feature	Service Description
General service Definition	▪ Unregistered users are shown general (common) data/front-page. ▪ Users can register their mobile phone number and email to receive alerts and notifications. ▪ Users can provide their location co-ordinates to receive local information. ▪ Data sources may be expanded in the future – more public networks and services (e.g. IGS, EDAS), external sensors, private networks, etc. ▪ The service will be operational continuously 24/7, with 99.9% availability (maximum downtime of 1.68 hrs./week).
GNSS parameters to monitor	▪ GPS & GLONASS L1 and L2 frequency bands, EGNOS ▪ Availability status of the entire GNSS system ▪ Number of visible healthy satellites, DOP, elevation angles ▪ Details of unhealthy satellites ▪ Total range error and SNR on every visible healthy satellite

	▪ Ionosphere: VTEC, ROTI, delay ▪ Troposphere: delay ▪ Satellite orbital errors and clock errors ▪ Positioning accuracy at FinnRef stations: 95% CEP time series. Comparison between accuracy with and without DGNSS, SSR, EGNOS corrections. ▪ Accuracy improvement using EGNOS corrections Future Requirements ▪ Status and other parameters of Galileo, BeiDou ▪ L5 frequency band ▪ Ionosphere: scintillation (S4), GIVE ▪ Possible GNSS signal jamming events ▪ Availability of additional monitoring data (in case special-purpose receivers are included into the network) ▪ Solar activity, geo-physical parameters of the Earth ▪ Prediction/monitoring of GNSS parameters at altitudes of 10-40 km.
Update rate of the information	▪ Real-time data : 1 Hz (once every second) ▪ Near real-time: once every minute ▪ Current: Once every hour ▪ Historical: Once every day ▪ Predictions: For next calendar day Future Requirements ▪ Predictions will be provided 2-3 calendar days in advance.
Data formats, protocols, etc.	▪ The service should support RTCM 3.x data standard, Ntrip over TCP/IP communication protocol. It should support data sourcing in text format via SFTP protocol. Future Requirements ▪ The service should support RTCM 2.x data standard, NMEA, RINEX, IONEX, SINEX.
User interface	▪ The service will be internet-based accessible via a web-interface. ▪ It will be accessible on a computer (Windows OS) as well as smartphone platform (Android, Windows, iOS). ▪ Language of information display: Finnish, Swedish, and English ▪ Front-page will contain most significant data with web-links to more detailed information or data download options. ▪ Information will be displayed graphically using heat maps, color codes, traffic lights, time series plots, and statistical tools. ▪ Notifications and alerts: SMS and email alerts will be standardized to NANU/NAGU format. Alerts will be sent immediately (as soon as an ongoing or predicted event is realized) and archived on service website. Future Requirements ▪ User configurability of thresholds, update rate, criteria for alert, etc.
Density of the reference GNSS data	▪ Determined by the density of the reference network from which the GNSS data is sourced (in the first implementation roll-out data will be sourced from the FinnRef network, which offers a density in the order of tens of km between each reference station). Future Requirements ▪ Additional sources of reference GNSS data (e.g. additional

	monitoring stations deployed at critical locations for detecting the presence of signal jamming) can be included in the service.
Historical data	▪ All data produced by the FinnRef network and used by GLAS-palvelu will be archived for a period of 24 months. ▪ Historical trends will be accessible and visible to users.
Other future requirements	▪ Periodic reports (monthly, yearly) about GNSS status in Finland and gaps in data. ▪ Data for user download.

11. Proof-of-Concept Demonstrator Service

This section describes briefly the proof-of-concept demonstrator service implemented as a prototype of the proposed GLAS-service, whose general architecture is shown in Fig. 3. The service is accessible via a web-interface. The GNSS data are provided by the FinnRef network and processed on a local server at the Finnish Geospatial Research Institute. The processed information is then transferred to the web-server which hosts the service website.

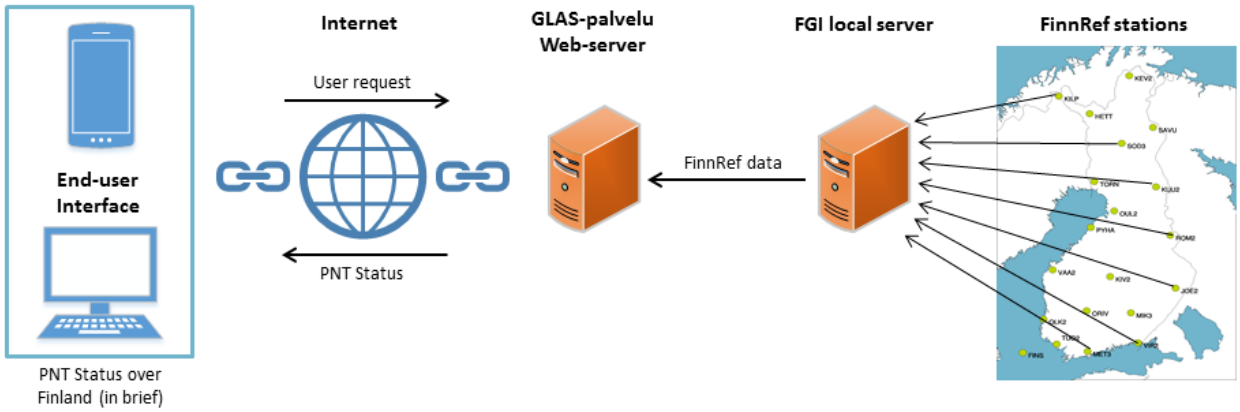


Fig. 3. GLAS-service proof-of-concept demonstrator architecture

The home page contains general information about the GNSS (only GPS at the current stage) signals quality at the various FinnRef stations (Fig. 4). A map of Finland shows the FinnRef stations' location, and a colored circle describes the status of the GNSS signals received at every station.

Three colors are used: green indicates very favorable GNSS status, orange indicates acceptable GNSS status, and red indicates unfavorable GNSS status. Since the criteria to classify the GNSS conditions as favorable, acceptable or unfavorable depend on the end-users application domain, in the final version of GLAS-service, registered users will be able to specify the thresholds to configure the colors code and then visualize personalized information. In the main page of the website, the FinnRef stations are also listed in a table containing the station identification code, the name of their location and their color-coded status. A tooltip on the “Status” column header of the table provides the user with a brief explanation of the colors code.

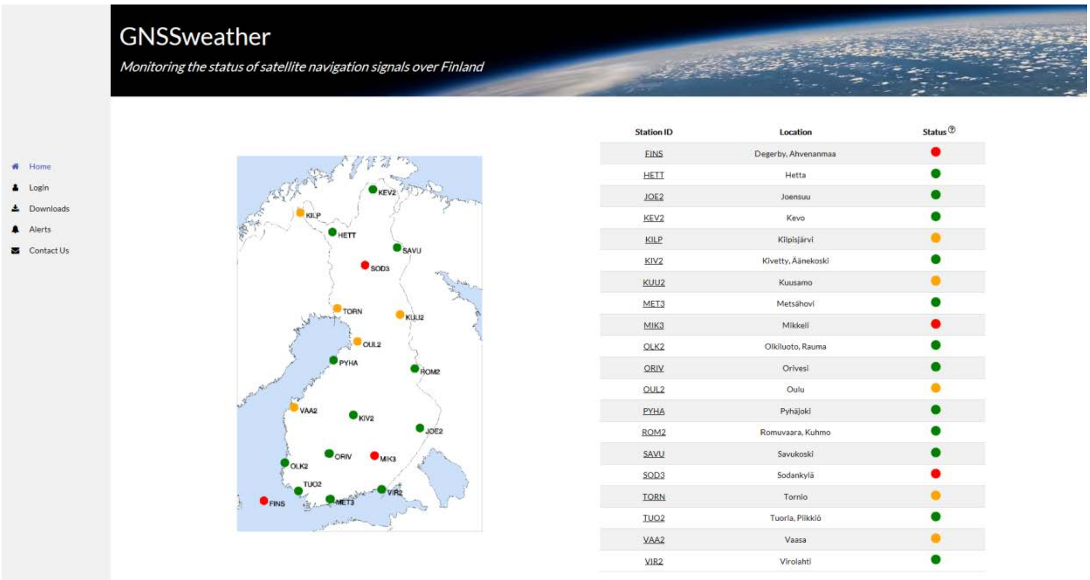


Fig. 4. Home page

By clicking on a colored circle on the map or on a station identification code in the table, the user accesses the detailed information about the corresponding FinnRef station. The “Station” page is shown in Fig. 5.

The station’s location name and coordinates (latitude and longitude) are displayed in the upper part of the page, together with a hoverable dropdown menu which allows the user to select any other FinnRef station and visualize the relevant information. Real time information at 1 Hz (once every second) is provided about several performance parameters: horizontal and vertical errors in the positioning solution, number of satellites visible from the station, Dilution of Precision, and pseudorange error for each visible satellite. The color of the bars in the pseudorange error chart can be green, orange or red, depending on the error magnitude for the corresponding satellite. The color-coded status of the satellites’ measurements is also shown in a table, containing the satellite ID and its status. A tooltip on the “Status” header provides the user with a brief explanation of the color code. In the final version of GLAS-service, the criteria to configure the color code, as well as the data update rates, will be adaptable based on the users’ preferences.

A sidebar menu allows the user to navigate through the website pages. The “Login” page would allow registered users to access more detailed and personalized information, whereas the “Downloads” page would allow registered users to download preferred data once they have logged in. Alerts and notifications sent to registered users via email or SMS to inform them of ongoing or upcoming events are archived in the service website and shown in the “Alerts” page table (Fig. 6). For each notification to the users, the table contains the identification number, the starting date (day and time) of the reported event, the date (day and time) in which the notification was sent, and the message’s content. The archived information is visible to both unregistered and registered users.

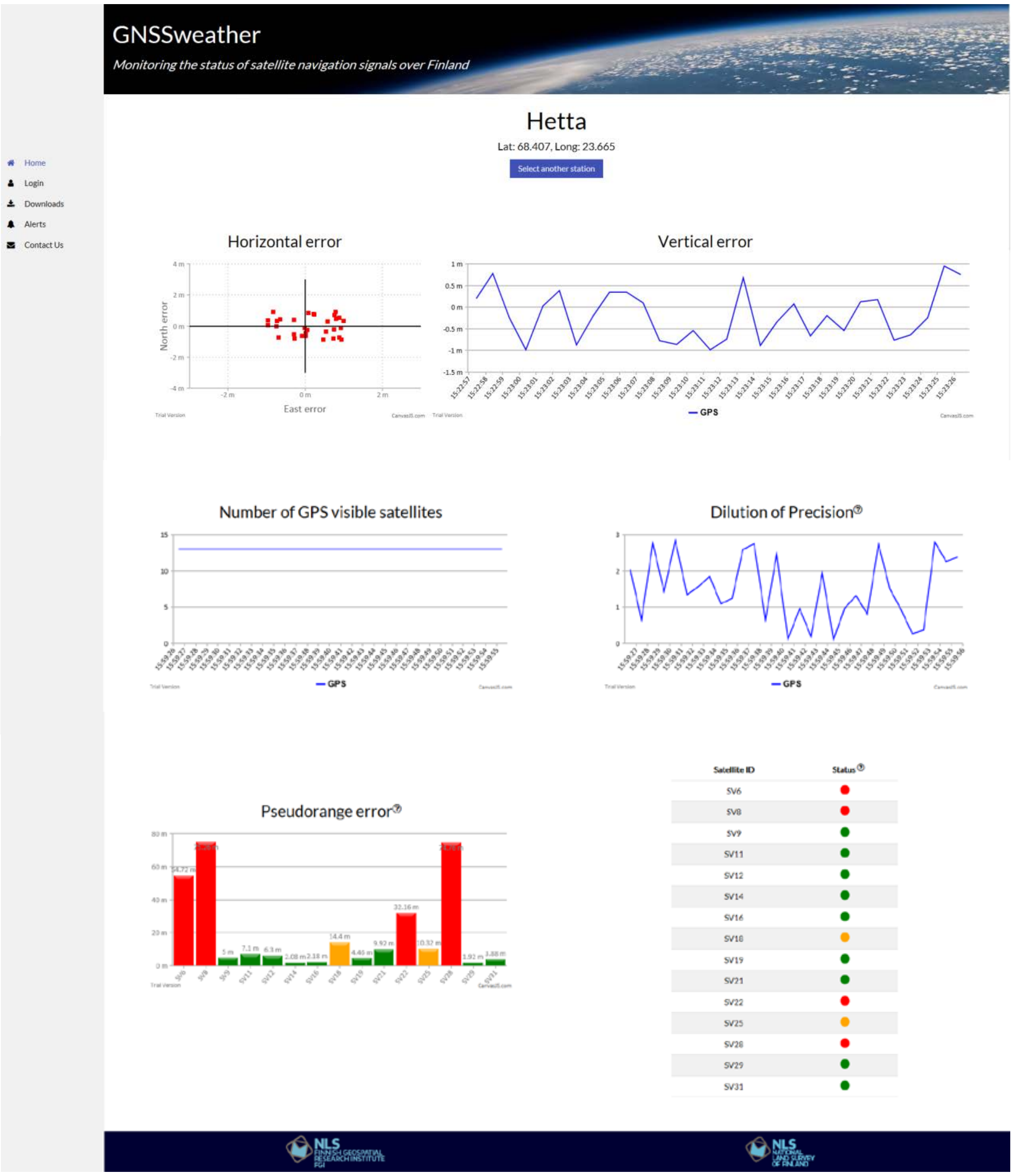


Fig. 5. Station page

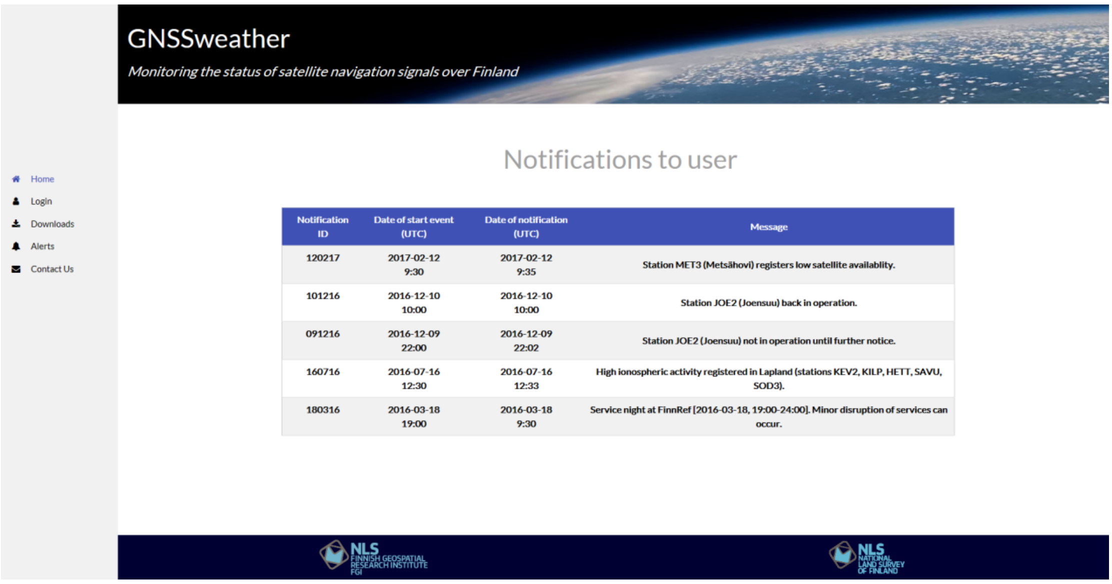


Fig. 6. Alerts page

Finally, any visitor can contact the Finnish Geospatial Research Institute for any issue related to GLAS-service through the “Contact Us” section (Fig. 7) at the bottom of the home page. Both contact details (address, telephone number and email address) and a form to directly send a message are provided in this section.

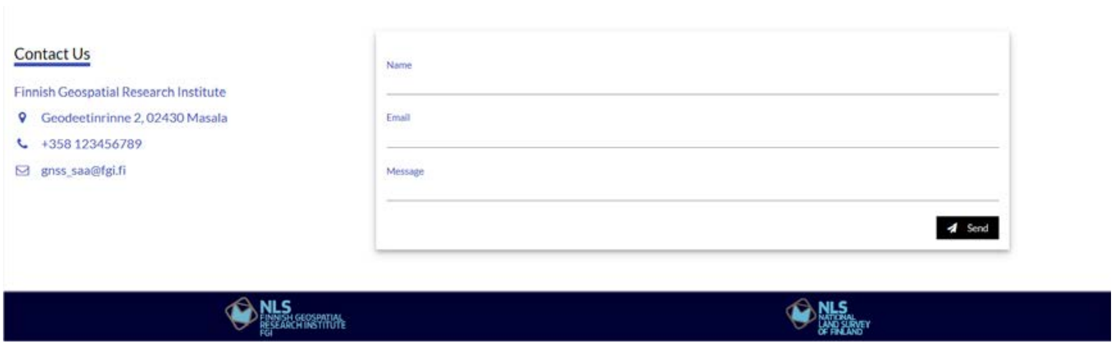


Fig. 7. Contact section

The proof-of-concept demonstrator implements only the basic functionality of the service. The next phase of the project will include a more detailed service and technology design for the other functionalities that have been identified and reported in this document (e.g. monitoring of other satellite systems in addition to GPS, heat maps showing PNT status all over Finland and not just at the FinnRef stations, monitoring of ionospheric activity, etc.).

Appendix 1: Details of End-user In-person Interviews

Interview 1: Land Survey

- The role of the interviewee's Department is to support field surveyors, procure RTK devices and test equipment (decide on the best alternative among different vendors and to make the purchase contract), provide background education/training to the field officers, and in few instances also provide actual production surveying services. The Department is not responsible for programming and maintenance of the equipment as that is the role of the dealer/manufacturer.
- Process of land surveying and the role of GNSS: it depends a lot on the actual surveying task. The legal requirement is that every surveying assignment has to be declared to the public at least two weeks in advance.
- Some surveyors may verify the background GNSS status before leaving on the assignment. The field officers are instructed during the training that they should study the terrain and GNSS situation in advance of a field survey. This enables them to locate the best time and place to perform their measurements, especially in open fields and/or forests.
- In general, the supervisors of the field officers do not plan the surveys. It is the field officers themselves. Therefore, they are the primary end-users.
- The proposed GLAS-service will be beneficial if the GNSS status is monitored via signals and data collected at the FinnRef stations. Before leaving for field work, land surveyors can have a place to verify the status of GNSS systems over the target area.
- Specific requirement: for a prediction 2/3 days in advance of the ionospheric effect over the target area of the survey. This predicted future status in addition to the actual conditions of the systems and errors at the present instant would be beneficial.
- GLAS-service should be available via internet and a smartphone-based application. This is because surveyors can be on a field trip for 4 days of a week. It may sometimes be 2-3 weeks before field officers return to their work-desks, and during this period, the only means of online connection is via smartphones.
- Although cellular service is widespread over Finland, there are few remote places where there is no coverage.
- The update rate of the data on the service should be equivalent to the update rate of the ionospheric predictions and update rate of the ephemeris (to determine the health status of individual satellites).
- The most important GNSS performance parameters are accuracy (of position solution), ionospheric errors, and availability (of satellites, signals, and the complete system). Therefore, these parameters should be monitored by the proposed service.
- Performance requirements of the proposed service are:
    - ease of use,
    - avoid information overload – provide only the most significant information on front-page with links to go to pages with more details if the user wishes,
    - available as smartphone app,
    - traffic-light interface rather than plain text, separate traffic lights interface for each of the GNSS systems,

    - heat-map interface also desired, with the map centered on the user's current location (or user provided co-ordinates),
    - notifications and warnings to users of ongoing/upcoming events,
    - the definition of an event should be user configurable. i.e. the user should be able to configure the thresholds of errors when the system should send warnings/notifications,
    - most critical warnings should be sent via SMS to mobile phones.
    - information should be displayed with a spatial resolution of a few km,
- Laser scanning data should be superimposed on the map-based interface to pinpoint areas of dense forests where GNSS signals may possible be interfered with. This LSD is open data and can be accessed by online file service.

Interview 2: Geodesy

- Data provided by the public interface of the FinnRef stations include differential corrections, both in RTCM (2.x, 3.x) format over Ntrip and with 1 Hz rate.
- Raw multi-GNSS multi-frequency data is currently available through the research interface. This data will soon be available through the public interface via EUREF's casters (stations applied to the EUREF permanent GNSS network.
- These data can be accessed using the Ntrip client on any platform.
- The reference station receivers support GPS, Galileo, GLONASS, BeiDou, and EGNOS systems. Although the GNSMART software supports at the moment only GPS, and GLONASS.
- The post processing data is collected in hourly files from each station separately and pushed to one common data server.
- Error modelling from the captured GNSS signals (e.g. tropospheric and ionospheric errors) is performed by the GNSMART software platform, and the errors are parametrized using the state-space representation (SSR) model.
- The differential corrections provided by the DGNSS service indicate the lump-sum error encountered in the GNSS signals at the reference stations.
- Pre-processing on the FinnRef data may be necessary if more complex information needs to be extracted from the data.
- Efforts are ongoing to set-up a service which will monitor the quality status of the FinnRef services and data products. Therefore, the GLAS-service should concentrate on monitoring the quality of the overall GNSS systems (and not the FinnRef services).
- If the data from FinnRef is used for the GLAS-service, an intermediate server would be necessary for temporary storage and pre-processing (if required) of estimated parameters output from GNSMART. Another reason is that currently, error modelling data provided from GNSMART is archived but tools necessary for its analysis are unavailable.
- Real-time information to end-users regarding any anomalies in the different GNSS systems – possibility for outreach to general public.
- In case end-users notice an anomaly with their PNT solutions, GLAS-service should be the first service they turn to cross-check if there is anything wrong with system availability, reliability, active ionosphere, etc.
- For geodesy, the proposed service may be beneficial if it can:
    - work directly on the raw data (instead of using the estimates or pre-processed data from GNSMART),

    - provide a more scientific way to determine the quality of raw data or positioning service provided by FinnRef,
    - analyze and display to end-users the quality of historical GNSS data collected and stored by FinnRef,
    - use the FinnRef data to display the movement of the Earth's crust or deformation in co-ordinate systems,
- Other requirements from proposed service:
    - option to predict/forecast the GNSS quality in future (one hour or for next day),
    - warnings and alerts of upcoming or ongoing events via SMS and email,
    - All data that can be accessed via FinnRef stations should be available to the end-users of the GLAS-service, however only if demanded by the user. Otherwise, the front-page interface should be simple with most critical data on front.
    - Frequency of updated information should be allowed to be configurable by the end-user (performed by integrating the 1 Hz FinnRef data over the interval configured by the end-user).
    - Hourly updates are also sufficient.
    - Alerts and notifications however, should be sent immediately based on the original 1 Hz data received from FinnRef.
    - Spatial resolution of the service can be same as FinnRef stations – divide Finland based on already recognized administrative regions and allow user to choose the region of interest.
    - Use graphical interface and ensure that fresh perspectives on existing data are displayed.
    - Provide the service over a smartphone application.
- Advise: start simple, use GNSMART and other existing software solutions as much as possible, monitor all parameters provided by the data.

Interview 3: Aviation

- Finavia is responsible for maintaining airports and providing air navigation services, aeronautical information services, and flight procedures. It provides an interface to GNSS as a navigation sensor. Technical support Department takes care of terrestrial systems of navigation while GNSS services are provided by external service providers.
- In the aviation sector there are two user groups of GNSS: flight operators (airlines, pilots, etc.) and air navigation services providers like Finavia. While providing services enabled by GNSS to airspace users, it is in the interest of Finavia to make sure that the applicable GNSS services are reliable.
- The status information of GNSS is very important before starting the flight and over the entire planned route. Therefore, both real-time and predicted/future status information could be necessary.
- NOTAM (Notice to Airmen) is the usual method of providing updates on ongoing or upcoming anomalies in equipment behavior to the flight operators. This is usually provided before the flight plan is finalized.
- Receiver autonomous integrity monitoring (RAIM) and GNSS augmentation using satellite-based or aircraft-based augmentation systems (SBAS/ABAS) are used in aviation.

- Currently, DFS (Germany) and Eurocontrol provides these RAIM prediction services to (some) airports in Europe and ESSP provides the EGNOS outage predictions to be promulgated by NOTAMs
- Predicted GNSS outages are provided to pilots. EGNOS NOTAM service by the European Satellite Services Provider (ESSP) provides information on EGNOS outages. Currently, in Finland only Joensuu airport has EGNOS enabled landing/approach assistance facility.
- For the end-users in aviation, the interface should provide very brief information on the status of GNSS/EGNOS – Yes/No – is GPS/RAIM usable or not – now and in the future when the plane is along its planned route.
- Air Traffic Controllers also receive NOTAMS. They could also be potential end-users of the GLAS-service, but development of such an operational system is complex and expensive because of strict regulatory requirements and the foreseen additional benefit of having such information available for ATCOs is limited. At the moment, they simply assume availability of GNSS. If a plane reports problems in navigation equipment, it is reported by ATC to other aircraft (in future, they can possibly verify this information from GLAS-service).
- GNSS status monitoring needs of ATC have been discussed for some time already on the international level. These discussions are still ongoing, but so far it has not agreed on the international level to require any real time monitoring capabilities.
- The challenge in aviation is that the status of GNSS will be measured at FinnRef stations on the ground. However, the end-user receiver is in the air at a height of few meters to 10 km. Conditions can be very different at these two locations.
- Eurocontrol also plans to provide status monitoring of GPS and EGNOS, however benefit of GLAS-service is that the reports would be based on more local GNSS data collected based on a denser network of reference stations.
- The proposed service can provide support for research and service development done by Finavia itself.
- The proposed service should:
  - show historical trends, timelines of major events and thus point out trends in GNSS activity.
  - Clearly mark the geo-area of impact of unavailability.
  - provide an additional layer of information in addition to NOTAMs. NOTAMS are based only on known problems in the GNSS systems and satellites. It is not based on local environmental, atmospheric, geo-magnetic, radio interference etc. conditions. This data can complement NOTAMS by providing more local information.
- The proposed service will need to go through a formal approval and accreditation process to be operational in the aviation community. However, at this point this need not be a primary objective. It should be sufficient if the service is operational and provides useful information (to be freely available as an additional reference to the end-users)
- Rate of information update: between 15 minutes and 1 hr should be sufficient. For historical data, an update of once per day is sufficient. As a reference, ESSP provides EGNOS availability map for each hour for previous 24 hours (which means an update rate of once per hour for historical data).
- Important parameters to monitor:
  - RAIM availability,
  - Dilution of Precision (DOP), number of visible and healthy satellites,
  - SBAS availability, and availability on APV-I and LPV200 levels,
  - Actual errors on each satellite and position accuracy status.

- Not all airports in Finland have local receivers to monitor the GNSS status. Therefore, the proposed service may be useful.
- Challenge is to show the right amount of data to the user, and to simplify the displayed information.
- Alerts should be via SMS and emails. As a reference, ESSP provides emails on service degradation.
- For historical data, smartphone-based app is not very useful. Most of the work occurs on computers.

Interview 4: GNSS Equipment and Expertise

- Example end-user can be a weather monitoring company with a range of products that ascend into the atmosphere attached to weather balloons and transmit the sensed parameters along with the position and time via a one way communication link to the ground receiver. Such weather monitoring apparatus contains a GNSS chip.
- In this case, a service such as GLAS-service would provide quality control though knowledge about the best time and place to release the weather monitoring equipment. This is significant because the weather balloons once released cannot be retrieved and therefore, this is the added value of the proposed service to this end-user. There is no luxury of taking measurement twice if the first time is in unfavorable GNSS circumstances. This application is mission critical.
- The service should provide not only GNSS status and quality information but also additional data, e.g. meteorological information over Finland.
- The weather balloons can travel up to a height of 40 km and over a considerable distance depending on the wind conditions. Can the GLAS-service provide status updates of GNSS quality at these locations?
- Frequency of data update can be once per hour (or equivalent to prevailing speed of atmospheric changes) if atmospheric data (ionosphere and troposphere) is concerned. If VRS or DGNSS data is concerned, it should be provided with an update frequency of once per second or once per five seconds.
- The proposed service should have an adaptable update rate based on the prevailing conditions – lower if the GNSS and atmospheric conditions are stable.
- There are existing commercial services similar to the proposed GLAS-service, e.g. from Omnistar, Correct Hemisphere, Atena, etc. The downside is that they are expensive (few thousands of Euros per year). They have their own base stations which monitor multi-GNSS, multi-frequency signals and weather/atmospheric parameters. The primary application is to assist receivers to perform precise point positioning corrections.
- The proposed service should not introduce any new data format/standard or communication protocol. It should use existing standards, e.g. aviation standards can be used.
- In aviation, the end-user is interested in the GNSS status at source, destination, and along the route at the relevant times. Also, similar to weather balloons, the GNSS status at height of up to 10 km rather than on the ground.
- Alerts and notifications should be provided about predicted degradations all along the route and throughout the time window of the journey.
- General users of GNSS – they require the status updates for now, rather than predictions for the future. Professional end-users – also interested in the predicted future status.

- A supplementary customer support service in addition to the proposed broadcast only GLAS-service would be beneficial.
- With regards to atmosphere – status updates of ionospheric activity and solar activity and their effects on GNSS are interesting to the end-user. Tropospheric activity is of lower importance. Therefore, if the effect of troposphere is modelled accurately, it can be removed from the source data used by the proposed GLAS-service.
- A prediction of future degradation due to upcoming solar activity is more important compared to notification regarding the outage of one GNSS satellite.
- Ability to show historical data would be beneficial.
- Forecasting of upcoming events, degradations, and disruptions would be beneficial – e.g. updated every few hours if possible or on day to day basis.
- Which GNSS performance parameter is of primary significance depends on the end-user application domain:
  - Surveying – positioning accuracy and system/signal availability.
  - Mechanical cranes – continuity of position solution, no cycle slips or jumps in data (caused due to multipath or other similar factors in local environment).
  - Weather monitoring – atmospheric conditions at different altitudes. The possibility that GLAS-service will provide added value to their products is of interest in this domain.
  - Aviation – reliability and notifications/alerts/warnings.
- A traffic light interface is fine – to show to the user if the current GNSS status is favorable or not. However, if the situation is RED, can some additional (correction data also be sent to fix/remedy the situation?
- Can the service be designed so that it provides some benefits directly to a GNSS receiver (e.g. differential corrections?), instead of the smartphone on which the service is viewed? Can the smartphone app initiate data transfer to receiver via an authenticated user profile and by providing some identification about the target receiver? If yes, the data should follow existing standards e.g. RTCM, GRAS, so that the service benefits are receiver independent.
- A challenge here is then the necessity for two way communication between the proposed service and the receiver.
- The service should not be a burden on the computational power of the end-user's computer/smartphone.
- Smartphone is a preferable medium for basing the service application.
- With regards to the notifications and alerts – user should have an opportunity to choose between an email/SMS alert. The alert should be very simple and concise, with a link to the webpage to display additional details.
- The alerts should also notify of any predicted downtime in the GLAS-service itself or in FinnRef (reference stations network from where the proposed service will source its data).
- User interface should be flexible and users should have option to also change it based on their preference.
- UI should be both graphical and text-based. Graphical UI helps to quickly know the alerts and GNSS status. Text-based information display should be implemented in a later phase, and it should also include advice or additional data to remedy the situation (gradually, end-users are going to demand this feature from the proposed service – because it is not going to be enough just to say that the situation is unfavorable.).
- Make the internet pages easy to follow and the smartphone app easy to download and install. Offer an online help service to end-users.

Appendix 2: Comparison of State-of-the-art Services similar to GLAS-service

Table 3. State-of-the-art Services similar to GLAS-service

List of references		
1	[ALBERDING]	https://www.alberding.eu/en/GNSSStatus.html
2	[Leica SpiderQC]	http://leica-geosystems.com/products/gnss-systems/software/leica-spiderqc
3	[Leica GNSS QC]	http://hds.leica-geosystems.com/en/Leica-GNSS-QC-Software_29436.htm?pagemode=print
4	[DLR – SWACI]	http://swaciweb.dlr.de/data-and-products/public/tec/tec-eu/?L=1
5	[SeSolstorm]	http://sesolstorm.kartverket.no/
6	[SGO]	http://www.sgo.fi/index.php
7	[ESSP-EGNOS]	https://egnos-user-support.essp-sas.eu/new_egnos_ops/index.php
8	[SWEPOS]	https://swepos.lantmateriet.se/
9	[GISMO]	http://www.nsl.eu.com/gismo.html
10	[ROB]	http://gnss.be/
11	[EDCN]	the project was shut down some months ago as EUROCONTROL stopped funding it
12	[EUREF]	http://epncb.oma.be/
13	[Trimble GNSS planning]	http://www.gnssplanningonline.com/
14	[US Coast Guard NavCen]	http://www.navcen.uscg.gov/?pageName=GPSmain
15	[AUGUR]	http://augur.ecacnav.com/augur/app/home
16	[NOAA Space Weather Prediction Center]	http://www.swpc.noaa.gov/
17	[EuGSC]	https://www.gsc-europa.eu/system-status/Constellation-Information

Table 4. Comparison of the state-of-the-art GNSS PNT status monitoring systems based on different parameters.

#	System	System/Service Description (Purpose and Structure)	Data Source	File/Data Formats	Comm. Protocols	User Interface and Alarms	Monitored Parameters	Special Features
1	[Alberding]	• Performance monitoring of GNSS reference station and its positioning services. • Modular - independent modules for data management, processing, analysis, alarming, visualization, etc. • Scalable - possible to include additional reference stations for monitoring. • Core central data management engine + auxiliary modules for other processing. • Customizable to user requirements.	• Real-time data from GNSS reference stations (raw data), • Ntrip casters, • other data sources.	• Receiver binary formats, • RTCM (2.x, 3.x), • CMR/CMR+, • RTCA, • RINEX (2.x, 3.x).	• TCP/IP, • UDP, • Ntrip.	• Traffic light status, • color coded status tables, statistical tables, • time series, scatter plots, bar graphs, histograms, skyplots, • interactive maps, • email, SMS alarms.	• Data availability, • positioning accuracy, • data age, • DGNSS/RTK/PPP pos. service performance, • External sensor data, • ref. Station coordinate stability, • real-time monitoring of severe weather events.	• Export performance reports (scheduled or on-demand) in PDF/CSV format, • Logs - event logs, system configuration logs, • Can integrate external modules: DGNSS/RTK pos., real-time/post-processed PPP pos. and tropo modelling, L1 VRS n/w, and user-defined modules.
2	[Leica SpiderQC]	• Multi-purpose GNSS data analysis software • Site Assessment and Quality Control • Network RTK Performance Monitoring • Reference Station Integrity Monitoring • Deformation Monitoring • RINEX data management (concatenation, decimation)	• Real-time data from GNSS reference stations (raw data),	• RINEX (2.x, 3.x), SINEX, IONEX • NMEA GGA, GNS, GGQ and LLQ	• TCP/IP • serial • SQL	• traffic light symbols, graphs, • email, SMS alarms • maps, scatter plots, vector maps	• raw data quality • Network RTK pos. service performance, • ref. station coordinate stability	• Export html reports, web pages

#	System	System/Service Description (Purpose and Structure)	Data Source	File/Data Formats	Comm. Protocols	User Interface and Alarms	Monitored Parameters	Special Features
3	[Leica GNSS QC]	• GPS/GLONASS quality control and data analysis, • Quality checking of RINEX data from network reference station, • Automated Analysis of GNSS Reference Station Data, • Analysis of Network RTK Processing • Displacement Analysis,	• Real-time data from GNSS reference stations (raw data),	• RINEX 2.1/2.11, • SINEX, • IONEX, • NMEA, • Leica data formats,	• TCP/IP, • SQL dB	• IONEX maps, • graphical display of code multipath and SNR, • coordinate visualization tools to show displacement or motion, • Traffic light status, • heat maps showing residual errors, • email & SMS messaging system, • time series, scatter plots and vector maps,	• Site evaluation, • Rx performance, • multipath environment, • residual errors for RTK users, • co-ordinate displacement up to 20Hz, • quantity of the data (tracking information, data gaps, cycle slips, multipath, SNR) and the format (compliance to the RINEX standard), • SNR,	• Analysis of single, dual and triple frequency data, • real-time and post-processing mode, • RINEX data management (concatenation, decimation), • support for GPS L5, • HTML based reports, web pages and graphs can be generated, • Supports Bernese, • free version of software available for download.
4	[DLS-SWACI]	• To provide specific space weather information, historical, current and forecast, of the ionospheric state, • Iono data is collected, checked for quality, calibrated, adjusted, analyzed, fed into models for generating higher data levels and finally distributed in near real time and/or archived.	• Ground-based stations (once every 5 sec), or existing European data sources.	-	-	• Ionosphere heat maps (TECU), • NmF2 Maps & 3D electron density distribution profiles, • alarms of extreme iono events, • historical data may be accessed and/or visualized by a professional Data and Information Management System,	• Temporal and spatial changes of the electron density (TEC) in the ionosphere, • rate of change of TEC index (ROTI), • equivalent iono slab thickness, • scintillation index S4, • other solar-terrestrial data.	• Near real-time data, • integrated into the Space Weather European Network.

#	System	System/Service Description (Purpose and Structure)	Data Source	File/Data Formats	Comm. Protocols	User Interface and Alarms	Monitored Parameters	Special Features
						• www access.		
5	[SeSolstorm]	• Iono status over Norway	• Satellite-based and ground-based data records,	-	-	• Heat maps and time series (24 hrs) of TEC content over Norway, • divides Norway into three regions: South, Central, North, • TECU in 4 categories: low, moderate, high, and very high activity, • shows current status on main page,	• ROTI, • TECU, • plasma content in the ionosphere (VTEC), • spatial gradients of VTEC, • Grid ionospheric Vertical Error (GIVE)	• Archived iono data accessible via www search,
6	[SGO]	• Continuous measurements of the Earth's magnetic field, cosmic radio noise, seismic activities, and cosmic rays.	Sensors, camera	-	-	• Magnetograms, • images from the All-Sky Camera, • www interface, • Ionograms, • heat maps, time series.	• Earth's magnetic field, • cosmic radio noise, • seismic activities, • cosmic rays.	• Tomographic imaging of a 2-D cross-section of the ionosphere from north Norway to south Finland, • real-time operation, • data archive (with a list of missing days), • free access to data.

#	System	System/Service Description (Purpose and Structure)	Data Source	File/Data Formats	Comm. Protocols	User Interface and Alarms	Monitored Parameters	Special Features
7	[ESSP-EGNOS]	• EGNOS system performance and service status website • SoL Service, Open Service, EDAS service • Availability monitoring and forecast • Real time accuracy at one reference station, historical accuracy at RIMS stations • Historical pass to pass accuracy	Satellites, RIMS reference stations, etc.	-	-	• Traffic light status on a calendar interface, • time series plots, • map based interface with airport locations, and heat maps, • color coding to show status, • each EGNOS satellite status/information displayed in a separate column, • alerts are provided via service notices (notice status = In Force, Superseded, Expired), and all notices are listed on webpage, • monthly and yearly performance reports are generated and archived on webpage.	• EGNOS system performance, status and outages, • EGNOS message broadcast status, and gaps, • number of GPS and EGNOS satellites monitored, active status, availability for precision/non-precision approach, their user differential range error indicator (UDREI), • Iono grid points and their GIVEI, • implementation status of LPV procedures at European airports, • SoL performance (availability and protection level), • status of EGNOS open service and EDAS service, • Open Service accuracy	• Real-time, historical, and forecasted information, • data display over 24 hrs, • EGNOS 24x7 phone and email helpdesk, • website contains several auxiliary information about EGNOS services and EU space/navigation activities, • excellent UI and webpages, • users can login for additional information.

#	System	System/Service Description (Purpose and Structure)	Data Source	File/Data Formats	Comm. Protocols	User Interface and Alarms	Monitored Parameters	Special Features
8	[SWEPOS]	• Support system for GNSS positioning in Sweden. • Subscriptions to different services: DGNSS (free), Network RTK, post-processing service. • Web-based support services.	• GNSS data from reference stations, • Ntrip casters.	• RTCM (2.x, 3.x), • RINEX.	• TCP/IP, • Ntrip.	• Tables, • plots • skyplots, • email, SMS.	• Ionospheric variability, • satellite availability (prediction), • position accuracy for a subset of ref stations, • ref stations operating status.	-
9	[Royal Observatory of Belgium]	• GNSS data for both real-time and post processing applications. • Ionosphere monitoring above Europe from EUREF Permanent Network data.	• GNSS data from reference stations, • Ntrip casters.	• RTCM (2.x, 3.x), • RINEX.	• TCP/IP, • Ntrip.	• Interactive maps, • statistical maps and plots, • time series.	• Ionosphere (VTEC statistics)	-
10	[GISMO]	• Software tool for GNSS performance analysis, providing metrics on a 24/7 basis. • By combining monitoring with prediction, GISMO can also identify scheduled black-spots in GNSS accuracy and integrity. • Used with data from private networks as well as IGS (worldwide), EUREF (Europe), OSNet (UK), regional networks (UK & Netherlands) and the EGNOS RIMS via EDAS.	• GNSS data from reference stations.	-	• TCP/IP.	• Bar graphs • skyplots, • graphs.	• Satellite availability, • signal reception and signal quality statistics , • satellite range error analysis, • predicted satellite availability, • station error analysis and modeling.	• Results can be either displayed online or used to generate periodic reports, • Identification of faults and failures.

#	System	System/Service Description (Purpose and Structure)	Data Source	File/Data Formats	Comm. Protocols	User Interface and Alarms	Monitored Parameters	Special Features
11	[EDCN]	• Performance monitoring of the EGNOS service. • Data collection platform + data visualization web tool.	• raw GNSS data from reference stations.	-	-	• Bar graphs, • maps, • tables, • plots. • email, SMS alarms.	• Accuracy: HPE, VPE (mean, std, maximum error, 95% percentile), • integrity: safety index (mean, std, maximum), • continuity risk, • satellite availability, •SNR.	• Generation of customized GNSS performance report, • Possibility to save the desired queries for future consultation.
12	[EUREF]	• Primary purpose is to realize the European Terrestrial Reference System (ETRS89). • Analysis center routinely analyses the GNSS data. • Supports long-term climate monitoring and numerical weather prediction.	• GNSS data from reference stations, • Ntrip casters.	• RTCM (for real-time data streams), • RINEX (daily, hourly).	• TCP/IP, • Ntrip.	• Plots, • skyplots.	• Multi-year residual position time series • maximum number of observations, number of cycle slips (daily) • RMS due to multipath (daily) • number of satellites, azimuth, elevation (monthly), •SNR.	-
13	[Trimble GNSS planning]	• GNSS availability planning • Web application	• probably almanacs and Trimble ref. Stations	-	-	• time series, skyplots, bar graphs, heatmaps	Satellite elevation, # of satellites, DOPs, visibility, iono map, TEC, scintillation	-
14	[US Coast Guard]	• Official status of GPS • Satellite status & outage information • GPS interference testing periods & areas	• GPS Control Segment	text	-	• text-based notifications • Notice Advisory to Navstar Users (NANU) • email alarms	• GPS status	• Planned interference tests information

#	System	System/Service Description (Purpose and Structure)	Data Source	File/Data Formats	Comm. Protocols	User Interface and Alarms	Monitored Parameters	Special Features
15	[AUGUR]	• Tool developed by Eurocontrol to provide information on GPS integrity for European aviation operations.	• GPS almanac	-	-	• route tool with predicted RAIM availability • airport terminal/approach RAIM availability	• GPS status, visibility • RAIM availability	• Flight planning tool to calculate RAIM availability for GPS guided flights as per ICAO requirements
16	[NOAA Space Weather Prediction Center]	• Space weather forecasts • Ionospheric TEC information • Geomagnetic & ionospheric storm warnings	• CORS network	text	-	• color coded status • heat maps (animated) • text-based notifications	• TEC	-
17	[EuGSC]	• European GNSS service center by the GSA • monitors the status of the Galileo constellation	• Galileo reference stations	-	-	• Tabular data in text format	• Satellites in the Galileo constellation and their current status • NAGU's (Notice to Galileo Users) sent until now	-

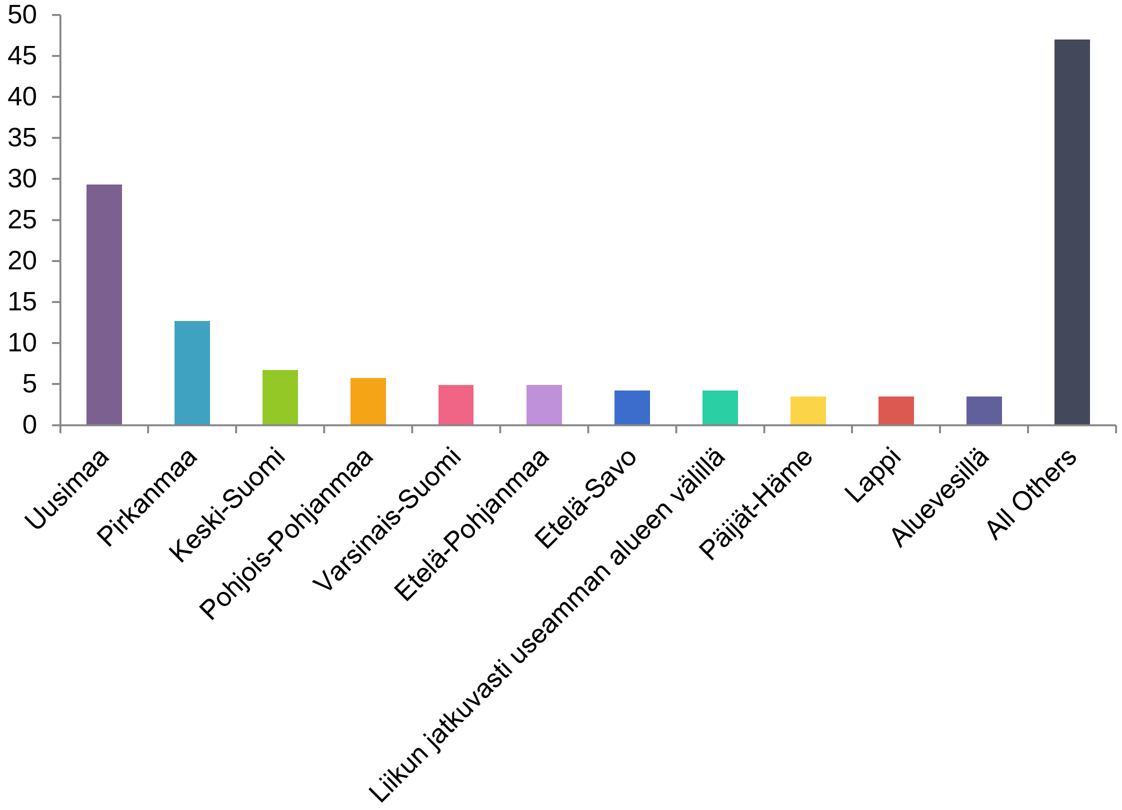
Appendix 3: Responses from the End-user Web-survey

Finnish Results

Response Counts

	Count	Percent
Complete	181	50.8
Partial	175	49.2
Disqualified	0	0
Total	**356**	

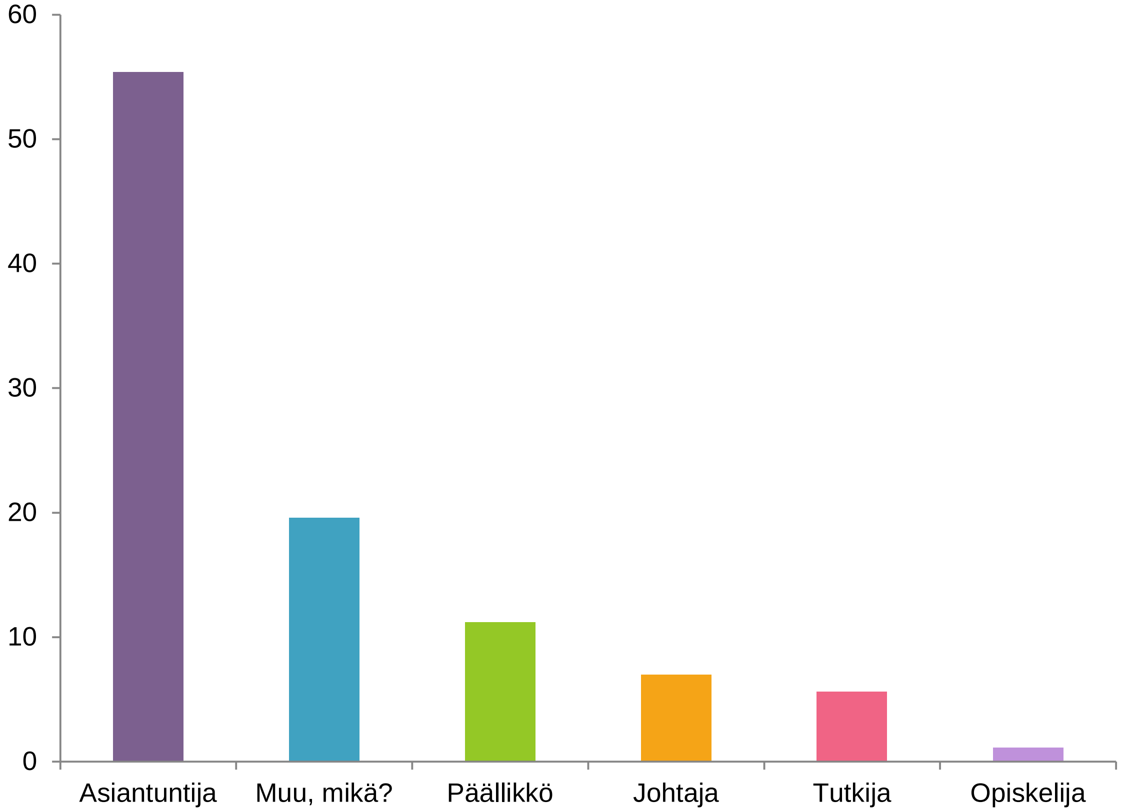
1. Missä päin Suomea työskentelet pääasiallisesti?



Value	Percent	Count
Uusimaa	29.3%	83
Pirkanmaa	12.7%	36
Keski-Suomi	6.7%	19

Pohjois-Pohjanmaa	5.7%	16
Varsinais-Suomi	4.9%	14
Etelä-Pohjanmaa	4.9%	14
Etelä-Savo	4.2%	12
Liikun jatkuvasti useamman alueen välillä	4.2%	12
Päijät-Häme	3.5%	10
Lappi	3.5%	10
Aluevesillä	3.5%	10
Pohjanmaa	2.8%	8
Pohjois-Savo	2.5%	7
Pohjois-Karjala	2.5%	7
Etelä-Karjala	1.8%	5
Satakunta	1.4%	4
Keski-Pohjanmaa	1.4%	4
Kainuu	1.4%	4
Kymenlaakso	1.1%	3
Kanta-Häme	1.1%	3
Ahvenanmaa	0.4%	1
Ilmatilassa	0.4%	1
Total		**283**

2. Missä asemassa työskentelet?

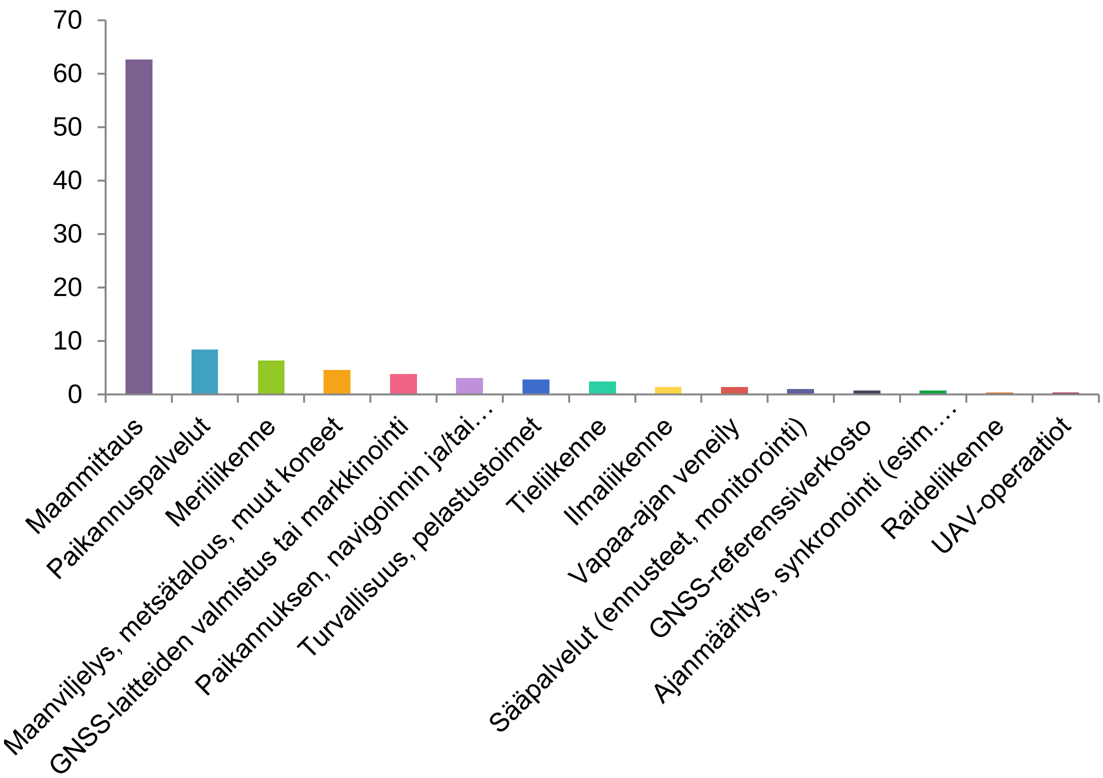


Value	**Percent**	**Count**
Asiantuntija	55.4%	158
Muu	19.6%	56
Päällikkö	11.2%	32
Johtaja	7.0%	20
Tutkija	5.6%	16
Opiskelija	1.1%	3
Total		**285**

Muu, mikä? *(vastaajien omin sanoin)	**Count**
Työntekijä	16
Kartoittaja	13
Toimihenkilö	3
Toimitusinsinööri	2
Asiantuntijaharjoittelija	1
Eläkeläinen	1

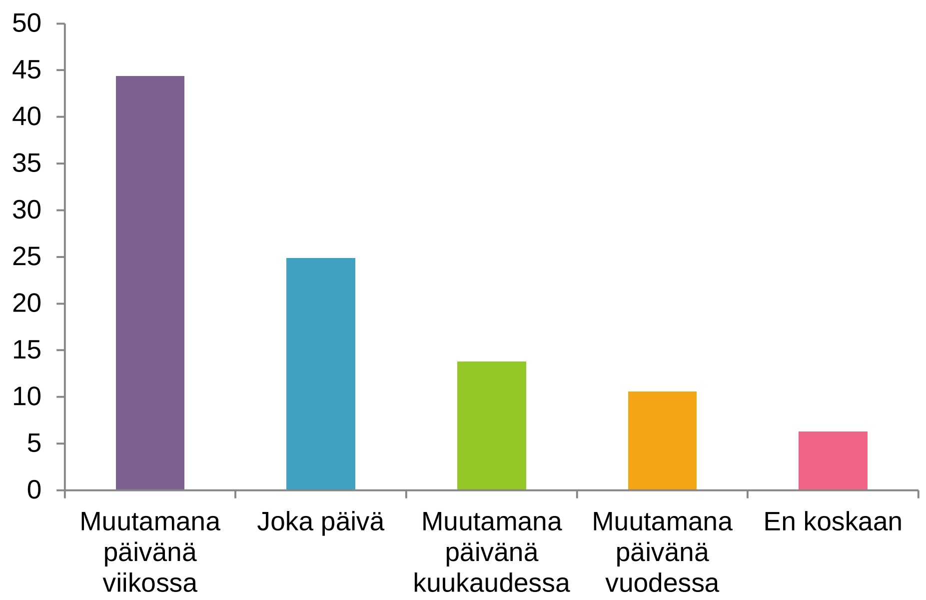
Jäänmurtajan Perämies	1
Maastohommissa	1
RND	1
Tuotesuunnittelija	1
Tutkimusassistentti	1
Yliperämies/Päällikkö	1
Yrittäjä	1
Asiakaspalvelija	1
Kenttätyö	1
Laite maastossa	1
Perämies	1
Tuotanto	1
Määrittelemätön	8
Total	48

3. Mihin toimialaan päätyösi liittyy?



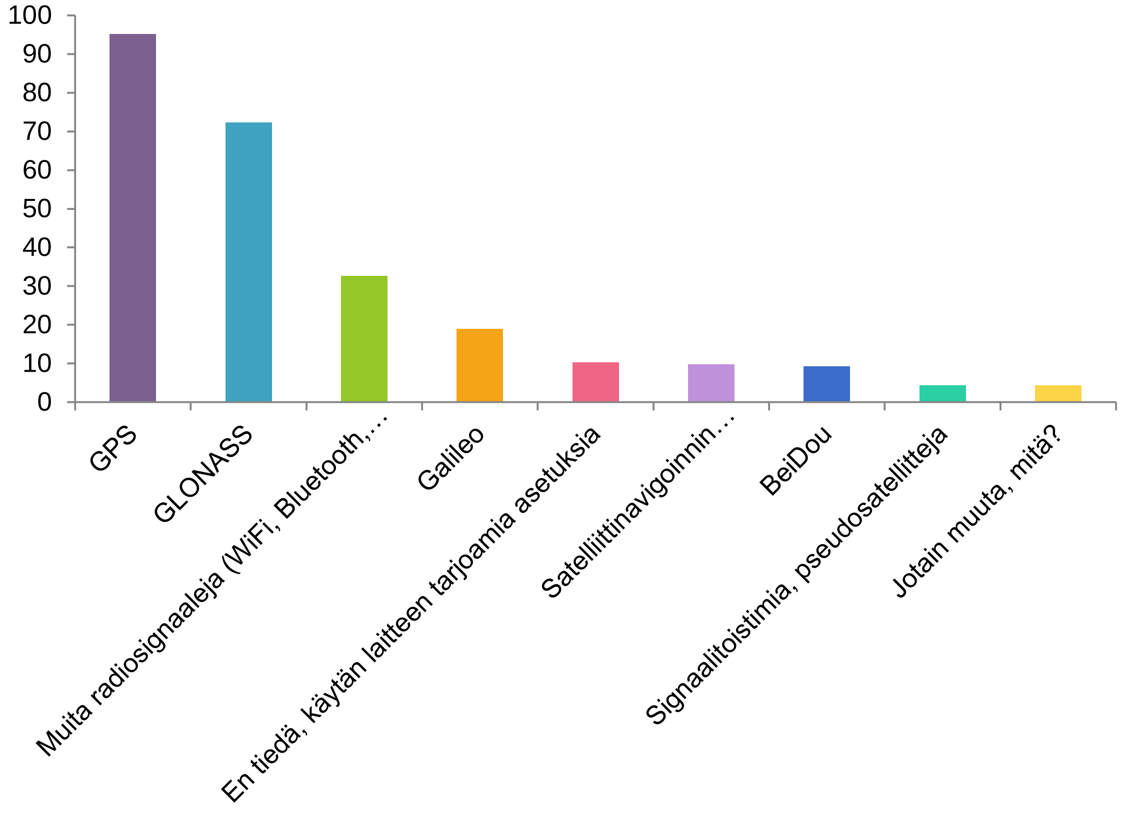
Value	Percent	Count
Maanmittaus	62.6%	179
Paikannuspalvelut	8.4%	24
Meriliikenne	6.3%	18
Maanviljelys, metsätalous, muut koneet	4.5%	13
GNSS-laitteiden valmistus tai markkinointi	3.8%	11
Paikannuksen, navigoinnin ja/tai ajanmäärityksen (PNT) tutkimus	3.1%	9
Turvallisuus, pelastustoimet	2.8%	8
Tieliikenne	2.4%	7
Ilmaliikenne	1.4%	4
Vapaa-ajan veneily	1.4%	4
Sääpalvelut (ennusteet, monitorointi)	1.0%	3
GNSS-referenssiverkosto	0.7%	2
Ajanmääritys, synkronointi (esim. pankki- tai energiaverkkojen aloilla)	0.7%	2
Raideliikenne	0.3%	1
UAV-operaatiot	0.3%	1
Total		**286**

4. Kuinka usein käytät GNSS-avusteista navigointi-, paikannus- tai ajanmäärityslaitetta työssäsi?



Value	Percent	Count
Muutamana päivänä viikossa	44.4%	84
Joka päivä	24.9%	47
Muutamana päivänä kuukaudessa	13.8%	26
Muutamana päivänä vuodessa	10.6%	20
En koskaan	6.3%	12
Total		**189**

5. Mitä navigointi-, paikannus- tai ajanmäärityssignaalia käytät työssäsi? Voit valita useamman vaihtoehdon.

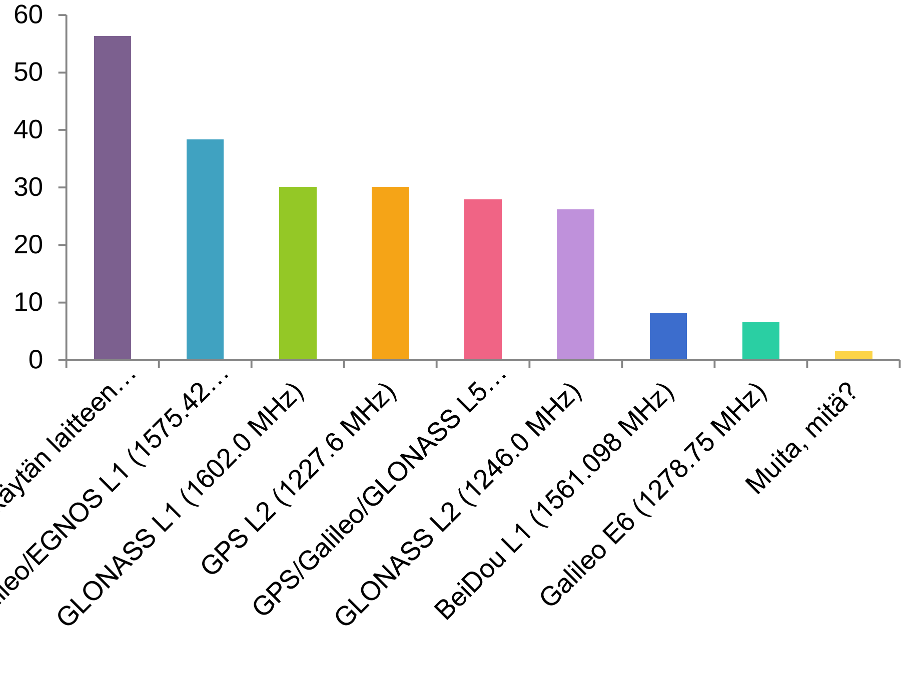


Value	Percent	Count
GPS	95.1%	175
GLONASS	72.3%	133
Muita radiosignaaleja (WiFi, Bluetooth, DVB, jne.)	32.6%	60
Galileo	19.0%	35

En tiedä, käytän laitteen tarjoamia asetuksia	10.3%	19
Satelliittinavigoinnin täydennysjärjestelmän signaalia (SBAS, EGNOS)	9.8%	18
BeiDou	9.2%	17
Signaalitoistimia, pseudosatellitteja	4.3%	8
Jotain muuta	4.3%	8

Jotain muuta, mitä? *(vastaajien omin sanoin)	**Count**
DGPS	1
IGS datacenterin rata/kello datoja	1
Trimble R10 GNSS laitetta kaikkine mahdollisine yhteyksineen + Geotrimin tarjoamaa VRS-RTK -korjauspalvelua. Myös Trimblen tarjoama x-fill -satelliittikorjauspalvelu käytössä.	1
Trimnet VRS	1
Usien myös laitteen tarjoamia asetuksia	1
Kuvaa	1
Virtuaaliverkkoa	1

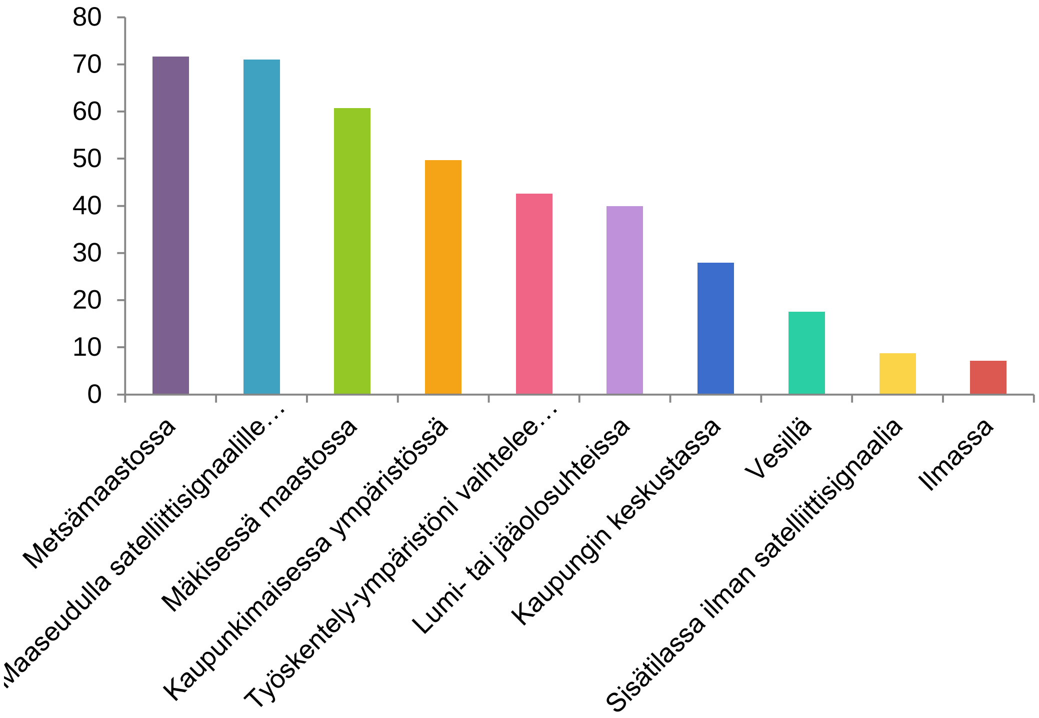
6. Tarvitsen työssäni seuraavia taajuuksia (voit valita useamman vaihtoehdon):



Value	Percent	Count
En tiedä - käytän laitteen tarjoamia asetuksia	56.3%	103
GPS/Galileo/EGNOS L1 (1575.42 MHz)	38.3%	70
GLONASS L1 (1602.0 MHz)	30.1%	55
GPS L2 (1227.6 MHz)	30.1%	55
GPS/Galileo/GLONASS L5 (1176.45 MHz)	27.9%	51
GLONASS L2 (1246.0 MHz)	26.2%	48
BeiDou L1 (1561.098 MHz)	8.2%	15
Galileo E6 (1278.75 MHz)	6.6%	12
Muita	1.6%	3

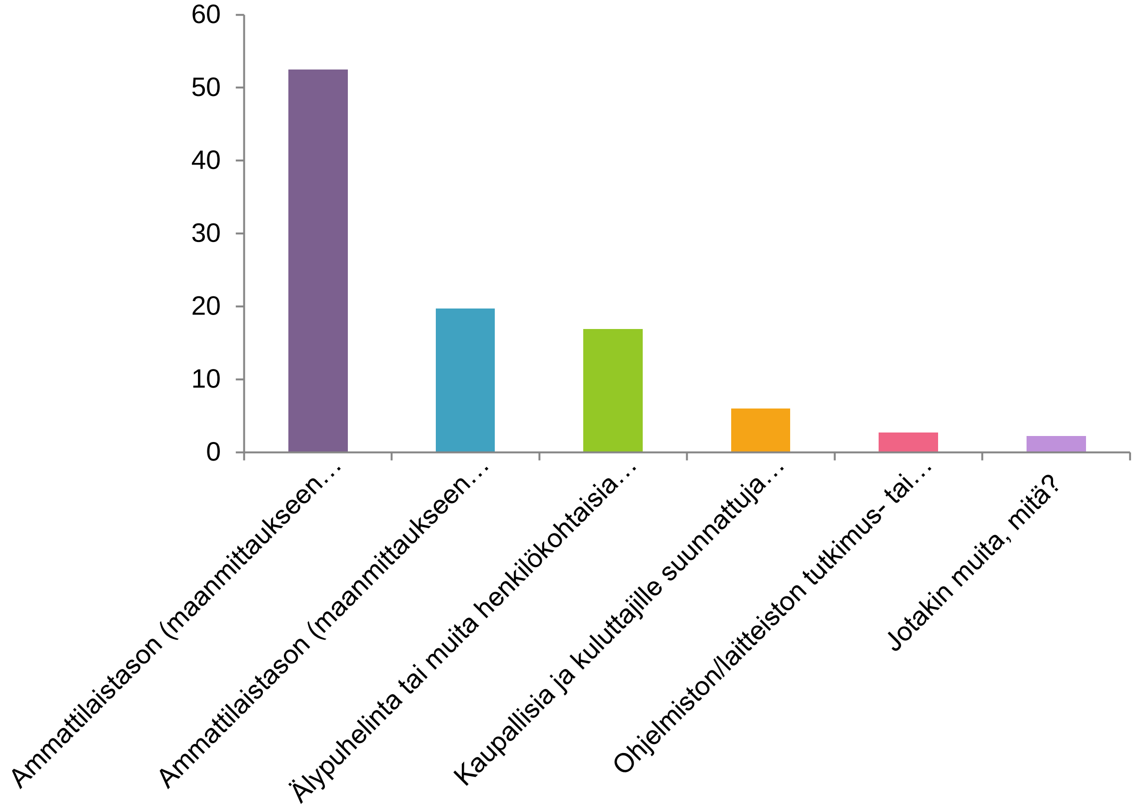
Muita, mitä? *(vastaajien omin sanoin)	**Count**
2400MHz	1
MML maastomittaustuki tietää	1
Tarkalleen en tiedä mitä kaikkia taajuuksia em. Laite käyttää, mutta kaikki kun siitä löytyy pitäisi olla käytössä.	1

7. Millaisessa ympäristössä käytät navigointisignaaleja omassa työssäsi? Voit valita useamman vaihtoehdon.



Value	Percent	Count
Metsämaastossa	71.6%	131
Maaseudulla satelliittisignaalille avoimessa ympäristössä	71.0%	130
Mäkisessä maastossa	60.7%	111
Kaupunkimaisessa ympäristössä	49.7%	91
Työskentely-ympäristöni vaihtelee jatkuvasti	42.6%	78
Lumi- tai jääolosuhteissa	39.9%	73
Kaupungin keskustassa	27.9%	51
Vesillä	17.5%	32
Sisätilassa ilman satelliittisignaalia	8.7%	16
Ilmassa	7.1%	13

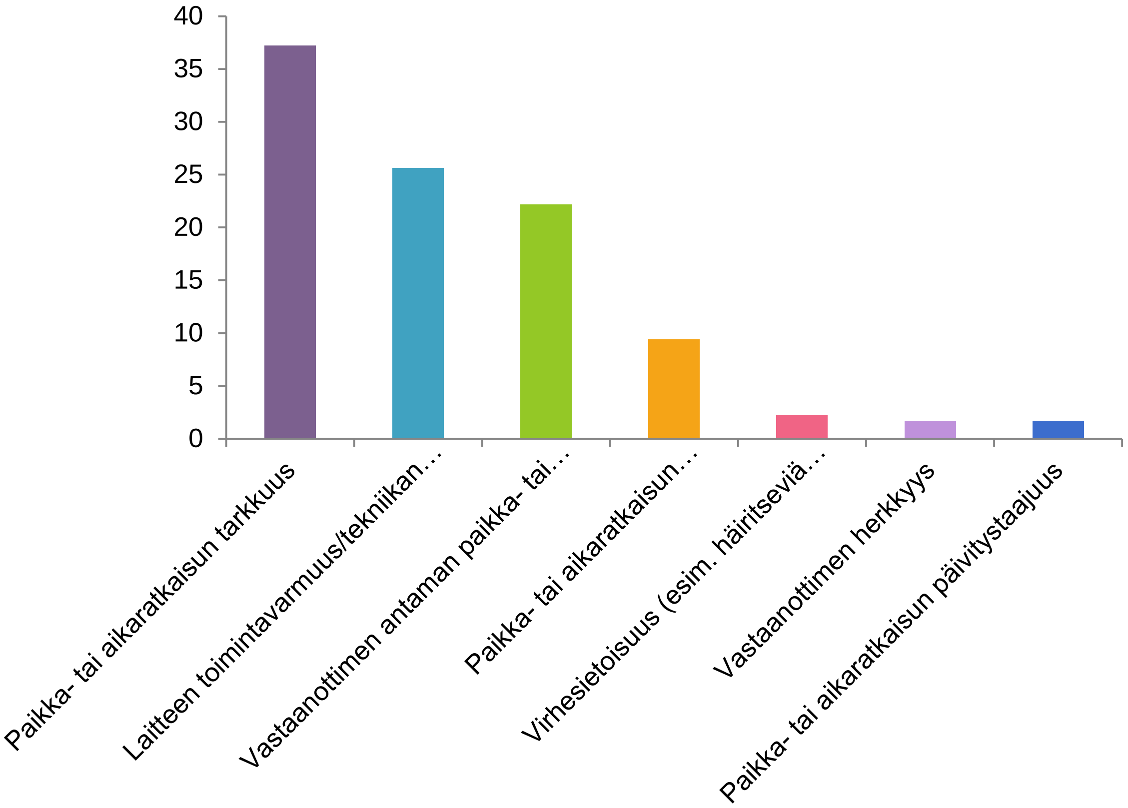
8. Minkä tason paikannus-, navigointi- ja ajanmäärityslaitteita käytät?



Value	Percent	Count
Ammattilaistason (maanmittaukseen soveltuva) Multi-GNSS-vastaanottimia	52.5%	96
Ammattilaistason (maanmittaukseen soveltuvia) kaksitaajuusvastaanottimia, vain GPS.	19.7%	36
Älypuhelinta tai muita henkilökohtaisia navigointilaitteita (PNA)	16.9%	31
Kaupallisia ja kuluttajille suunnattuja OEM-vastanottimia	6.0%	11
Ohjelmiston/laitteiston tutkimus- tai prototyyppivastaanotinta	2.7%	5
Jotakin muita	2.2%	4
Total		183

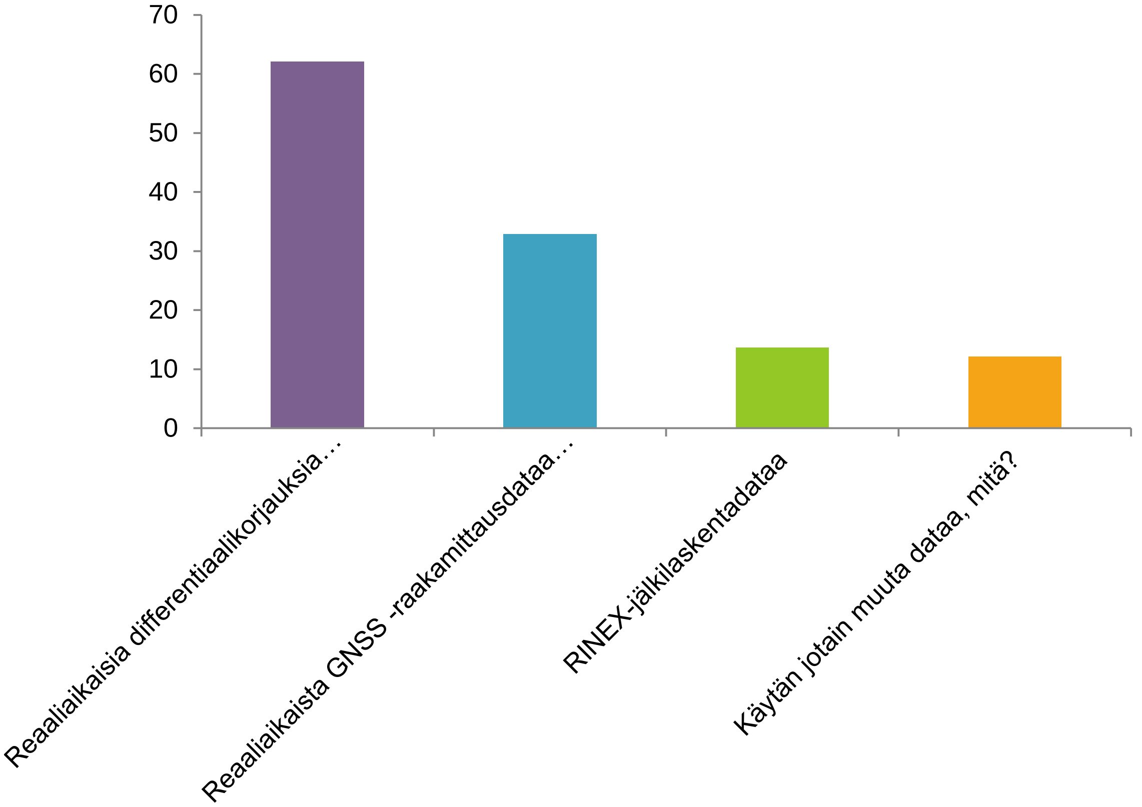
Jotakin muita, mitä? *(vastaajien omin sanoin)	**Count**
Joskus myös noita halpanavigaattoreita.	1
Ruorimerkittyjä merenkulku GPS vastaanottimia	1
Aluksenpaikannuslaitteita	1

9. Mikä on vastaanottimen tärkein suoritustekijä/suorituskykyarvo työsi kannalta?



Value	Percent	Count
Paikka- tai aikaratkaisun tarkkuus	37.2%	67
Laitteen toimintavarmuus/tekniikan luotettavuus	25.6%	46
Vastaanottimen antaman paikka- tai aikaratkaisun sekä tämän virhearvion luotettavuus	22.2%	40
Paikka- tai aikaratkaisun saatavuus(prosentti)	9.4%	17
Virhesietoisuus (esim. häiritseviä radiosignaaleja tai ilmakehävirheitä vastaan)	2.2%	4
Vastaanottimen herkkyys	1.7%	3
Paikka- tai aikaratkaisun päivitystaajuus	1.7%	3
Total		**180**

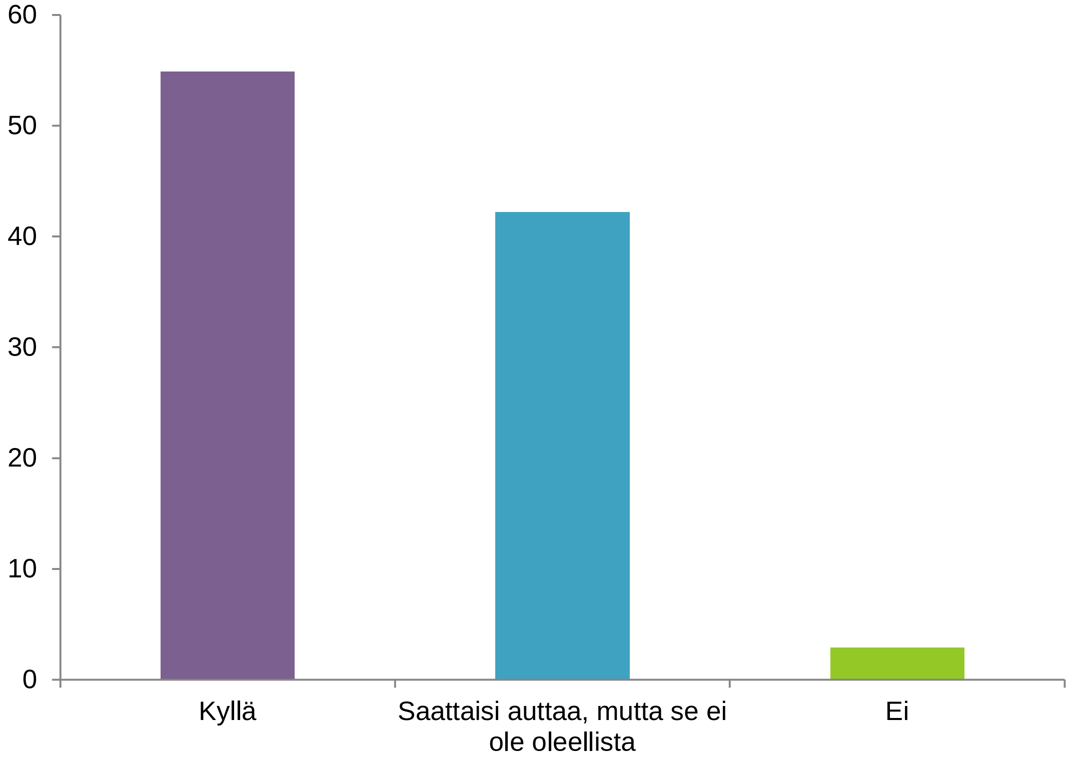
10. Mitä suomalaisen GNSS-referenssiverkoston (FinnRef) tietoaineistoja käytät? Voit valita useamman vaihtoehdon.



Value	Percent	Count
Reaaliaikaisia differentiaalikorjauksia (DGNSS)	62.1%	87
Reaaliaikaista GNSS -raakamittausdataa (GPS, Galileo, GLONASS, BeiDou, EGNOS) (yleensä vain tutkimuskäytössä)	32.9%	46
RINEX-jälkilaskentadataa	13.6%	19
Käytän jotain muuta dataa	12.1%	17

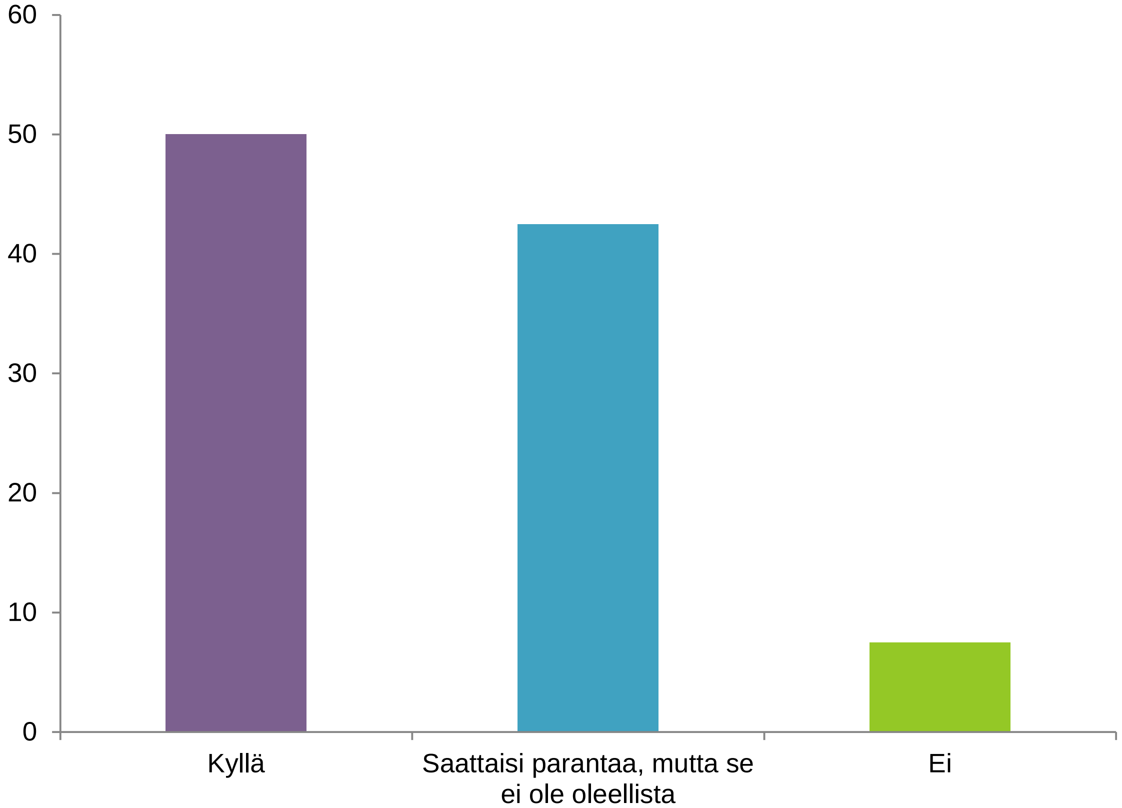
Käytän muita kaupallisia palveluita, kuten: *(vastaajien omin sanoin)	Count
Geotrimin Trimnet VRS reaaliaika ja jälkilaskenta,	10
IGS datacentereiden datoja, BIPM:n PPP-tuloksia	2
Korjauspalvelu sekä Trimblen tarjoama x-fill –satelliittikorjauspalvelu	1
Leica Smartnet	1
Paikallinen rtk-tukiasema	1
En vielä mitään dataa	1

11. Auttaisko Suomessa saatavissa olevan GNSS/EGNOS-järjestelmien reaaliaikaisen toimintatilanteen tietäminen tehostamaan työskentelyäsi?



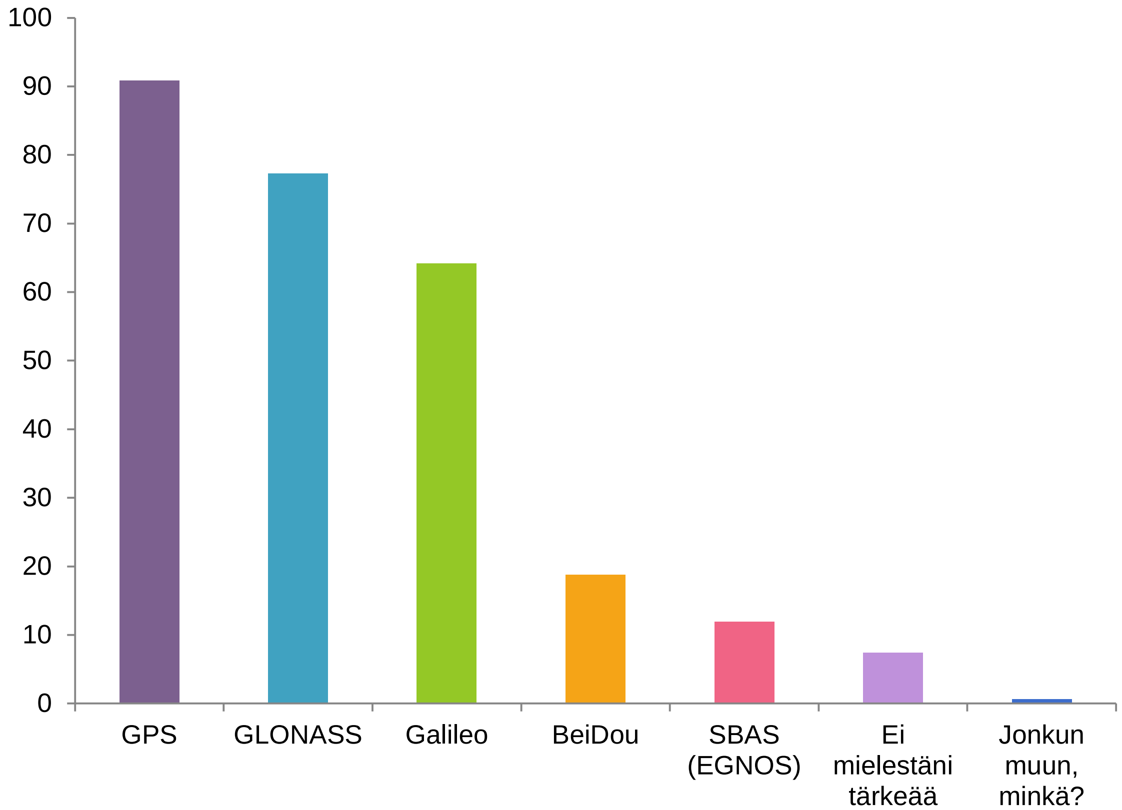
Value	Percent	Count
Kyllä	54.9%	95
Saattaisi auttaa, mutta se ei ole oleellista	42.2%	73
Ei	2.9%	5
Total		**173**

12. Parantaisiko omaa työtäsi jatkuvasti päivittyvä tilannetieto ilmakehän (ionosfäärin ja troposfäärin) vaikutuksesta Suomessa ?



Value	Percent	Count
Kyllä	50.0%	87
Saattaisi parantaa, mutta se ei ole oleellista	42.5%	74
Ei	7.5%	13
Total		**174**

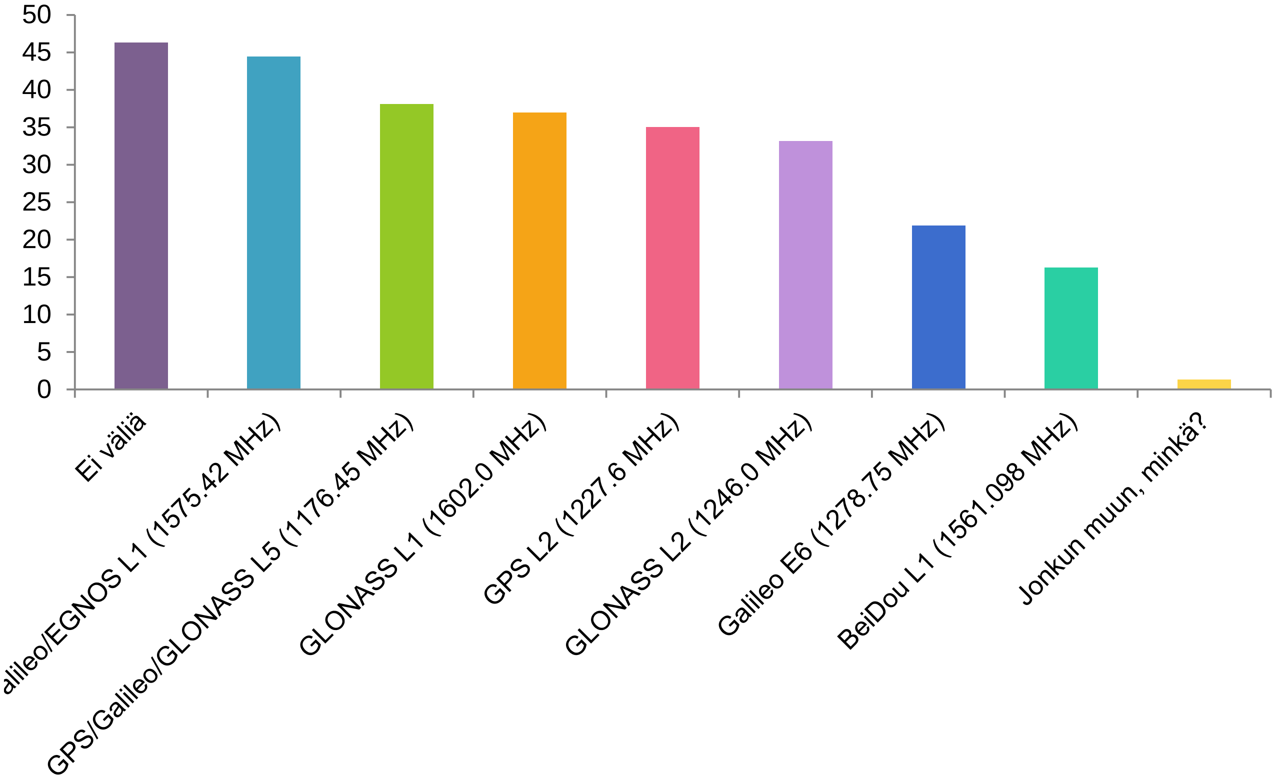
13. Minkä GNSS-signaalijärjestelmän laatua haluaisit Suomessa tarkkailtavan? Voit valita useamman vaihtoehdon.



Value	**Percent**	**Count**
GPS	90.9%	160
GLONASS	77.3%	136
Galileo	64.2%	113
BeiDou	18.8%	33
SBAS (EGNOS)	11.9%	21
Ei mielestäni tärkeää	7.4%	13
Jonkun muun	0.6%	2

Jonkun muun, minkä? *(vastaajien omin sanoin)	**Count**
QZSS	1
Määrittelemätön	1

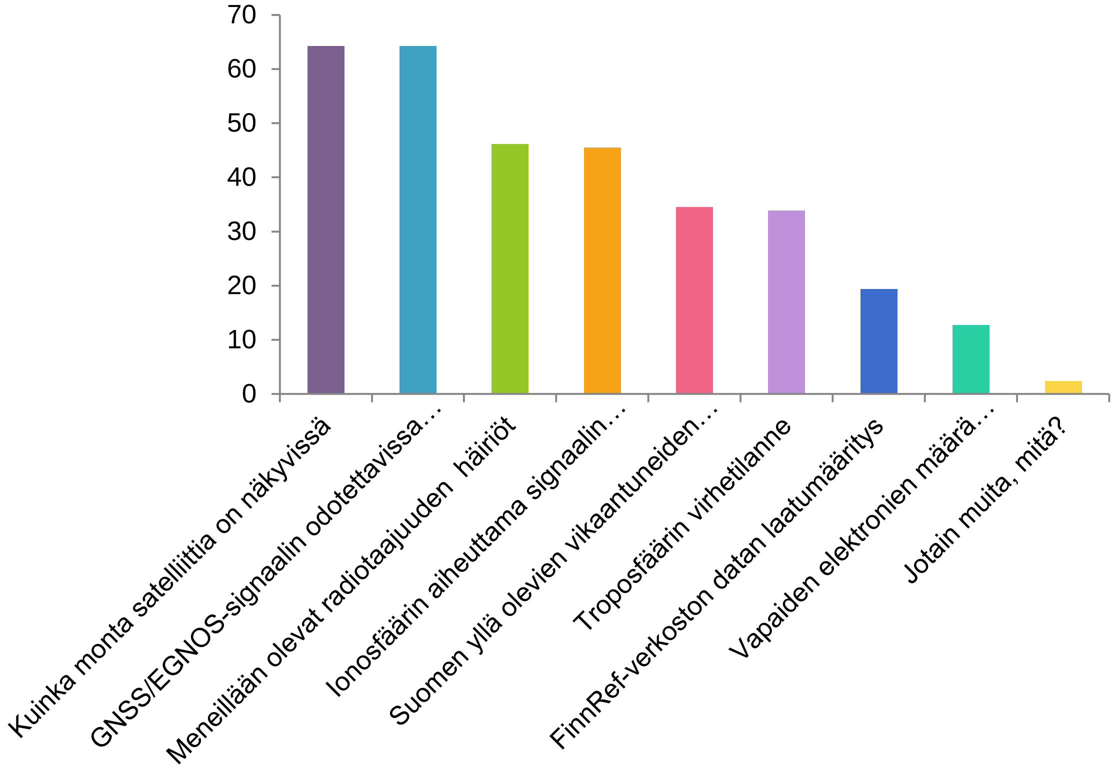
14. Minkä GNSS-taajuuskaistan laatua haluaisit Suomessa tarkkailtavan? Voit valita useamman vaihtoehdon.



Value	Percent	Count
Ei väliä	46.3%	74
GPS/Galileo/EGNOS L1 (1575.42 MHz)	44.4%	71
GPS/Galileo/GLONASS L5 (1176.45 MHz)	38.1%	61
GLONASS L1 (1602.0 MHz)	36.9%	59
GPS L2 (1227.6 MHz)	35.0%	56
GLONASS L2 (1246.0 MHz)	33.1%	53
Galileo E6 (1278.75 MHz)	21.9%	35
BeiDou L1 (1561.098 MHz)	16.3%	26
Jonkun muun	1.3%	2

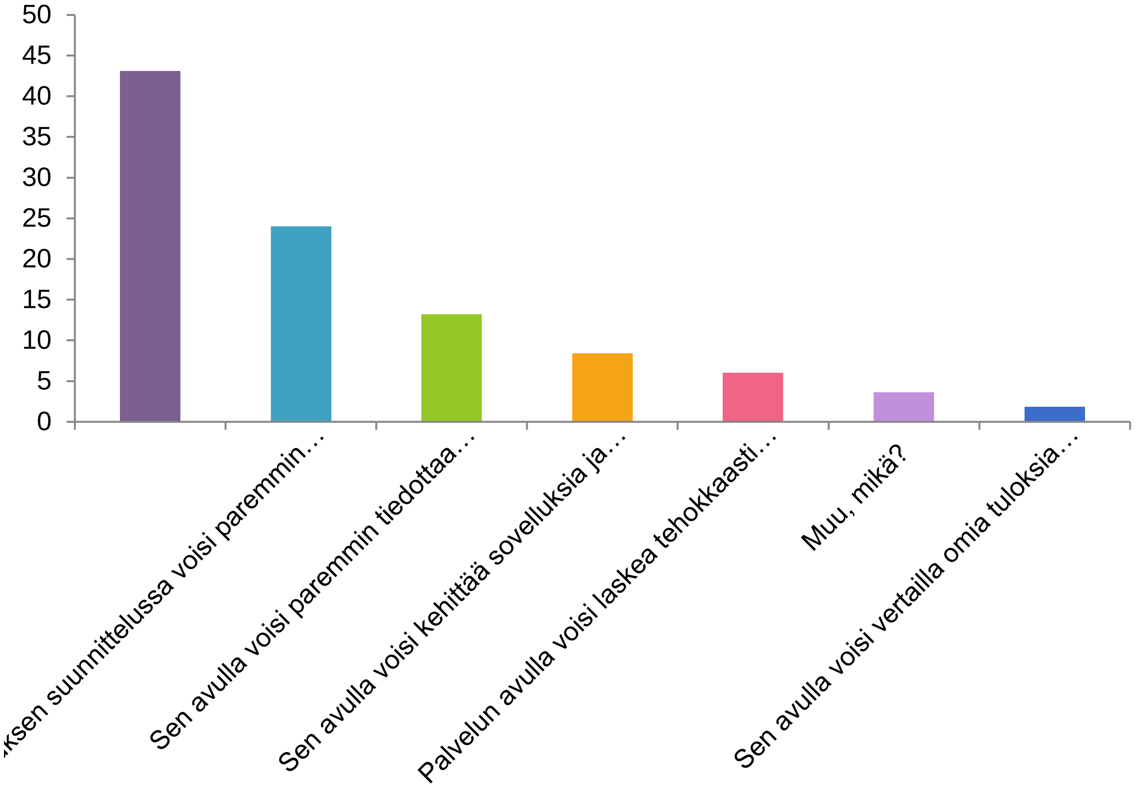
Jonkun muun, minkä? *(vastaajien omin sanoin)	**Count**
QZSS	1
Määrittelemätön	1

15. Mitä GNSS-signaalin ominaisuuksia toivoisit tarkkailtavan Suomessa?



Value	Percent	Count
Kuinka monta satelliittia on näkyvissä	64.2%	106
GNSS/EGNOS-signaalin odotettavissa oleva tarkkuustieto	64.2%	106
Meneillään olevat radiotaajuuden häiriöt	46.1%	76
Ionosfäärin aiheuttama signaalin voimakkuuden vaihtelu	45.5%	75
Suomen yllä olevien vikaantuneiden satelliittien määrä	34.5%	57
Troposfäärin virhetilanne	33.9%	56
FinnRef-verkoston datan laatumääritys	19.4%	32
Vapaiden elektronien määrä ionosfäärissä	12.7%	21
Jotain muita	2.4%	4

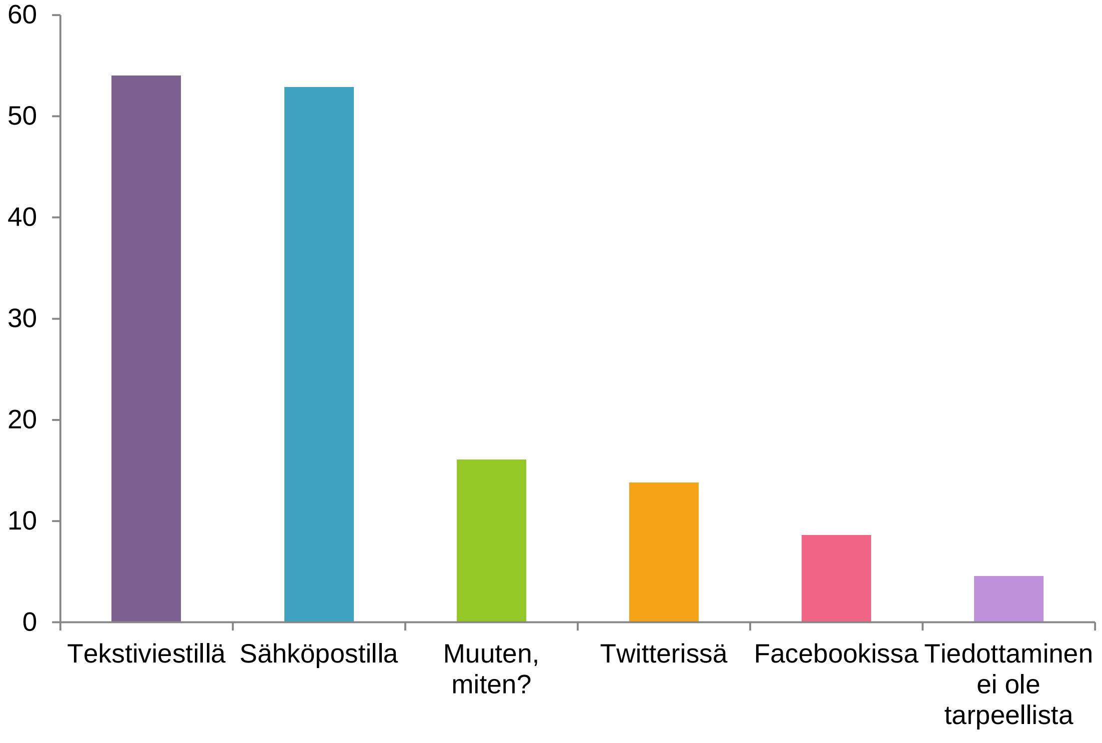
16. Mikä olisi mielestäsi ensisijainen hyöty tällaisesta palvelusta?



Value	Percent	Count
Se auttaisi valitsemaan parhaan ajankohdan ja paikan GNSS-pohjaisten mittausten tekemiseen	43.1%	72
Mittauksen suunnittelussa voisi paremmin varautua GNSS-signaalin häiriöihin varasysteemillä	24.0%	40
Sen avulla voisi paremmin tiedottaa asiakkaille mahdollisista häiriöistä ja laadun heikkenemisestä	13.2%	22
Sen avulla voisi kehittää sovelluksia ja palveluita	8.4%	14
Palvelun avulla voisi laskea tehokkaasti mittausvirheet	6.0%	10
Muu	3.6%	6
Sen avulla voisi vertailla omia tuloksia todellisiin skenaarioihin	1.8%	3
Total		**167**

Muu, mikä?	Count
Hyöty on pieni koska laitteen tulisi työn kannalta toimia joka työpäivä klo 8 - 17. Ei siinä auta tieto siitä että signaalit ovat huonolaatuisia, kun niitä käytännössä tarvitsee joka päivä.	1
Mittauksen toteuttaminen voidaan optimoida tilanteen mukaan (kustannus säästöjä)	1
Pystyisi varautumaan paikan vaihteluuihin ja mahdolliseen suureen paikan epätarkkuuteen. Vaikuttaa osin turvallisuuteen ahtailla kulkuväylillä	1
Aaluksen asemointi	1
Ei tarvetta	1
Saisi lisätietoa ympäristöstä	1

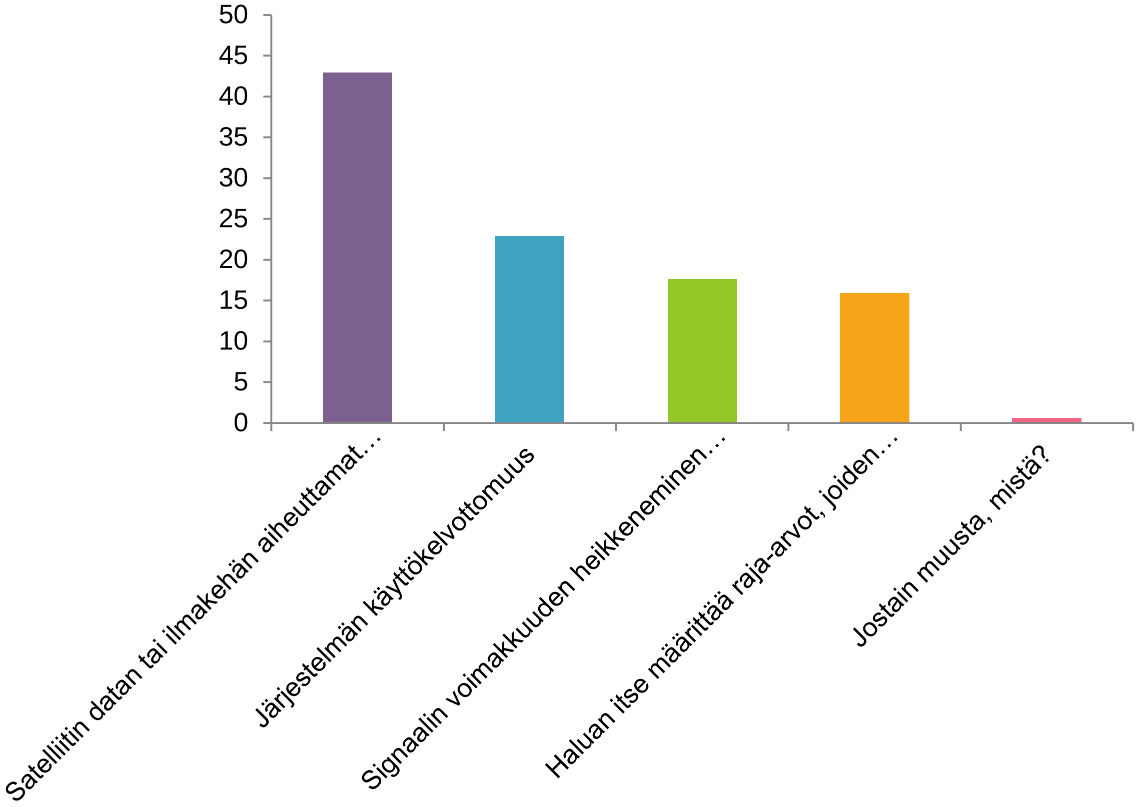
17. Miten GNSS-signaalin saatavuuden keskeytyksistä tai signaalin heikkenemisestä Suomessa pitäisi tiedottaa?



Value	Percent	Count
Tekstiviestillä	54.0%	94
Sähköpostilla	52.9%	92
Muuten, miten?	16.1%	28

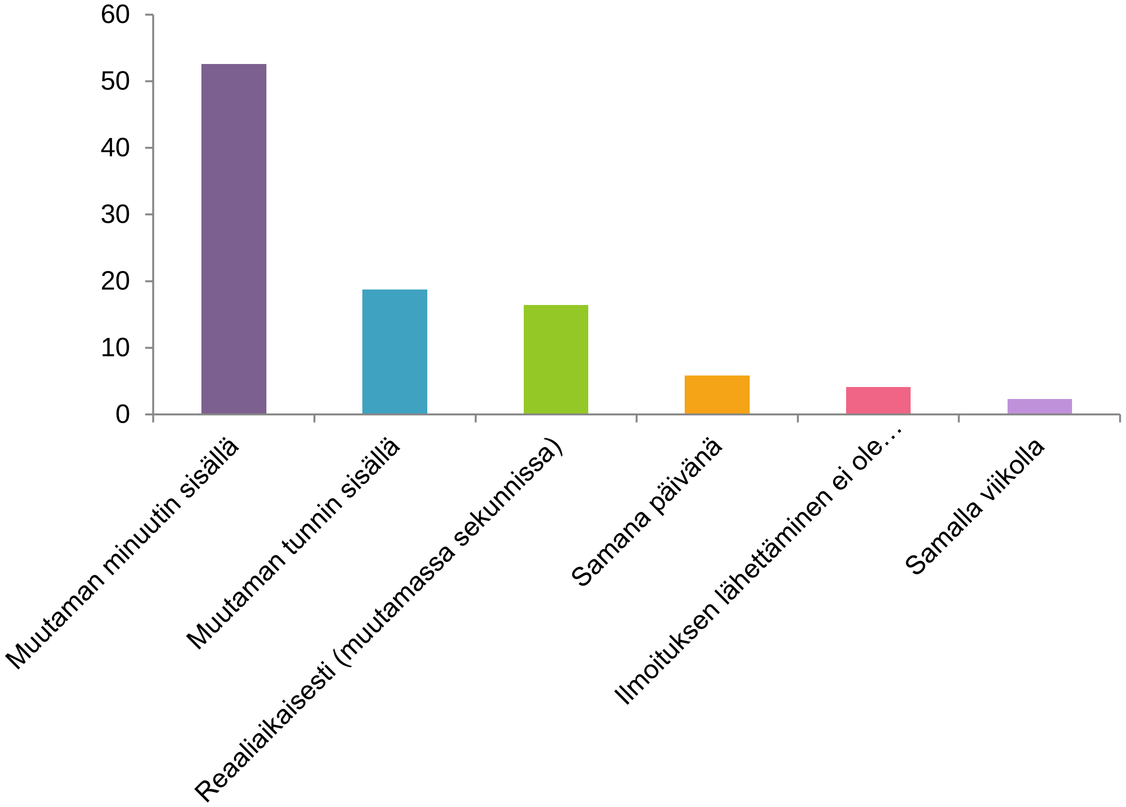
Twitterissä	13.8%	24
Facebookissa	8.6%	15
Tiedottaminen ei ole tarpeellista	4.6%	8

18. Millaisista GNSS-signaalin laadun heikkenemisistä haluaisit vastaanottaa tiedotteita?



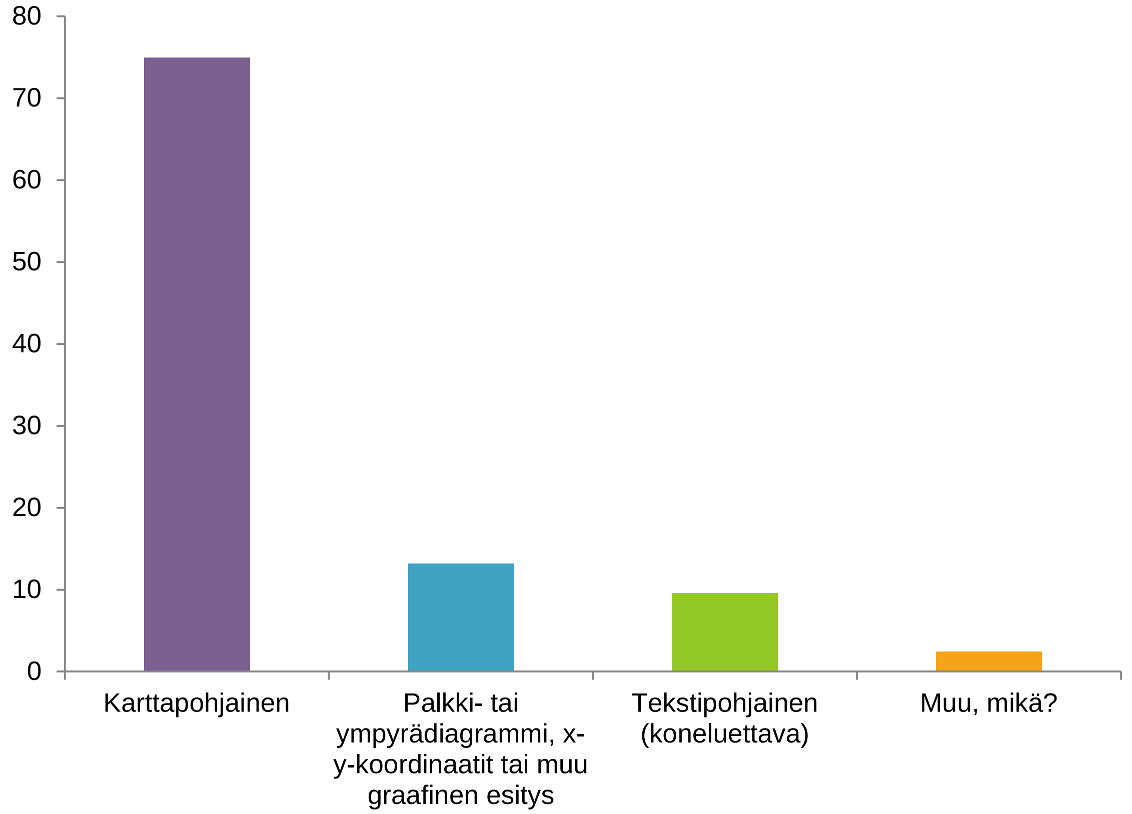
Value	Percent	Count
Satelliitin datan tai ilmakehän aiheuttamat suuret mittausvirheet	42.9%	73
Järjestelmän käyttökelvottomuus	22.9%	39
Signaalin voimakkuuden heikkeneminen ionosfäärin tai häiritsevien radiosignaalien vuoksi	17.6%	30
Haluan itse määrittää raja-arvot, joiden ylityksestä minua tiedotetaan	15.9%	27
Jostain muusta	0.6%	1
Total		**170**

19. Mikä olisi mielestäsi enimmäisviive signaalin huononemisen havaitsemisen ja ilmoituksen antamisen välillä? Ilmoitus pitäisi lähettää käyttäjille



Value	Percent	Count
Muutaman minuutin sisällä	52.6%	90
Muutaman tunnin sisällä	18.7%	32
Reaaliaikaisesti (muutamassa sekunnissa)	16.4%	28
Samana päivänä	5.8%	10
Ilmoituksen lähettäminen ei ole välttämätöntä	4.1%	7
Samalla viikolla	2.3%	4
Total		**171**

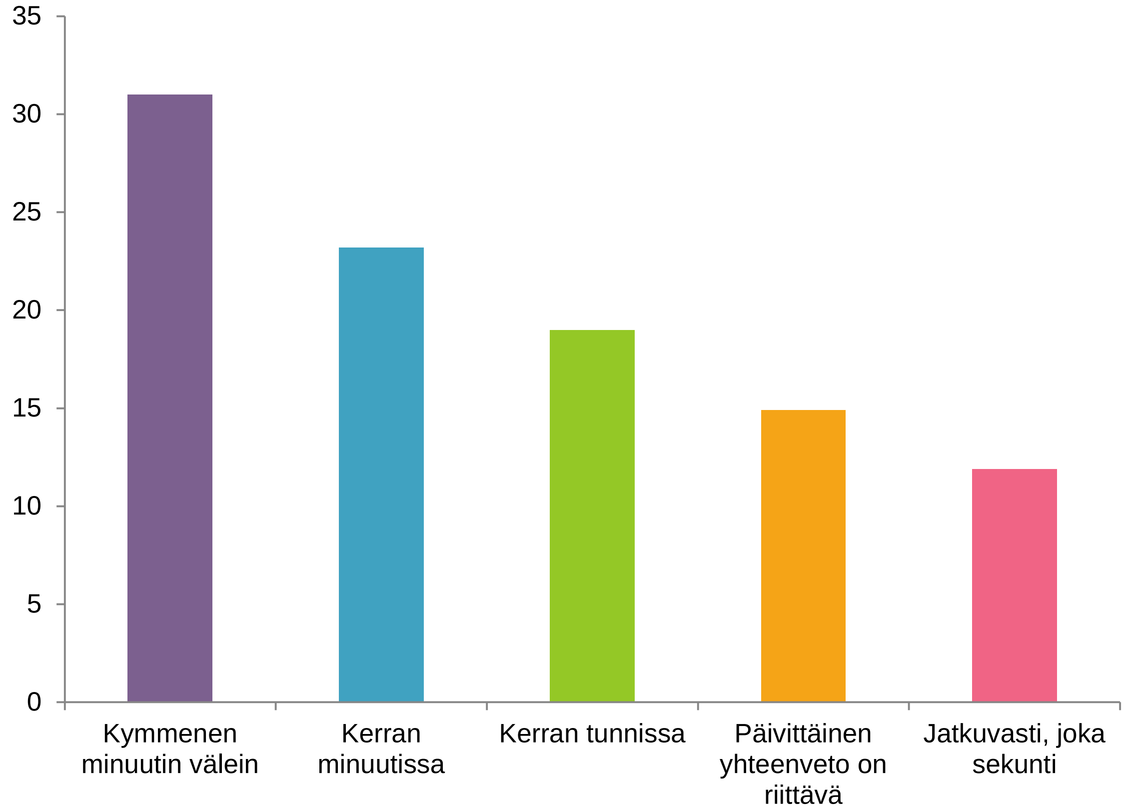
20. Mikä on mielestäsi paras käyttöliittymä palvelulle?



Value	Percent	Count
Karttapohjainen	74.9%	125
Palkki- tai ympyrädiagrammi, x-y-koordinaatit tai muu graafinen esitys	13.2%	22
Tekstipohjainen (koneluettava)	9.6%	16
Muu	2.4%	4
Total		**167**

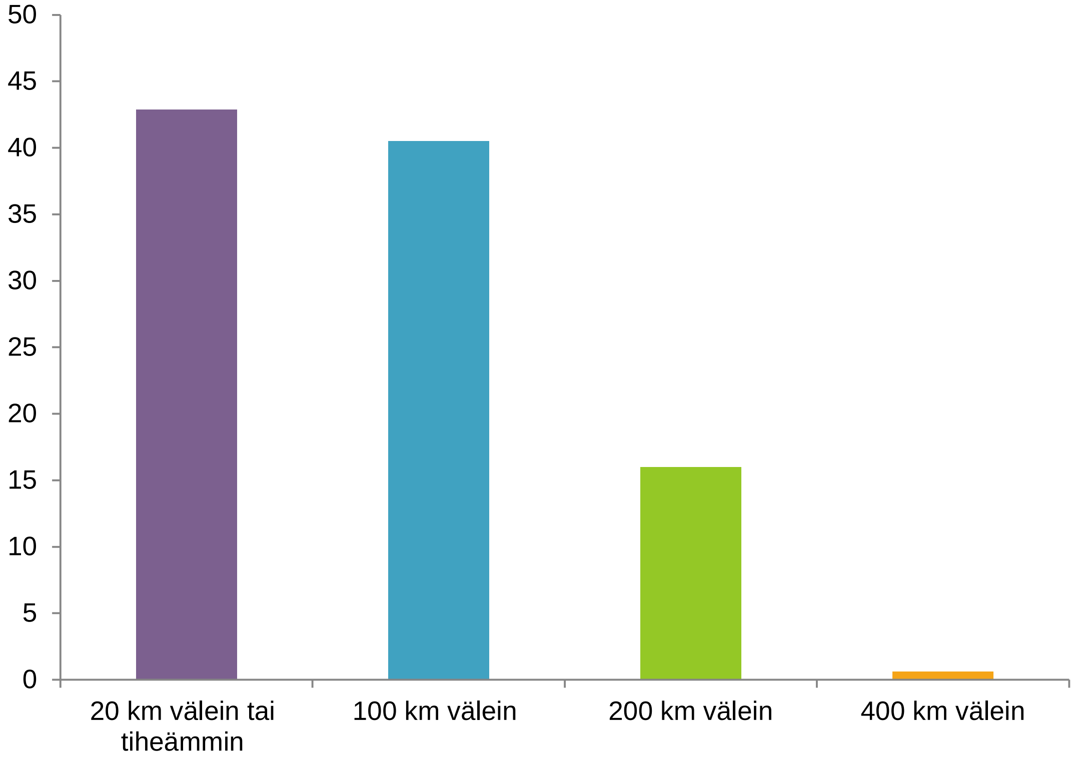
Muu, mikä? *(vastaajien omin sanoin)	**Count**
REST API	1
Sovellus älypuhelimeen	1
Väri- / symboliskaala	1
Ei tarvetta	1

21. Miten usein web-palvelun informaation pitäisi päivittyä?



Value	Percent	Count
Kymmenen minuutin välein	31.0%	52
Kerran minuutissa	23.2%	39
Kerran tunnissa	19.0%	32
Päivittäinen yhteenveto on riittävä	14.9%	25
Jatkuvasti, joka sekunti	11.9%	20
Total		**168**

22. Kuinka tiheällä resoluutiolla GNSS-tilannetieto Suomessa pitäisi ilmoittaa, jotta se riittäisi sinun työsi tarkoituksiin?



Value	Percent	Count
20 km välein tai tiheämmin	42.9%	70
100 km välein	40.5%	66
200 km välein	16.0%	26
400 km välein	0.6%	1
Total		**163**

23. Pitäisikö järjestelmän noudattaa joitakin olemassaolevia standardeja?

Response *(vastaajien omin sanoin)
Yleisesti olemassaolevien standardien - jos sellaisia on - noudattaminen on hyvä ja kannatettava asia.
Palvelu saisi olla webservice samaan tapaan kuin esim. sääpalvelut, jolloin info on helppo näyttää käyttäjälle web- tai natiivisovelluksella.
RTCM3, avoimet ja yhteensopivat standardit
XML, JSON
EOS

24. Onko sinulla muita kommentteja tai odotuksia tulevan GNSS-käytettävyyspalvelun suhteen?

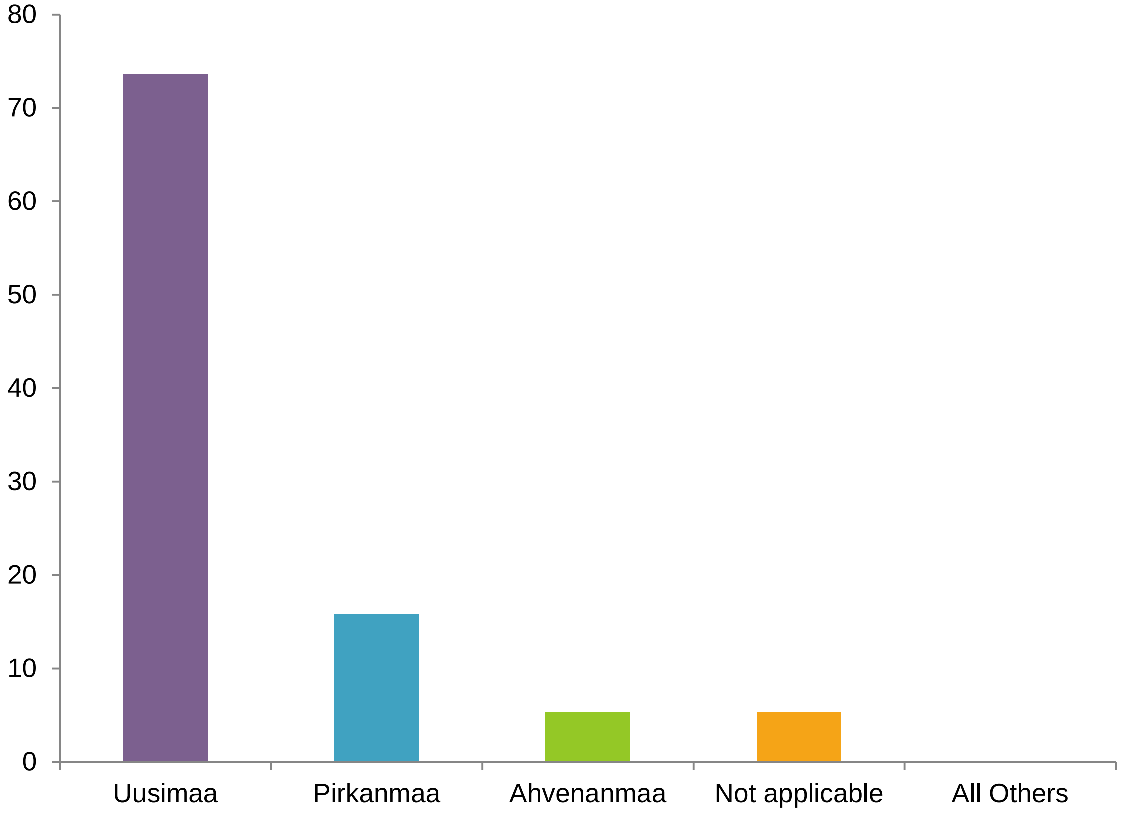
Response *(vastaajien omin sanoin)
Almanakat, ionosfäärit ym. pitäisi olla yhden linkin takana kaikki selkokielellä esitettynä.
Datan tulisi olla koneellisesti luettavissa toisiin ohjelmiin.
Ehdottomasti sovellus älypuhelimeen.
Erityisesti kiinnostaa Glonassin tarkkuus, meille esim.Geotrim sanoo että ne on pienemmällä painolla mukana laskennassa, onko se edelleen niin huonoa dataa?
Että palvelu kattaisi koko Suomen eikä vain Etelä-Suomea.
Palvelun oman sovelluksen kautta päivittyvä tieto olisi paras vaihtoehto (android, iOS). Sen voisi aina avata maastossa, jos on tarve saada tietoa tilanteesta. Muuten koen reaaliaikainen tiedottaminen sosiaalisen median kautta hankalaksi.
Minua kiinnostaa se, miten hyvin GNSS signaalin häiriösignaalit saadaan yhdistettyä muuhun saatavilla olevaan dataan ja voidaan hyödyntää maan tai ilmakehän tutkimuksessa ja päinvastoin.
Myös vakiintuneet kuuluvuusalueen rajat voisi visualisoida karttapohjalle
Riittävä tarkkuus maanrakentamiseen
Tarvitsemme yksinkertaistettua tietoa kuten arvio tilanteesta kuten 'oletettu virhe hyvissä oloissa matkapuhelimella metreinä' tai arvoa 0.0-1.0 jonka voimme muuttaa esim. liikennevaloksi
Toimintavarmuus
Toimittava ios ja android puhelimilla
Turvallisuusviranomaiset tarvitsevat GNSS käytettävyystietoja toiminnassaan
Tämä teidän suunnittelema palvelu on melko hifistelyä raa'an ja päivittäisen perustyön kannalta. Ensin pitäisi saada maanmittauslaitoksen oma korjauspalvelu / finref -verkko (+rtk -palvelu) niin tiheäksi ja siihen kuntoon sekä luetettavuustasoon, että ko. palvelua ei enää tarvitsisi ostaa talon ulkopuolelta.
Valinnaisia palvelinkeskuksia, jopa Suomen ulkopuolella. 24/7-luotettavuus yli 99.9%.
Aajansiirrossa suurin epävarmuus 1-taajuusvastaanottimilla lienee ionosfääri. jos tähän saadaan parannusta voisi tehdä esim Rb-kellojen ohjausta paremmin common-view tekniikalla referenssi labraa/vastaanotinta vastaan. 2-taajuus vastaanottimilla ja PPP tekniikalla troposfääri lienee suurin ongelma - onkohan tähän jotain ratkaisua?
Toivoisin Galileo-järjestelmän olevan nopeasti käytössä

English Results

Response Counts

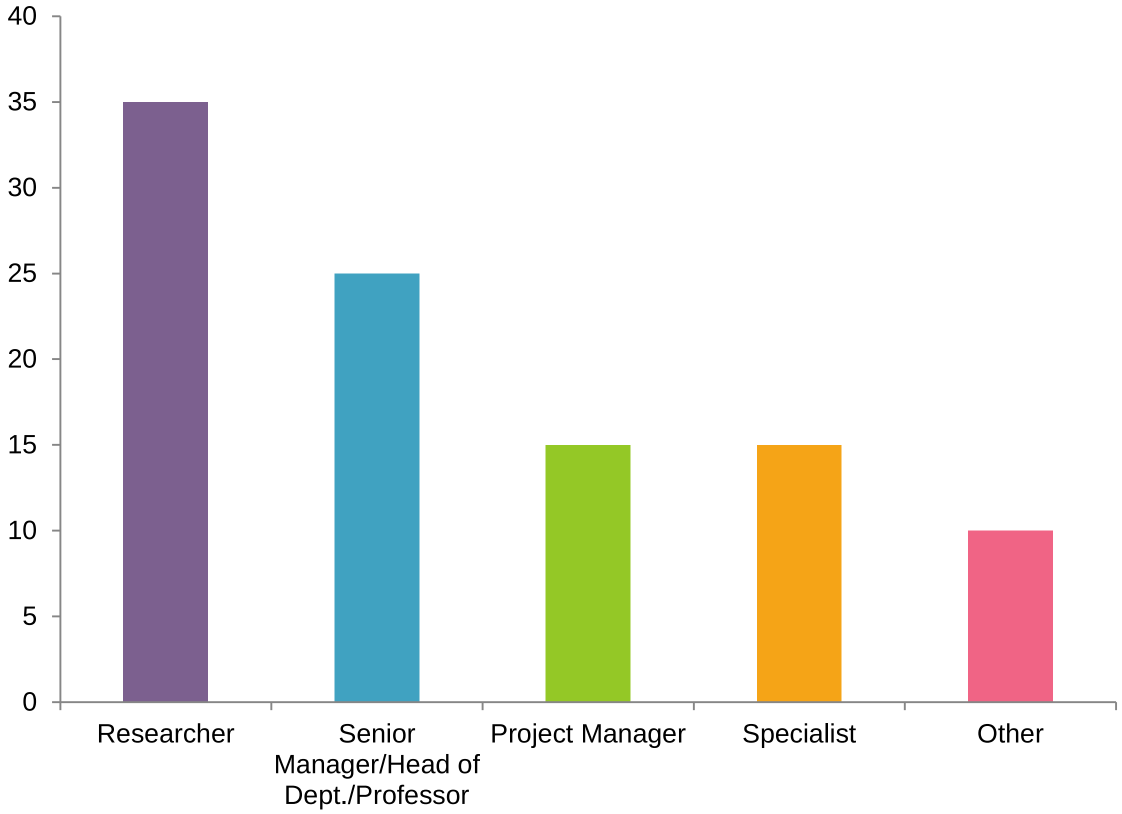
	Count	Percent
Complete	15	35.7
Partial	27	64.3
Disqualified	0	0
Total	**42**	

1. In which region of Finland do you conduct the majority of your work?



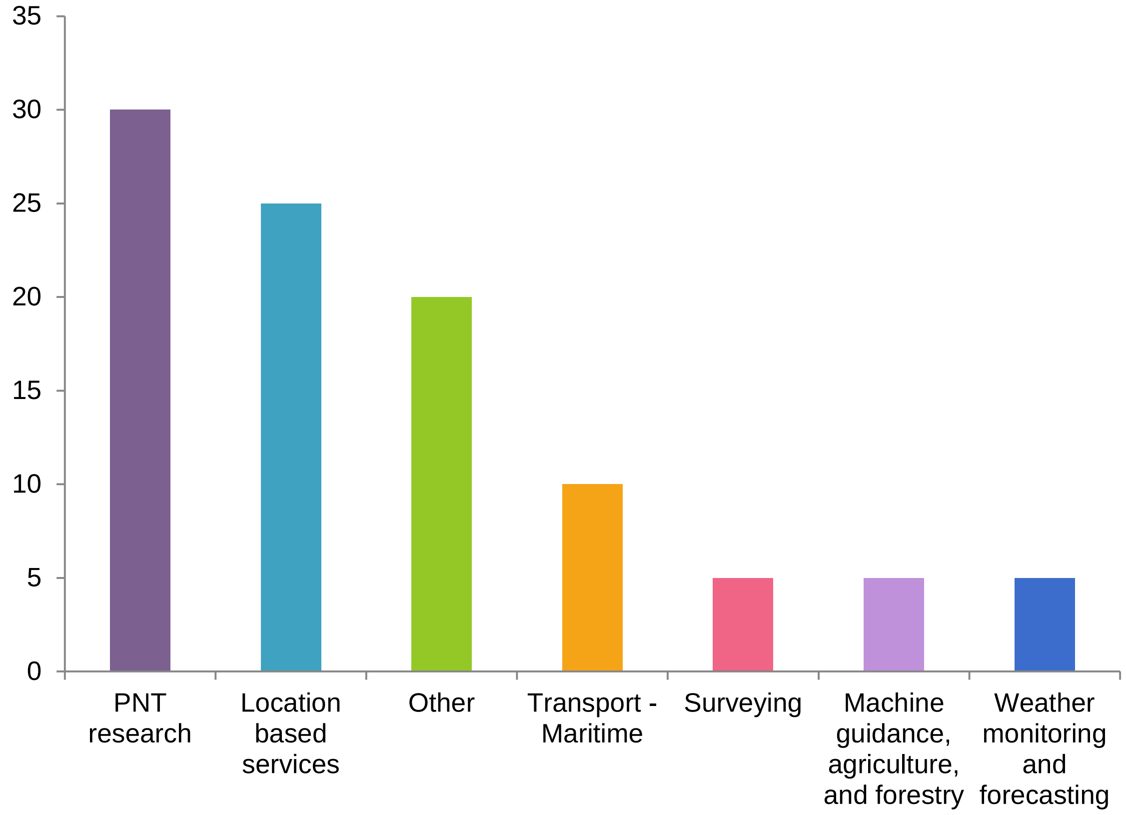
Value	Percent	Count
Uusimaa	73.7%	14
Pirkanmaa	15.8%	3
Ahvenanmaa	5.3%	1
Not applicable	5.3%	1
Total		**19**

2. What is your employment position?



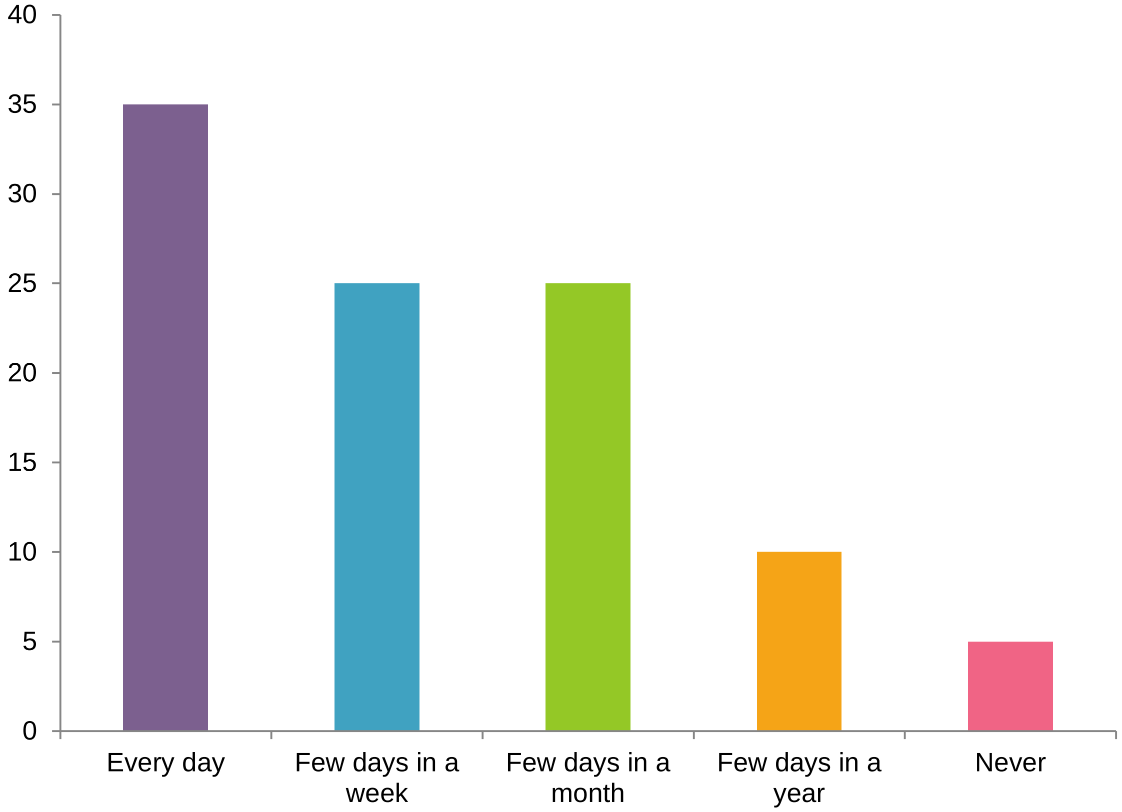
Value	Percent	Count
Researcher	35.0%	7
Senior Manager/Head of Dept./Professor	25.0%	5
Project Manager	15.0%	3
Specialist	15.0%	3
Other	10.0%	2
Total		**20**

3. Which market segment (application domain) is your primary work related to?



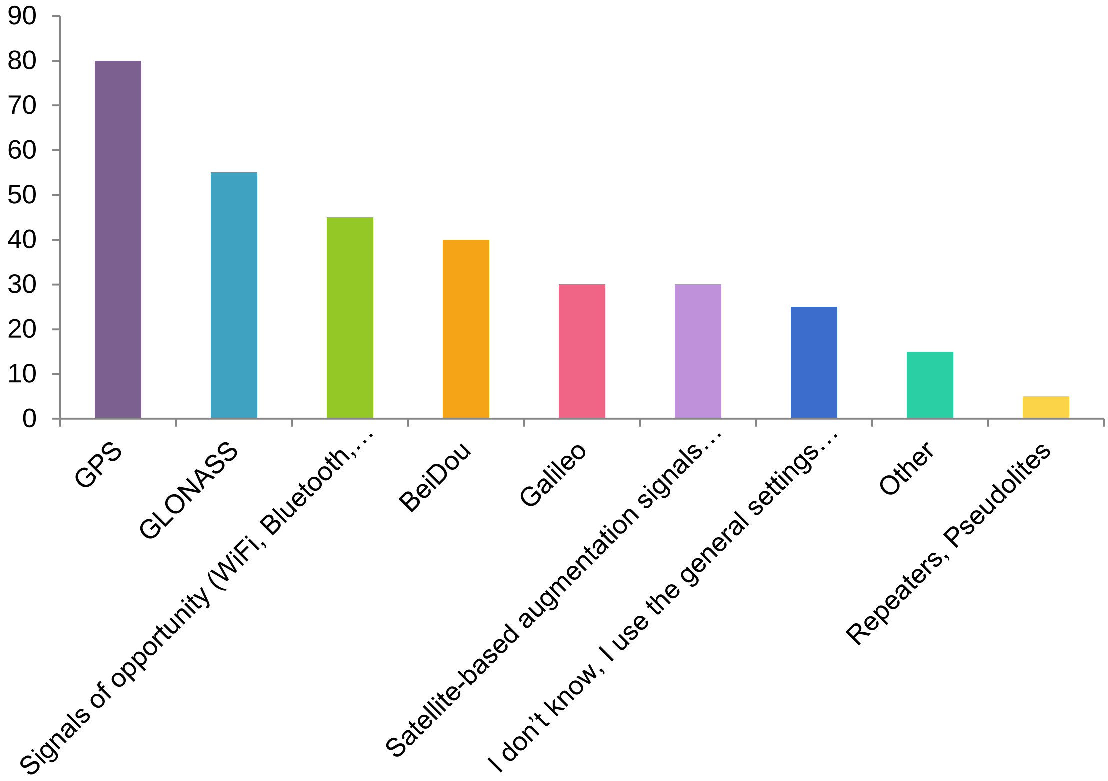
Value	Percent	Count
PNT research	30.0%	6
Location based services	25.0%	5
Other	20.0%	4
Transport - Maritime	10.0%	2
Surveying	5.0%	1
Machine guidance, agriculture, and forestry	5.0%	1
Weather monitoring and forecasting	5.0%	1
Total		**20**

4. How many times during the week do you use GNSS-enabled positioning, navigation, and timing (PNT) in your work?



Value	Percent	Count
Every day	35.0%	7
Few days in a week	25.0%	5
Few days in a month	25.0%	5
Few days in a year	10.0%	2
Never	5.0%	1
Total		**20**

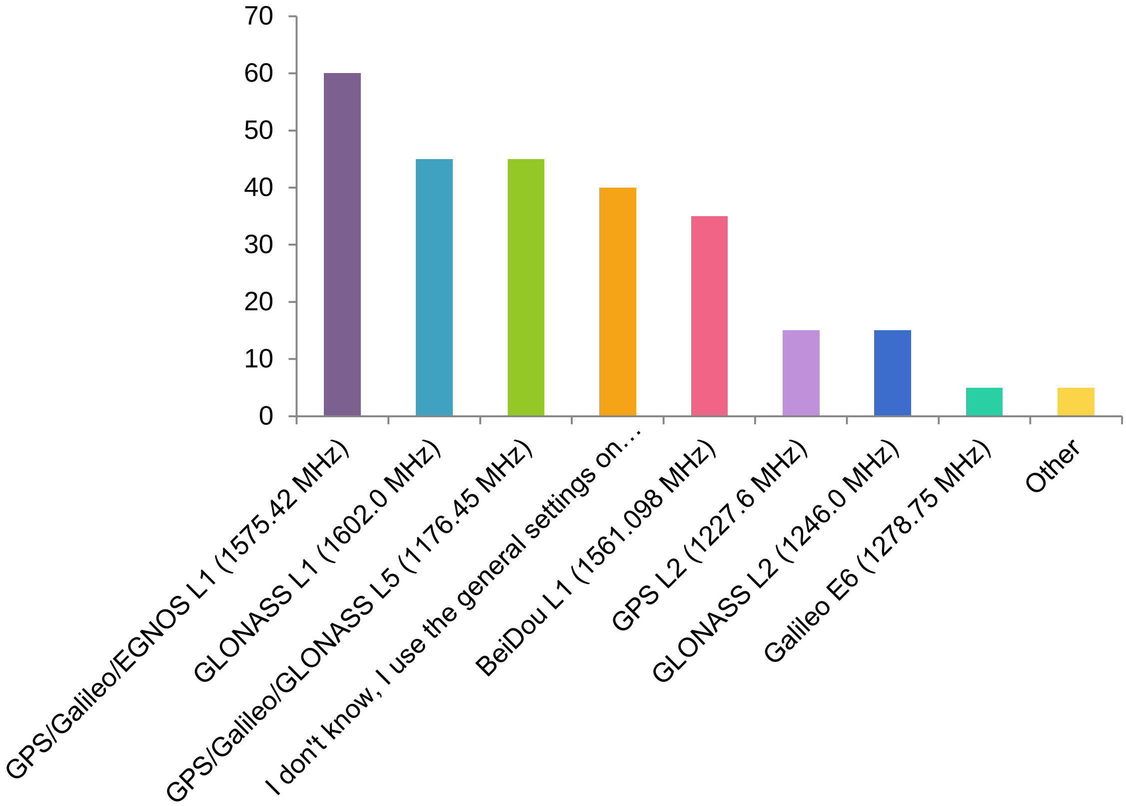
5. Which signals for positioning, navigation, or timing do you use in your work?



Value	Percent	Count
GPS	80.0%	16
GLONASS	55.0%	11
Signals of opportunity (WiFi, Bluetooth, DVB, etc.)	45.0%	9
BeiDou	40.0%	8
Galileo	30.0%	6
Satellite-based augmentation signals (SBAS - EGNOS)	30.0%	6
I don't know, I use the general settings on the equipment provided	25.0%	5
Other	15.0%	3
Repeaters, Pseudolites	5.0%	1

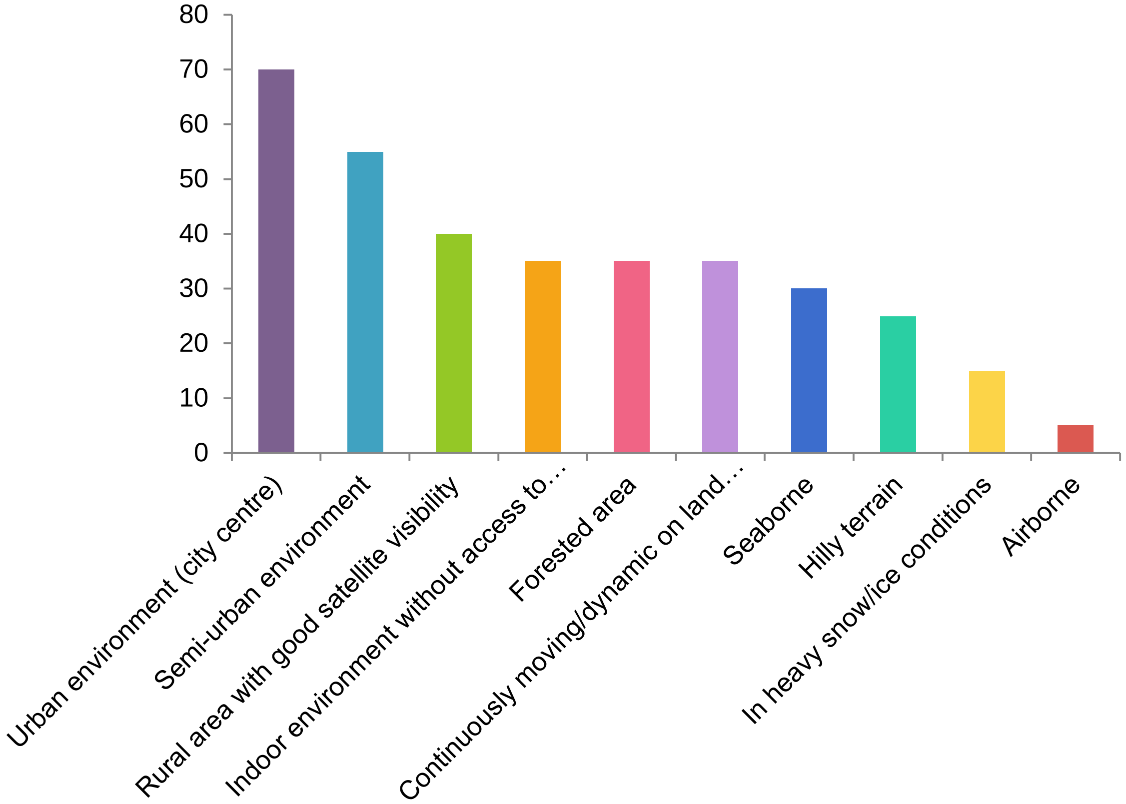
Other *(respondents own words)	Count
Mobile network positioning	1
Signals from cellular communications	1
Information fusion	1

6. Which GNSS frequency bands do you use in your work?



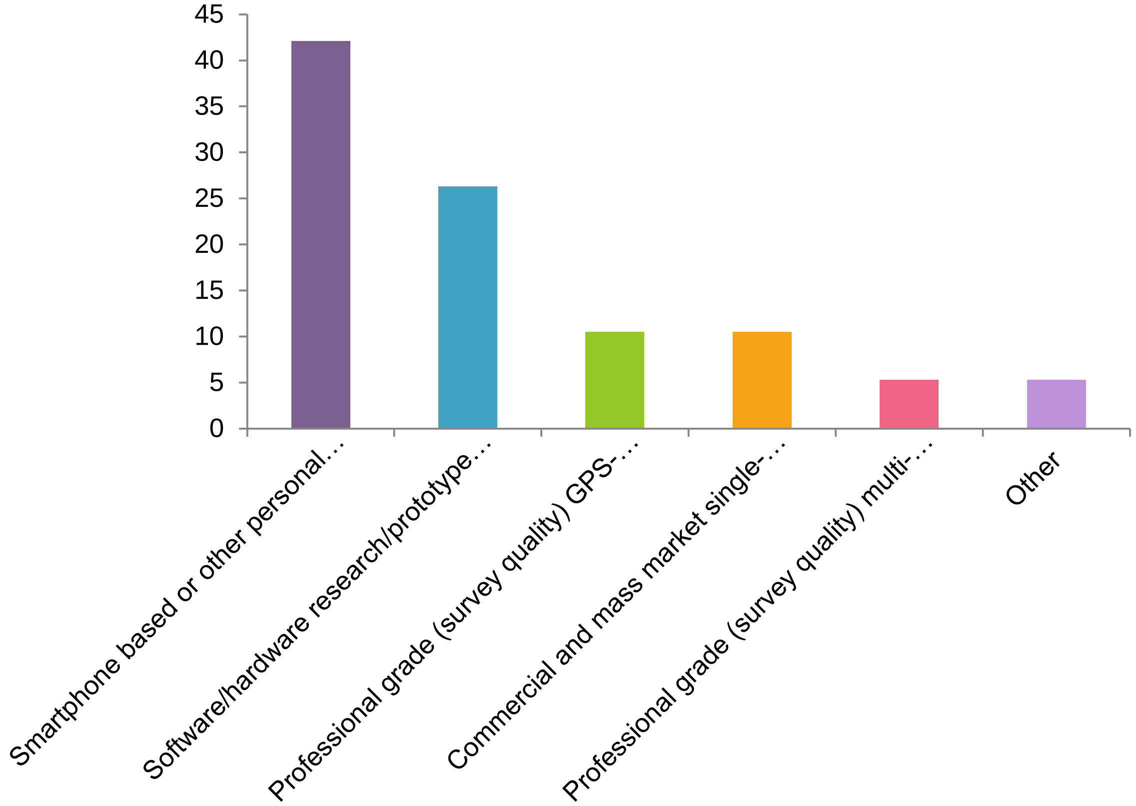
Value	Percent	Count
GPS/Galileo/EGNOS L1 (1575.42 MHz)	60.0%	12
GLONASS L1 (1602.0 MHz)	45.0%	9
GPS/Galileo/GLONASS L5 (1176.45 MHz)	45.0%	9
I don't know, I use the general settings on the equipment provided	40.0%	8
BeiDou L1 (1561.098 MHz)	35.0%	7
GPS L2 (1227.6 MHz)	15.0%	3
GLONASS L2 (1246.0 MHz)	15.0%	3
Galileo E6 (1278.75 MHz)	5.0%	1
Other	5.0%	1

7. In what environment do you conduct most of your work with navigation signals?



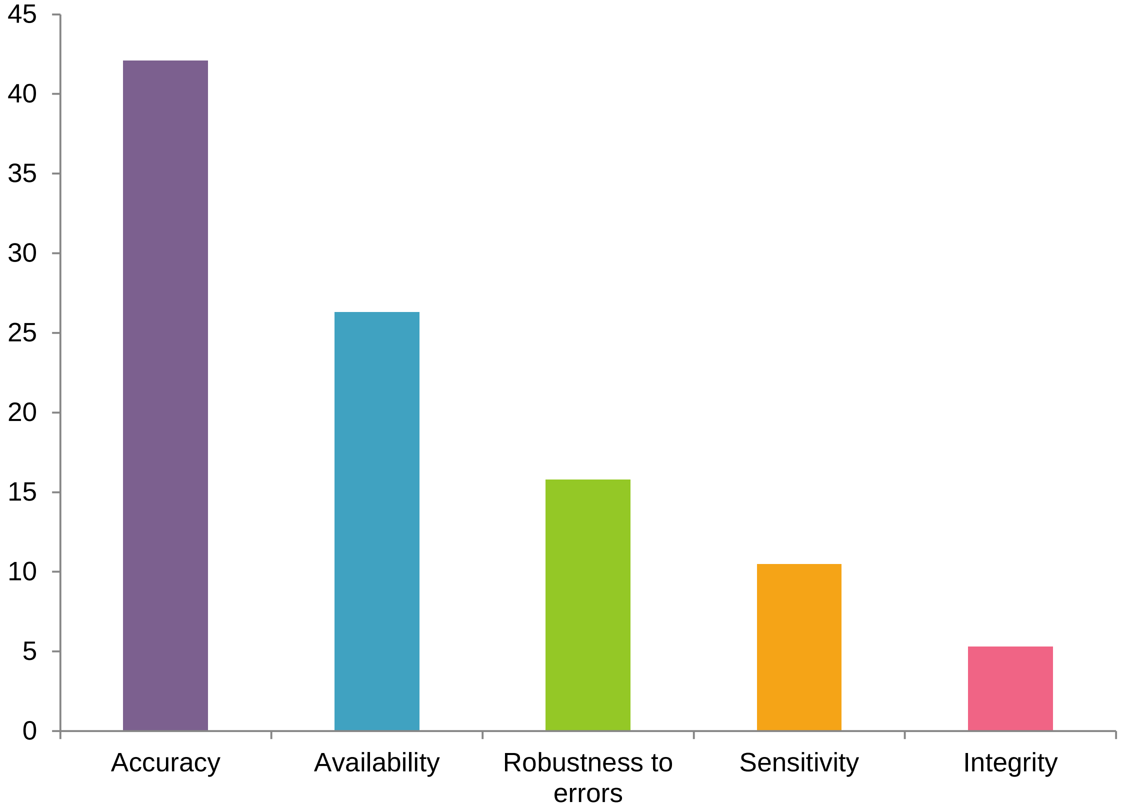
Value	Percent	Count
Urban environment (city centre)	70.0%	14
Semi-urban environment	55.0%	11
Rural area with good satellite visibility	40.0%	8
Indoor environment without access to satellite signals	35.0%	7
Forested area	35.0%	7
Continuously moving/dynamic on land (for example on a bus or a train)	35.0%	7
Seaborne	30.0%	6
Hilly terrain	25.0%	5
In heavy snow/ice conditions	15.0%	3
Airborne	5.0%	1

8. What type of PNT (position, navigation and timing) receiver equipment do you primarily use in your work?



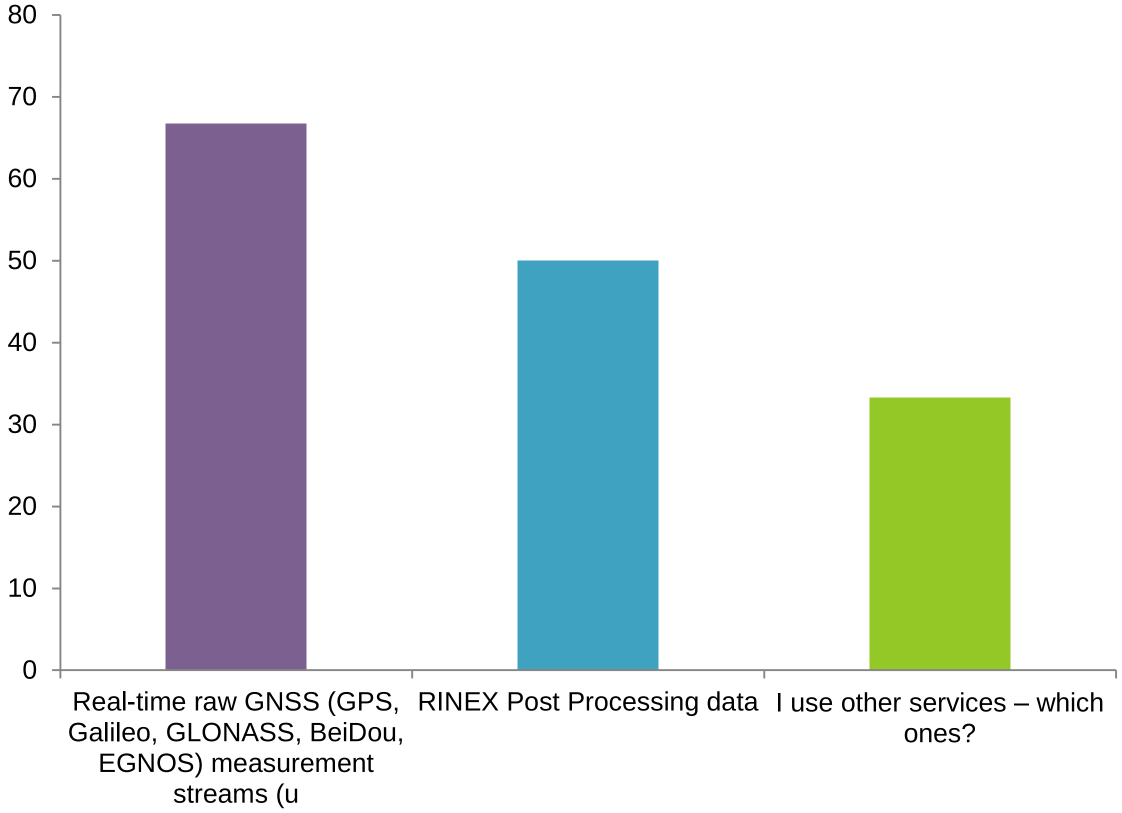
Value	Percent	Count
Smartphone based or other personal navigation assistant (PNA) device	42.1%	8
Software/hardware research/prototype receiver	26.3%	5
Professional grade (survey quality) GPS-only dual-frequency receivers	10.5%	2
Commercial and mass market single-frequency receivers	10.5%	2
Professional grade (survey quality) multi-GNSS multi-frequency receivers	5.3%	1
Other	5.3%	1
Total		**19**

9. What is the most critical performance parameter of the positioning receiver in your work domain?



Value	Percent	Count
Accuracy	42.1%	8
Availability	26.3%	5
Robustness to errors	15.8%	3
Sensitivity	10.5%	2
Integrity	5.3%	1
Total		**19**

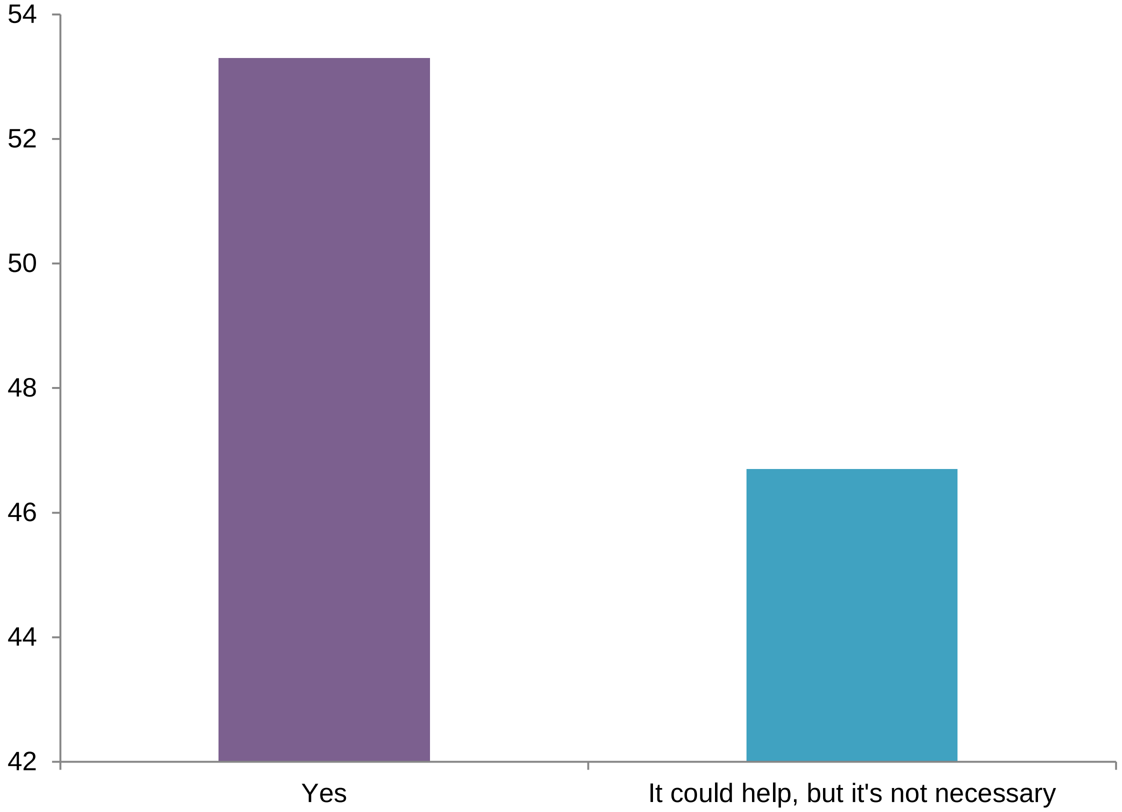
10. Do you use data products from the Finnish GNSS Reference Network (FinnRef)? If yes, which ones?



Value	Percent	Count
Real-time raw GNSS (GPS, Galileo, GLONASS, BeiDou, EGNOS) measurement streams (usually for research purposes only)	66.7%	4
RINEX Post Processing data	50.0%	3
I use other services – which ones?	33.3%	2

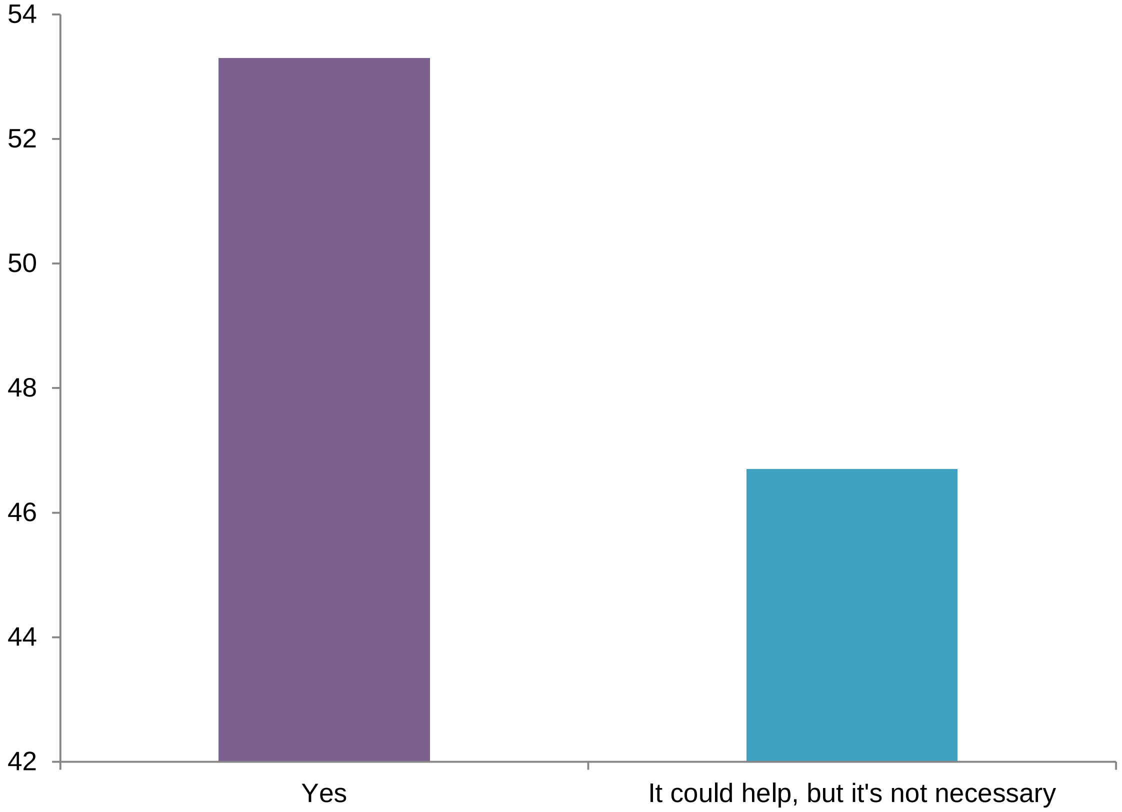
I use other services – which ones? *(respondents own words)	Count
IGS	1
Undefined	1

11. Will knowing the operational status of satellite navigation (GNSS/EGNOS) systems over Finland benefit you in conducting your work more effectively?



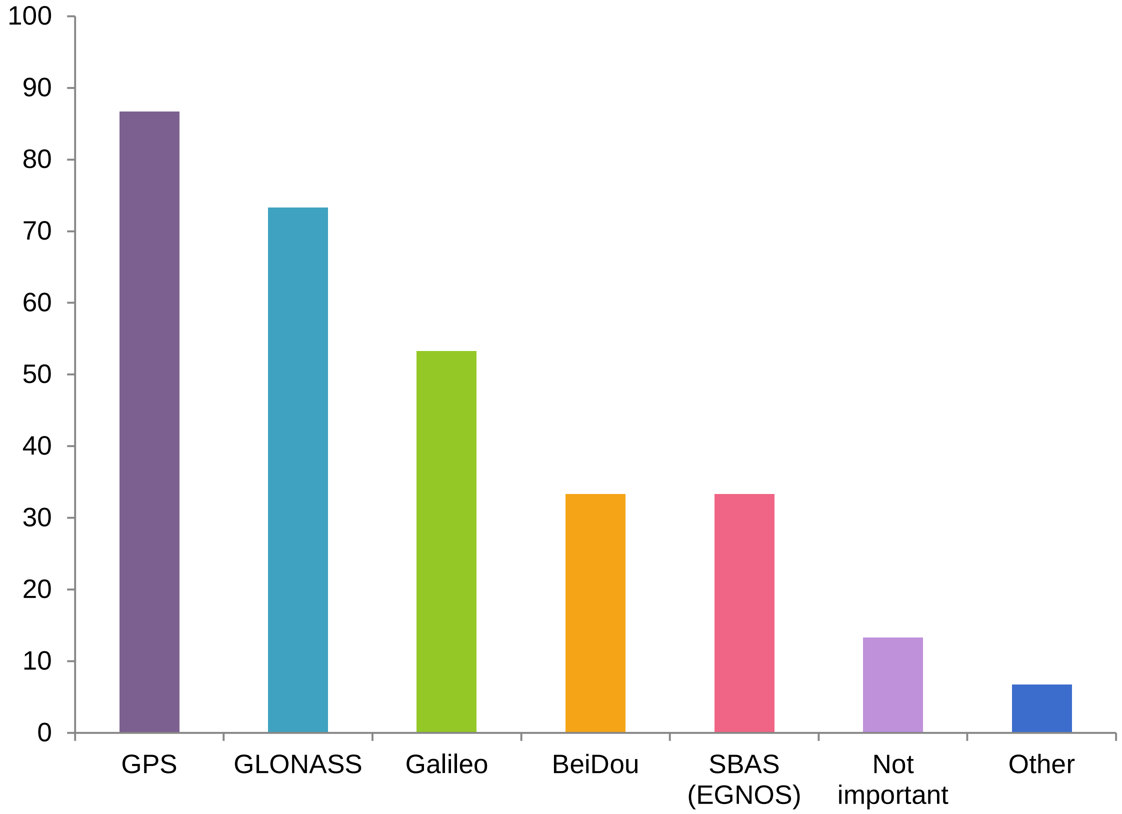
Value	Percent	Count
Yes	53.3%	8
It could help, but it's not necessary	46.7%	7
Total		**15**

12. Will knowing the current status of the atmospheric effects (ionosphere and troposphere) over Finland benefit you in conducting your work more effectively?



Value	Percent	Count
Yes	53.3%	8
It could help, but it's not necessary	46.7%	7
Total		**15**

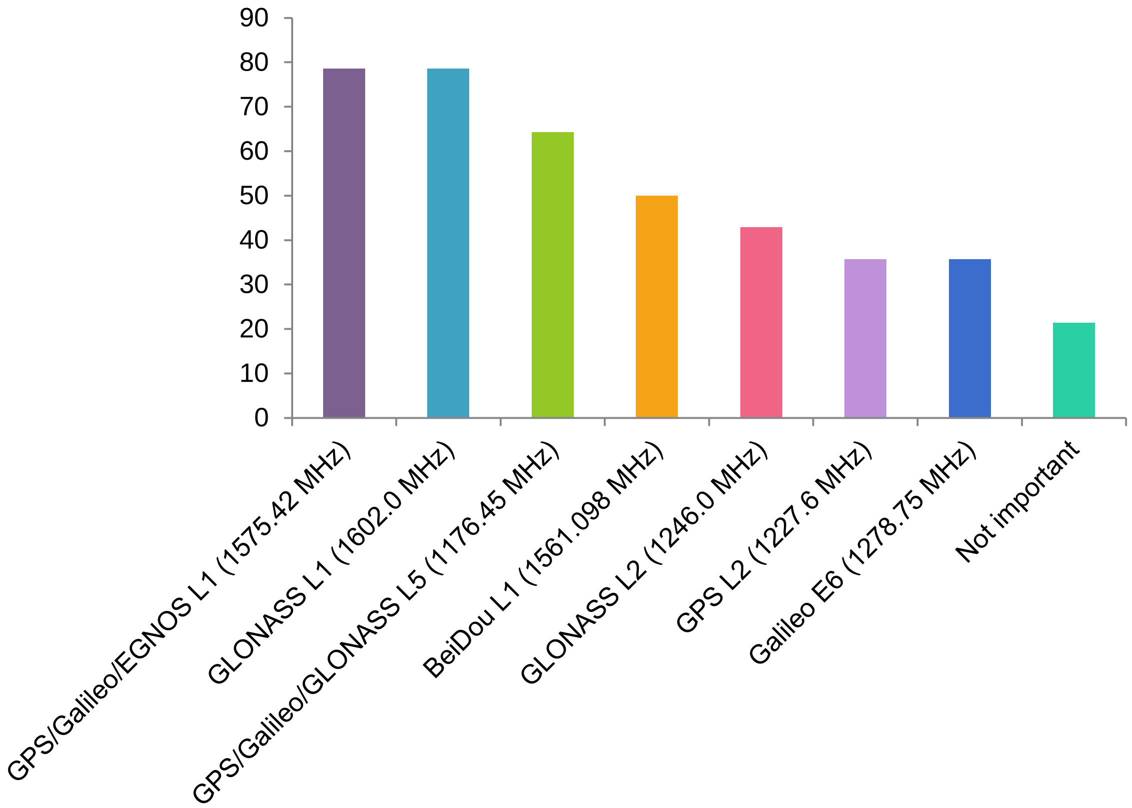
13. The quality of which GNSS system(s) would you like to see monitored over Finland?



Value	**Percent**	**Count**
GPS	86.7%	13
GLONASS	73.3%	11
Galileo	53.3%	8
BeiDou	33.3%	5
SBAS (EGNOS)	33.3%	5
Not important	13.3%	2
Other	6.7%	1

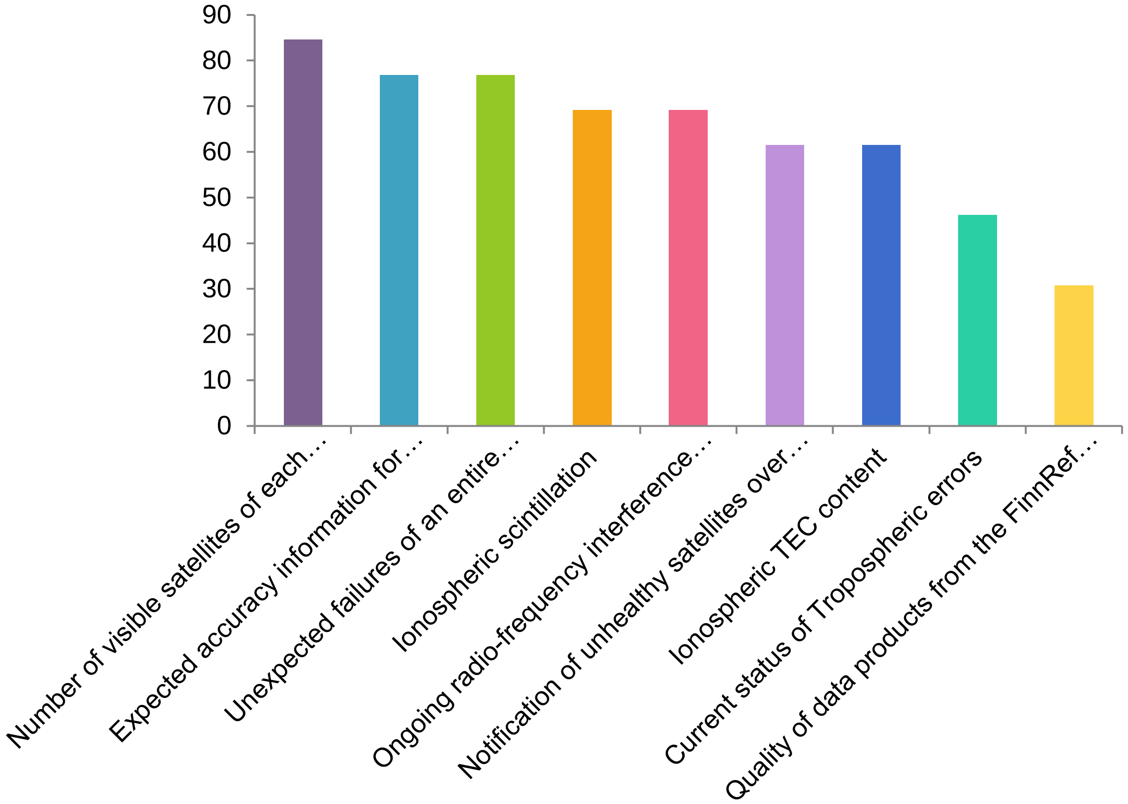
Other *(respondents own words)	**Count**
Mobile network positioning	1

14. The quality of which GNSS frequency bands would you like to be monitored in Finland?



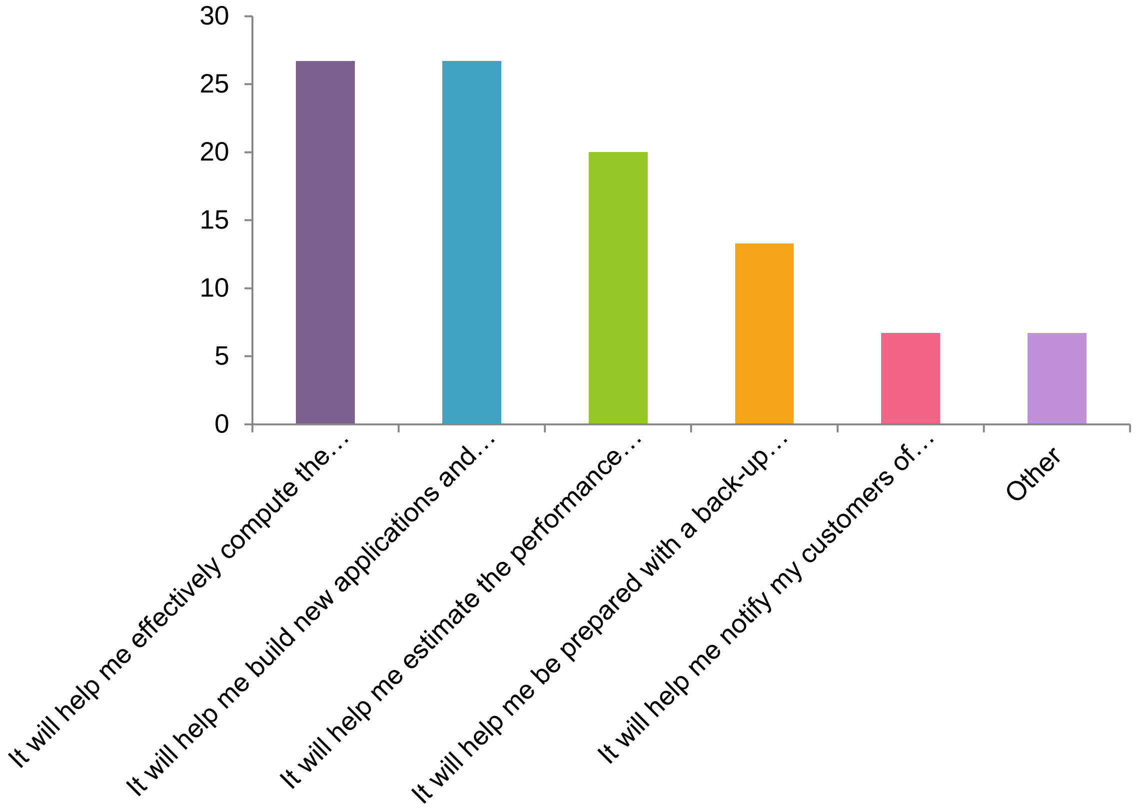
Value	Percent	Count
GPS/Galileo/EGNOS L1 (1575.42 MHz)	78.6%	11
GLONASS L1 (1602.0 MHz)	78.6%	11
GPS/Galileo/GLONASS L5 (1176.45 MHz)	64.3%	9
BeiDou L1 (1561.098 MHz)	50.0%	7
GLONASS L2 (1246.0 MHz)	42.9%	6
GPS L2 (1227.6 MHz)	35.7%	5
Galileo E6 (1278.75 MHz)	35.7%	5
Not important	21.4%	3

15. What performance parameters of GNSS/EGNOS signals would you prefer to monitor over Finland?



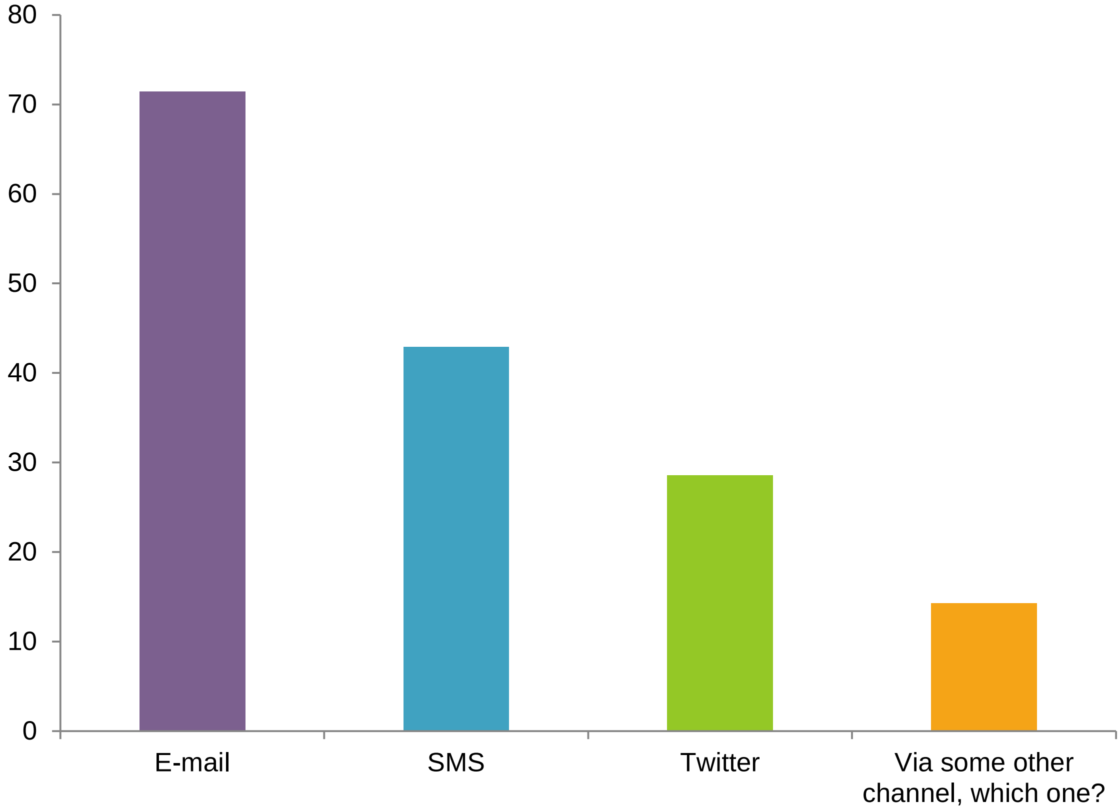
Value	Percent	Count
Number of visible satellites of each constellation	84.6%	11
Expected accuracy information for GNSS/EGNOS signals	76.9%	10
Unexpected failures of an entire navigation system	76.9%	10
Ionospheric scintillation	69.2%	9
Ongoing radio-frequency interference events	69.2%	9
Notification of unhealthy satellites over Finland	61.5%	8
Ionospheric TEC content	61.5%	8
Current status of Tropospheric errors	46.2%	6
Quality of data products from the FinnRef network	30.8%	4

16. What according to you would be the primary benefit of the GNSS-Weather service?



Value	Percent	Count
It will help me effectively compute the errors in the measurements I have taken	26.7%	4
It will help me build new applications and services based on this information	26.7%	4
It will help me estimate the performance of my position-based products and services	20.0%	3
It will help me be prepared with a back-up solution in case of any disruptions to the GNSS signals	13.3%	2
It will help me notify my customers of potential disruptions and degradations	6.7%	1
Other	6.7%	1
Total		**15**

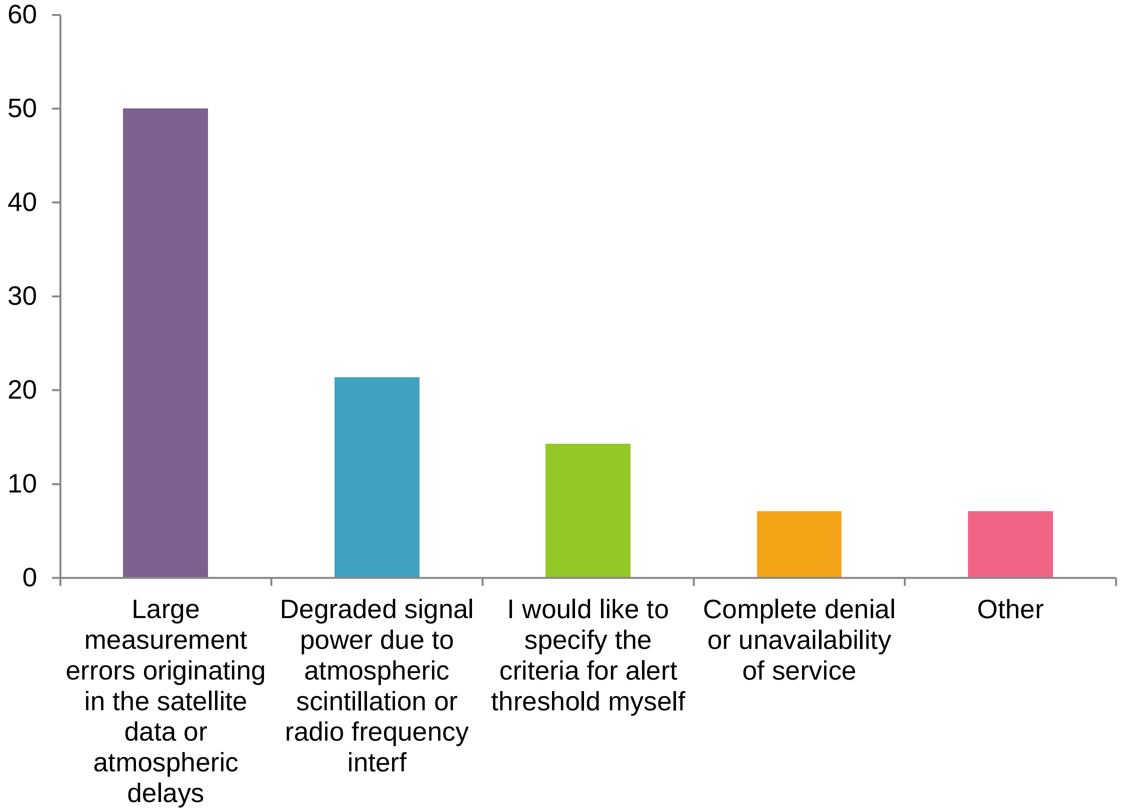
17. In case of an ongoing interruption or degradation in GNSS/EGNOS signal quality over Finland, how would you like to be notified?



Value	Percent	Count
E-mail	71.4%	10
SMS	42.9%	6
Twitter	28.6%	4
Via some other channel, which one?	14.3%	2

Via some other channel, which one? *(respondents own words)	**Count**
GeoRSS	1
Webpage	1

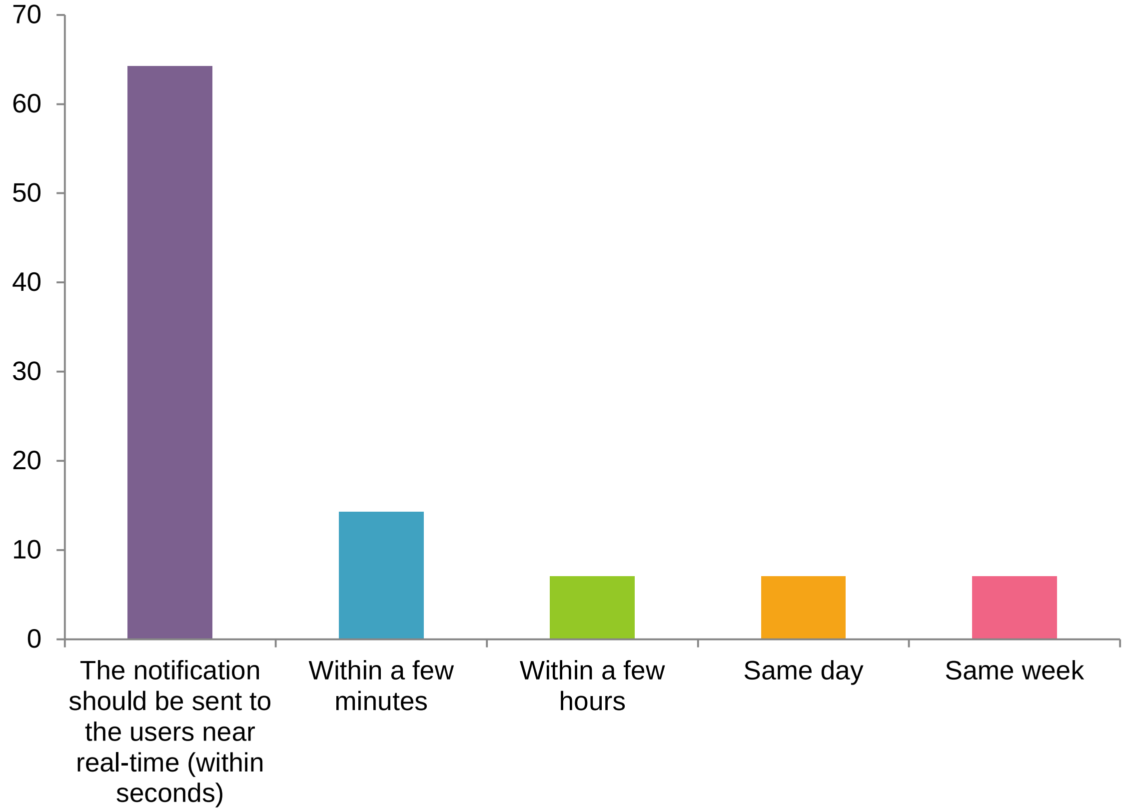
18. What is the level of GNSS signal quality degradation at which you would like to be notified?



Value	**Percent**	**Count**
Large measurement errors originating in the satellite data or atmospheric delays	50.0%	7
Degraded signal power due to atmospheric scintillation or radio frequency interference	21.4%	3
I would like to specify the criteria for alert threshold myself	14.3%	2
Complete denial or unavailability of service	7.1%	1
Other	7.1%	1
Total		**14**

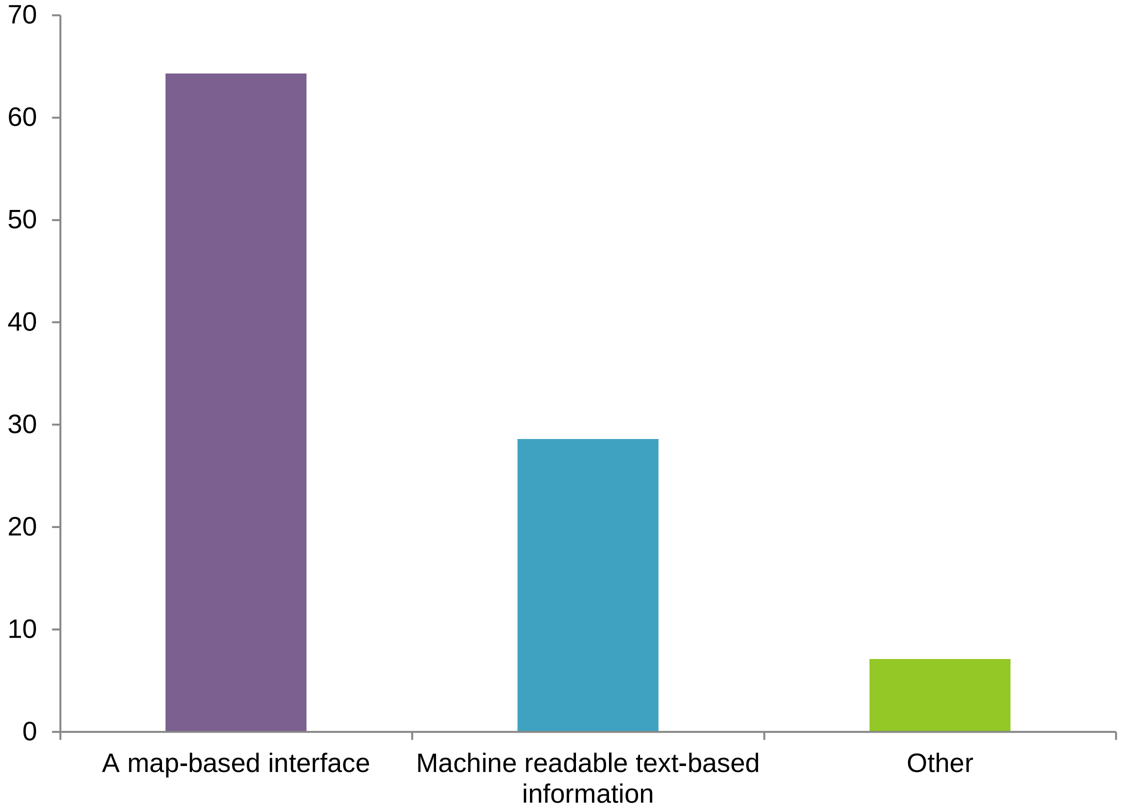
Other *(respondents own words)	**Count**
Accuracy of fix beyond predefined level	1

19. What is the maximum time delay acceptable for you between an event or signal degradation and notification to the users?



Value	Percent	Count
The notification should be sent to the users near real-time (within seconds)	64.3%	9
Within a few minutes	14.3%	2
Within a few hours	7.1%	1
Same day	7.1%	1
Same week	7.1%	1
Total		**14**

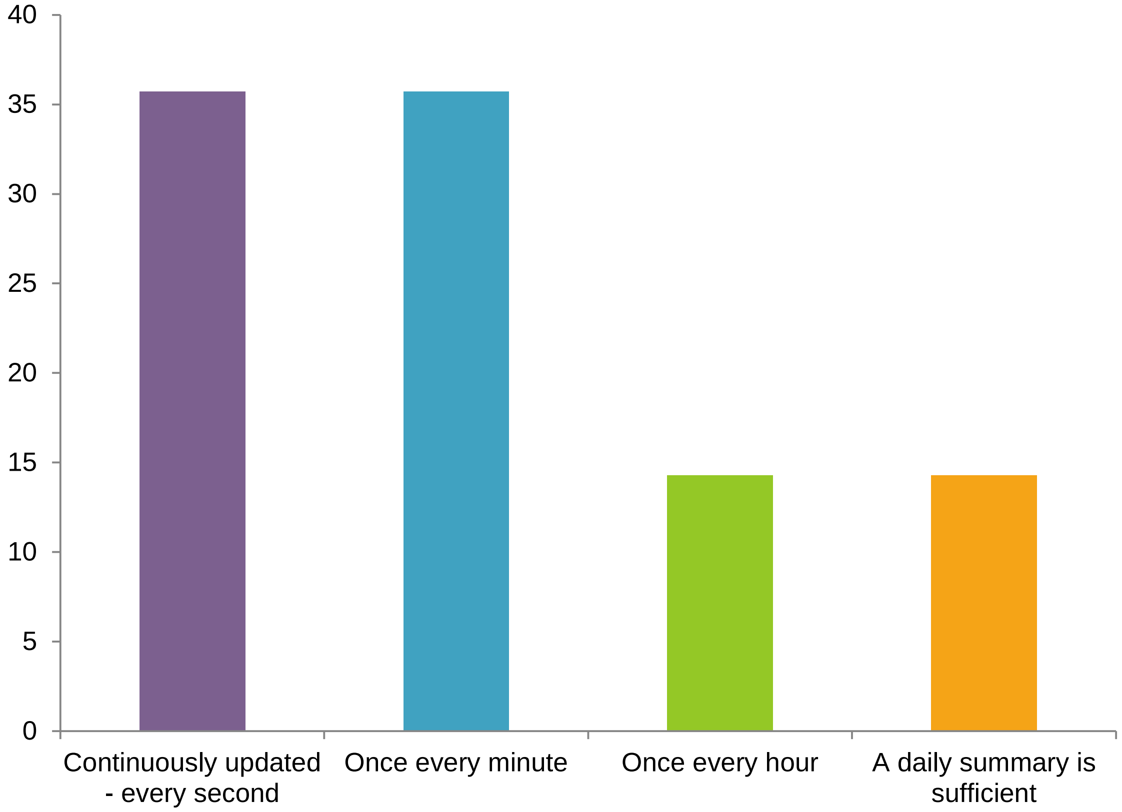
20. In your opinion, what is the most suitable user interface for the service?



Value	Percent	Count
A map-based interface	64.3%	9
Machine readable text-based information	28.6%	4
Other	7.1%	1
Total		**14**

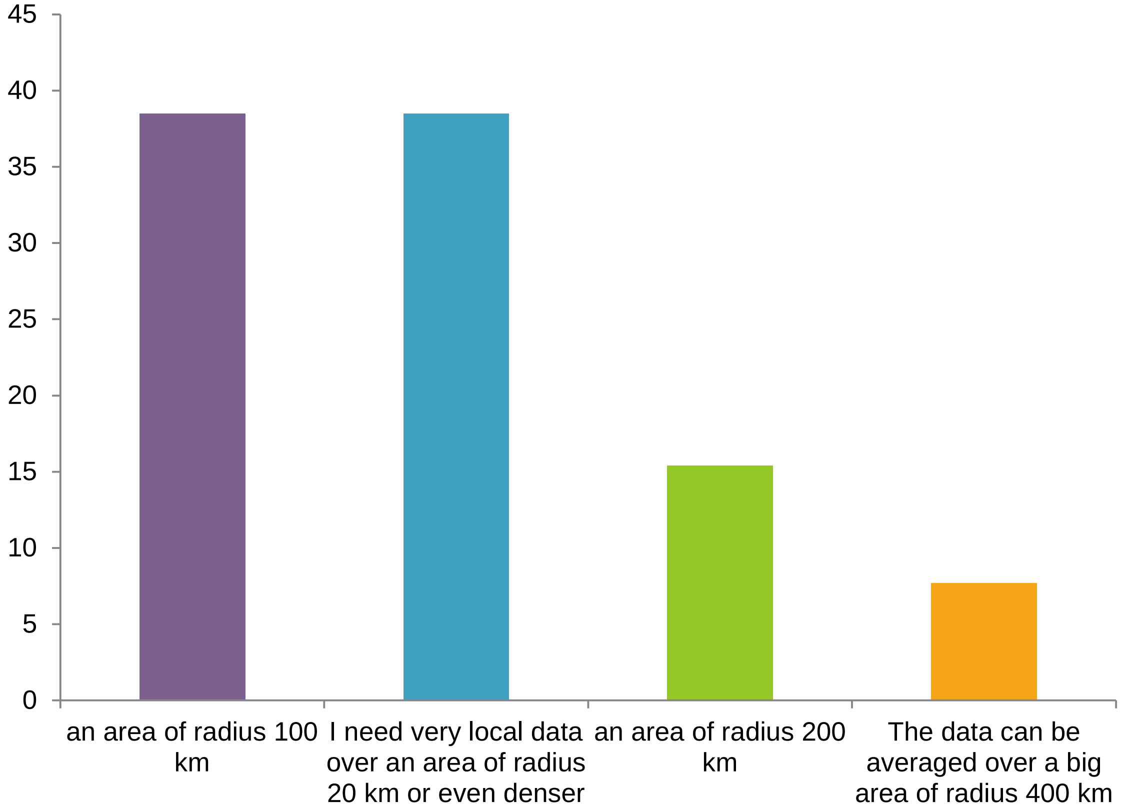
Other *(respondents own words)	**Count**
Map-based and machine readable	1

21. How often would you like the information provided on the service webpage to be updated?



Value	Percent	Count
Continuously updated - every second	35.7%	5
Once every minute	35.7%	5
Once every hour	14.3%	2
A daily summary is sufficient	14.3%	2
Total		**14**

22. What spatial resolution for the GNSS-Weather service would be sufficient for your work?



Value	Percent	Count
An area of radius 100 km	38.5%	5
I need very local data over an area of radius 20 km or even denser	38.5%	5
An area of radius 200 km	15.4%	2
The data can be averaged over a big area of radius 400 km	7.7%	1
Total		**13**

23. Are there any existing data/interface standards this service should conform to?

Response *(respondents own words)
Not yet
nTrip maybe