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KEIJO HÄMÄLÄINEN, DIETER FRITSCH, ANNA JENSEN AND SANDRA VERHAGEN

# International Evaluation of the Finnish Geospatial Research Institute, FGI

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Keijo Hämäläinen, Dieter Fritsch, Anna Jensen and Sandra Verhagen

Ministry of Agriculture and Forestry Helsinki 2023

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## International Evaluation of the Finnish Geospatial Research Institute, FGI

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### Abstract

This is the report of an international panel for the 2022 Evaluation of the Finnish Geospatial Research Institute (FGI). The Ministry of Agriculture and Forestry commissioned a team of proven scientists and science managers to review the FGI's activities and competencies and make recommendations for the coming years.

The evaluation panel focused their work on 1) the quality of research and expert work of FGI, 2) FGI's societal impacts and relevance to society (public sector, private companies, citizens), 3) FGI's activity and leadership in research collaboration and networks and 4) foresight and innovativeness of FGI's activities.

The evaluation panel prepared a description of FGI's strengths, weaknesses, threats and opportunities. In addition, the panel made suggestions and recommendations for further development of FGI's research and expert work.

**Keywords** land surveying, geospatial information, research institutes, research, assessment

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## Paikkatietokeskuksen (FGI) kansainvälinen arviointi

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### Tiivistelmä

Tämä on Paikkatietokeskuksen (FGI) toimintaa vuonna 2022 arvioineen kansainvälisen paneelin raportti. Maa- ja metsätalousministeriö antoi tunnetuista tieteen tekijöistä ja tiedeorganisaatioiden johtajista koostuvalle tiimille tehtäväksi tarkastella Paikkatietokeskuksen toimintaa ja kyvykkyyksiä ja antaa suosituksia tuleville vuosille.

Arviointipaneelin työ keskittyi 1) Paikkatietokeskuksen tutkimuksen ja asiantuntijatyön laatuun, 2) Paikkatietokeskuksen yhteiskunnallisiin vaikutuksiin ja vaikuttavuuteen yhteiskunnassa (julkinen sektori, yksityiset yritykset, kansalaiset), 3) Paikkatietokeskuksen toimintaan ja johtajuuteen tutkimusyhteistyössä ja verkostoissa ja 4) Paikkatietokeskuksen toiminnan ennakoivuuteen ja innovatiivisuuteen.

Arviointipaneeli laati kuvauksen Paikkatietokeskuksen vahvuuksista, heikkouksista, uhkista ja mahdollisuuksista. Lisäksi paneeli antoi ehdotuksia ja suosituksia Paikkatietokeskuksen tutkimuksen ja asiantuntijatyön jatkokehittämiseen.

**Asiasanat** maanmittaus, paikkatiedot, tutkimuslaitokset, tutkimus, arviointi

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## Internationell utvärdering av Geodatacentralen (FGI)

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### Referat

Det här är en rapport av en internationell panel för utvärderingen av Geodatacentralen (FGI) 2022. Jord- och skogsbruksministeriet gav en grupp erkända forskare och forskningschefer i uppgift att utvärdera Geodatacentralens verksamhet och kompetenser och ge rekommendationer inför de kommande åren.

I sitt arbete fokuserade utvärderingspanelen på 1) kvaliteten på Geodatacentralens forskning och sakkunnigarbete 2) Geodatacentralens samhälleliga inverkan och betydelse för samhället (offentliga sektorn, privata företag, medborgare) 3) Geodatacentralens aktivitet och ledarskap i forskningssamarbeten och forskningsnätverk 4) förutseende och nytänkande i Geodatacentralens verksamhet.

Utvärderingspanelen utarbetade en beskrivning av Geodatacentralens styrkor, svagheter, hot och möjligheter. Dessutom tog panelen fram förslag och rekommendationer för fortsatt utveckling av Geodatacentralens forskning och sakkunnigarbete.

**Nyckelord** lantmäteri, geografisk information, forskningsinstitut, forskning, utvärdering

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# 1 Foreword

This is the report of an international panel for the 2022 Evaluation of the Finnish Geospatial Research Institute (FGI). The Ministry of Agriculture and Forestry commissioned a team of proven scientists and science managers to review the FGI's activities and competencies and make recommendations for the coming years. The evaluation panel, chaired by Prof. Keijo Hämäläinen, University of Jyväskylä, Finland, with members Prof. Dieter Fritsch, Univ. Stuttgart, Germany, Prof. Anna Jensen, Danish Assessment Agency, and A/Prof. Sandra Verhagen, TU Delft, The Netherlands, was able to gain a picture of the current research landscape within and outside the FGI on the basis of extensively submitted materials as well as through a two-day site visit in November 2022 in course of lectures and, above all, interviews. In total we have met more than 60 people including the managers and staff of FGI, and representatives from other organizations collaborating with FGI. We want to thank all these people who have expanded their time and energy to deliver the best possible input for the international evaluation process.

We also would like to thank the Ministry of Agriculture and Forestry, and here Jaana Husu-Kallio, Permanent Secretary, Mikko Peltonen, Research Director, and Mari Laakso, for their trust and constructive support. In addition, we thank Leena Sukselainen and Juho Hellstén, Project Coordinators and Evaluation Organizers, for their great support to prepare the documents and to guide us through the on-site visit. Last, but not least we are grateful for the kind attention we have received from Jarkko Koskinen, Deputy Director General of NLS/FGI, Tiina Sarjakoski, Research Director of NLS, and the FGI Department Directors Juha Hyypä, Sanna Kaasalainen, Hannu Koivula and Juha Oksanen.

*Keijo Hämäläinen, Jyväskylä*      *Dieter Fritsch, Stuttgart*

*Anna Jensen, Copenhagen*      *Sandra Verhagen, Delft*

## 2 Executive Summary

All detailed suggestions and recommendations are given in section 8 of this report. Below is a short summary:

**Strengths:** The FGI is a unique Finnish Research Institute and has got a worldwide reputation in geodesy, GNSS, laser scanning technologies, remote sensing, UAV, and geoinformatics. During more than 100 years, sometimes of uncertainty and continuously changing working conditions, FGI had tended to its duties and conducted research in a very competent manner. From the beginning, it has been a characteristic feature of Finnish geodesy that the leaders and the staff of the FGI have continuously been outstanding scientists. Based on these brilliant performances, the FGI is an international brand and highly respected by all international geospatial bodies. The Metsähovi Research Station is unique, at a national and international level, and therefore contributes to FGI being a competent and globally sought-after partner. The success of all four departments over the last 10 years, exemplified by the establishment of the Center of Excellence Laser Scanning Research, the Location Innovation Hub, and being leader of the UAV cluster, demonstrates capabilities not only in excellent research but also to contribute to the Finnish society, in terms of forest inventory and fast and reliable mapping. The worldwide reputation attracts many young scientists to start a scientific career at FGI.

**Weakness:** FGI runs officially under the budget of NLS and needs continuous services, i.e. to operate the unique Metsähovi Research Station. Thus, based on the size of FGI today, its total funding depends heavily on external research programs, at national and European level. Quite often short-term external funding cannot offer mid-term and long-term contracts for young scientists, which makes recruitment difficult. FGI is carrying out a lot of research in collaboration with or having impact to other ministries beyond the MAF (e.g. ministries of Transport and Communications, Environment and Defence). This important and high impact role of FGI should be articulated more visibly and supported financially beyond MAF budget funding. FGI should not try to overcome all challenges by itself, like applications of Machine Learning and Deep Learning, but should seek cooperations with competent partners (i.e. with Aalto University).

**Opportunities:** FGI has excellent scientists and facilities. Thus, it has the potential to carry on with the national tasks (geodetic reference systems, geoid determination, GNSS services, OpenData mapping and visualizations, laser scanning & forest inventory, UAV

mapping) and to attract new funding resources. The most recent geospatial challenges are: Digital Twins of cities including underground facilities, climate modeling using 3D and 4D environments, quantum geodesy, robotics and smart manufacturing, 3D data integration using all kind of available sources (SAR, IfSAR, laser scanning, photogrammetry), and real time mapping - to name only few. Furthermore it should cooperate with NLS to further develop the cadastre, from 2D via 2.5D via 3D to 4D. OpenData and OpenScience offer opportunities for SMEs, also this option should be further developed.

**Threats:** The ministry should be congratulated for a successful merging process of FGI and NLS which has created resilience to the FGI operations and finances, and has opened extended support services while letting research at FGI to flourish. The role of FGI within NLS as a unique international level research institute requiring a certain level of dynamics in operations should be guaranteed. Based on these dynamics about 60% of FGI funding is outside funding, through national and international research projects. This requires heavy engagements of the FGI scientists to draft new project proposals and to publish peer-reviewed journal and conference papers. Young scientists, however, need supervision for conducting their own research and also to finish their PhDs. This might sometimes be contradictory and a right balance should be found, such that FGI should be an excellent address for scientific careers also in near future.

## 3 Introduction / Background

Geospatial Research, Developments and Services are about to change all over the world completely. Today all mapping and research institutions are heading towards Geospatial Ecosystems as a backbone of modern societies. The main issues of geospatial concern are: agriculture, climate change, constructions and infrastructures, logistics and supply chains, cities, public safety and security, autonomous driving, land administration and management, and energy transition. The United Nations Statistics Division, UN Headquarter, New York, USA, which is also supervising the UN Global Geospatial Information Management (UN-GGIM) Expert Group, launched in 2022 in cooperation with Geospatial World Inc, New Delhi, India, for the first time a comprehensive report “Geospatial Knowledge Infrastructure” with detailed tables about the “Readiness Index and Value Proposition in World Economy, Society and Environment” [8]. In this report each UN member country is scored with max. 100 scores. The scoring system is subdivided into: (1) Integrated Policy Framework, (2) Foundation Data, (3) Partnerships and Collaborations, (4) Industry Leadership, (5) Applications, Analytics and Modelling, and (6) Geospatial Dimension to Digital Infrastructure. The United States of America (USA) scored 100 and is the front runner, followed by the United Kingdom (rank 2, score 83.89) and Denmark (rank 3, score 81.52). Finland is ranked 14 with a score of 70.55, with its neighbors Sweden (rank 13, score 71.19) and Norway (rank 15, score 70.21). This introductory example demonstrates potential for improving national Key Performance Indicators (KPI), which are also driven by the National Land Survey (NLS) and the Finnish Geospatial Research Institute (FGI) in cooperation with public and non-public cooperation partners.

### 3.1 Rationale for the 2022 International Evaluation

Following the internal directive of Finnish Government, the Ministry of Agriculture and Forestry (MAF), responsible for the National Land Survey (NLS) and the Finnish Geospatial Research Institute (FGI), decided in March 2022, to arrange an international evaluation of the FGI. The objectives of the evaluation were to be to get an independent international expert view of the FGI, in more detail:

- (1) to review the quality of scientific research and expert work
- (2) to evaluate impacts and benefits for society: business, policy and decision making

- (3) to look at its role in networks and collaboration: activity and leadership
- (4) To check for preparedness meeting the challenges of the future: foresight and innovativeness

This evaluation was triggered by strategy discussions between NLS and the Ministry in 2021, and at that point in time it became clear that facts and figures should be answered by a renewed evaluation of FGI, as the last evaluation was accomplished 1998 [1]. Nowadays, 24 years later, scientific research at FGI has changed more or less completely, so did the operation environment of research organizations change in Finland and here in particular, the merger of NLS and FGI was successfully accomplished in 2015.

The expected outcome of the 2022 International Evaluation of FGI on behalf of the MAF were set to be:

- (A) to deliver a Strengths, Weaknesses, Threats, and Opportunities (SWOT) analysis
- (B) to review the interaction between FGI and NLS, and in particular, how to increase synergies
- (C) to make concise and concrete conclusions and recommendations

The evaluation results will be taken in heavy use, by the NLS/FGI to further develop operations (jointly and independently), by the MAF as a performance guidance, and lastly, it will be communicated to the general public to increase a general awareness of the FGI's scientific and societal impacts.

## 3.2 History of FGI

At the end of the 19th century, it became clear that the mapping situation in Finland, then part of the Russian Empire, required a thorough overhaul. Plans for this fundamental change were put forward by a Mapping Committee but nothing really happened until Finland became independent in 1917.

A new committee proposed to establish a Geodetic Institute, and the Finnish government accepted this idea in July 1918. The new institute was placed under the authority of the Senate Agricultural Committee, i.e. the predecessor of the present Ministry of Agriculture and Forestry. The tasks of the institute were to be primarily research in surveying and geodesy. The statute from 1918 specified that the institute was to operate in a collegial fashion in such a way, that the most important issues were discussed within a group

of senior scientists, headed by the institute's director. In many ways an interesting constitution, which has demonstrated its quality by surviving, in slightly different form, till today.

In the first years of independence another mapping institution, the National Board of Survey (NBS, today the National Land Survey), was organized and it was proposed to merge FGI with this new institution. The FGI was strongly against the merger and in 1923 an attempt to settle the dispute was made in a government regulation concerning the Survey Authority. Even a new regulation, issued 1933 (placing the responsibility for the precise leveling and the gravity surveying with FGI, which are still national tasks until today, and making the director of the NBS an "ex officio" member of the directing board of FGI) failed to end the dispute.

In 1973 a MAF working group recommended, that due to most recent technology developments (electronic surveying instruments, satellite geodesy, computer technology) and new theoretical modeling (math geodesy, geoid determination, software) the FGI should remain a separate research institute, a new department dealing with photogrammetry should be launched, and FGI should engage in external funding. These recommendations were adopted as a law by the Finnish Government 1977. 10 years later, a new working group identified the need for the unification of research in mapping, i.e. cartography, photogrammetry and remote sensing, and a new law was passed 1987, thus also a new department of cartography (today Geoinformatics & Cartography) at FGI was started.

The 1998 evaluation recommended to include Geodynamics into the FGI portfolio, thus the Department of Geodesy has been expanded. In addition the independence of FGI was emphasized. The Department of Navigation and Positioning was established in 2001. Political pressure for structural reform of the public research institutes increased after the turn of the millennium. As a follow-up of internal MAF, NLS and FGI discussions 2012–14 the merger of NLS and FGI was performed in 2015 to overcome funding issues and to let similar institutions cooperate more closely.

During more than 100 years, sometimes of uncertainty and continuously changing working conditions, FGI has tended to its duties and conducted research in a very competent manner. From the beginning, it has been a characteristic feature of Finnish geodesy that the leaders and the staff of the FGI have been outstanding scientists. Based on these brilliant performances, the FGI is an international brand and highly respected by all international geospatial bodies. Thus, many FGI members took over leading positions being president, secretary general and working group chairs volunteering for science and research worldwide.

The **Metsähovi** research station is Finland's contribution to global geodesy and one of the fundamental points of the global geodetic network [10]. The first Satellite Laser Ranging (SLR) was built in the mid-1970s, and a permanent GPS reference station has produced a continuous series of observations since the early 1990s. Gravity observations using the superconducting gravimeter were begun in the mid-1990s and in 2004 Very Long Baseline Interferometry was started with the radio telescope of Aalto University. Today, Metsähovi is one of the most modern geodetic research stations in the world, thanks to heavy investments from the MAF, NLS and FGI. All big geodetic observational equipment has in the meantime been renewed and a new radio telescope was completed in 2022. This station is part of a global and a European network of such stations that utilize several observation methods, and is therefore, alongside the FinnRef network, the main link of Finland to global coordinate reference systems and services. It also represents the Finnish contribution to the UN General Assembly 2015 resolution on sustainable global geodetic reference frames. It houses all the GNSS positioning systems, a SLR system (can theoretically also be used for space debris monitoring), the VLBI telescope, equipment to measure gravity changes, and for example, a DORIS beacon of the French Space Agency and radar corner reflectors of the German Space Agency (DLR).

## 4 Quality and impact of research

The research and expert work carried out by the FGI is at an exceptionally high international level compared with similar (European) institutes, the evaluation leaves no doubt about that. This is supported by the KPIs including a high number of publications, a high number of citations and a large amount of external funding, and this has been obtained continuously during all years of the evaluation period (2017–2022).

The excellence of the FGI is internationally well known, and the FGI is highly respected for the research quality within all major fields of research covered by the organization. Also, the FGI has an outstanding reputation internationally, and is as such a sought for partner and collaborator in projects and in relation to mobility of researchers. This is illustrated for instance by international awards received by FGI employees, and also by the large number of positions of trusts held by FGI employees in the international scientific community as is further discussed in Section 5.

The outstanding *research project portfolio* and the scientific activities of the FGI matches the FGIs research strategy excellently. However, some of the more recent activities go beyond the strategy, and this is exemplary, because the research strategy is five years old, from 2018, and it is important to stay on top of the very strong technical development within the fields of research of the FGI.

In terms of societal impact and relevance in Finland, compared with similar institutes in other countries, the FGI is also outstanding. The FGI is involved in many R&D activities in cooperation with private companies, where research results are used directly for a more effective and improved production and/or for development of new products and services to the benefit of the society in general. The FGI also has a close cooperation with many public bodies, for instance a number of government agencies and the Finnish Defense, where research results from the FGI are applied and adapted to the benefit of Finnish society in terms of new services, standardization activities and improved governance. Such activities are also carried out by similar institutes in other countries, but the amount of external cooperation, and the success of the application of research output by the FGI to the private and public sector in Finland is exceptional and show an outstanding societal impact compared to similar institutes.



Despite the excellent external cooperation, as described above, there is still untapped potential for new business opportunities, products and services from FGIs research, because much of the research can be applied and tailored to business opportunities - with a smaller or larger effort depending on the topics. For research institutes, it is, however, always a tradeoff between the focus on scientific research aimed at being first with new discoveries, new publications and a high number of citations on the one hand, and work on refinement and the raising of technological readiness level on the other hand. The FGI is first and foremost a scientific research institute, and research should come first. But the **FGI is encouraged to keep in mind that possibilities for e.g., more patents and spin-off companies do exist.**

## 4.1 Department of Geodesy and Geodynamics (FGI-GeoGeo)

The department of Geodesy and Geodynamics (FGI-GeoGeo) is the oldest one in the history of FGI and comprises four research groups on Reference Systems, Gravity, Space Geodesy and Metrology. Apart from outstanding scientific research, the department is also responsible for maintaining the national reference systems in terms of compliance with accuracy and stability requirements and is also the national standards laboratory for acceleration of free fall and length in geodesy. These services are logically embedded in this department given the ongoing need for scientific research that is needed, plus the research opportunities arising from them.

FGI-GeoGeo has excellent research facilities, notably the Metsähovi Geodetic Research Station, FinnRef network, and metrology lab facilities. These are all nationally and internationally recognized as crucial infrastructure of a very high standard. Apart from the important services, the facilities provide excellent opportunities for scientific research as evidenced by the research output of FGI-GeoGeo.

Overall, the research portfolio of the department is well aligned with the strategic aims of FGI, and there is a good mix of funding sources, including collaboration with companies. The connection with Aalto University is well-established, and recently strengthened with the appointment of Mirjam Bilker-Koivula as Professor of Practice.

**It is recommended that FGI-GeoGeo revisit its own mission and vision for the coming 5–10 years, where specifically sea level rise and quantum geodesy may be areas to further explore. There are strong synergies with the other departments, which could be further explored by intensified collaboration in fields of GNSS and remote sensing.**

**In addition, FGI may consider to connect to the GENESIS proposal [11] to have a satellite platform co-locating four space geodetic techniques in order to establish a Terrestrial Reference Frame with unprecedented accuracy and stability.**

## 4.2 Department of Geoinformatics and Cartography (FGI-GeoInfo)

The Department of Geoinformatics and Cartography (FGI-GeoInfo) was established in 1987, originally as the Department of Cartography). Its overall topic deals actually with “Efficient management, processing, analysis, distribution and visualization of geospatial information” to resolve global challenges - a headline which is also future oriented. The publications of the department are of high quality. Three research groups work on relevant topics of today: (1) Digital Twins, in particular Spatial Data Infrastructures (SDI), geospatial data ecosystems and interoperability; (2) Big Data, in particular big data management, processing and analysis, Artificial Intelligence and privacy; and (3) Geospatial Representation and Interaction, in particular visualization, maps and map applications, interaction and usability of map applications, and finally SDI in extended reality.

This outstanding research is in line with the hot topics in the geospatial data domain worldwide, which was also discussed at the 2nd United Nations World Geospatial Information Congress 2022, Hyderabad, India, 10. to 14. October 2022.

Thus the department should continue its missions towards complete interoperability with harmonized and seamless data streams across administrative and sectoral borders, in collaboration with European partners in the project GeoE, and the Geoportti research infrastructure to enable and promote the use of geospatial methods and technologies on High Performance Computers (HPC), such as the LUMI computer. Obviously FGI-GeoInfo is a main service provider for this powerful infrastructure. **It is recommended to strengthen this service and to provide the geospatial data foundations for OpenData and OpenScience policies in Finland.**

In future, the cadastre will evolve from 2D via 2.5D via 3D to 4D (including time epochs) in most of the developed countries, also in Finland. **Thus it is recommended to support the NLS with research and pilot projects in this direction. In particular it is recommended to offer a countrywide LoD2 model (CAD buildings with real roof structures) as OpenData, to offer SMEs the data they need for energy transitions (solar potential, heat pumps, insulations).**

### 4.3 Department of Remote Sensing and Photogrammetry (FGI-Kauko)

The Department of Remote Sensing and Photogrammetry (FGI-RS) is for many years the flagship in terms of research and the biggest department of FGI. About 100 researchers are covering topics like airborne, terrestrial and mobile laser scanning, Unmanned Aerial Vehicles (UAVs) and photogrammetry. During 2014 to 2020 the department was host of the CoE Laser Scanning Research (LaSR) and made a huge impact on the development and application of laser scanning worldwide. The FGI is therefore the most reputed research institution in this domain, which is also acknowledged by the Academy of Finland (AoF) citing 2021: "Laser Scanning 22nd most scientifically impactful research cluster in Finland". The department's backpack laser scanning R&D has stimulated industrial developments such as 3D Laser Mapping ROBIN (3D Laser Mapping), Leica Pegasus (Hexagon), and Heron (Gexcel). Recently NASA announced that they are aiming to use the FGI-developed laser backpack technology for moon explorations. In addition, this department is the leader of the Finnish drone research cluster, which is also part of the flagship UNITE 2020–2024, citing the AoF 2021: "Drones and remote sensing is the 4th most scientific research cluster in Finland". Thus FGI-RS is leading 2 out of 24 best Finnish research clusters. The outcome is superb - to name here that FGI-RS scientists belong to the top 2% scientists worldwide and are leading scientists in Finland in engineering, technology and environmental sciences, according to a Remote Sensing 2009–2019 review this is the best Remote Sensing group globally, and it has published 486 papers listed in the Web of Science (WoS).

The FGI-RS is leader in the National Laser Scanning Programmes 2008–2019, 2020–2025, 2026-X and it should continue its service in the future with the same strength as in the past and present. This service has a huge societal impact: 10 MEUR annually for the Finnish society since 2008, and the area-based forestry inventory saves also 20–30 MEUR annually. The individual tree-based forest inventory will be operational in 2026 and FGI-RS knowledge is exported to the USA, Japan and Canada. Some patents will obviously provide external funding. **It is recommended to be a leader in this domain also in the future and to further develop hardware miniaturization, and software with regards to AI/Machine Learning and Deep Learning algorithms.** A byproduct of the FGI-RS is a car equipped with sensors for autonomous driving. It is obvious that the automotive industry worldwide is further developing this technology, such that FGI-RS should not compete with giants but should look for niches in this domain.

At present and in the future Ground Penetrating Radar (GPR) is a new technology which belongs also to the remote sensing domain. European countries just started to have nationwide GPR campaigns mapping critical infrastructures (e.g. Italy, United Kingdom) and are enriching their digital city twins with underground data. **It is highly**

**recommended that FGI-RS is also going into this direction to provide further societal impact wrt to underground infrastructure mapping and monitoring by intensive research and developments.**

## 4.4 Department of Navigation and Positioning (FGI-Navi)

The Department of Navigation and Positioning (FGI-Navi) is doing outstanding research within the field of positioning, navigation and timing (PNT). The research is related to Global Navigation Satellite Systems (GNSS) but there is also much focus on other sensors and hybrid navigation. Recently also new positioning methods using, for instance, satellites in Low Earth Orbit (LEO), are being explored.

The quality of the research of the FGI-Navi is excellent, and the FGI-Navi is internationally in the lead in exploration of e.g., sensor fusion for navigation applications, open-source software receiver platform development, in research aimed at resilient PNT, as well as in several research aspects related to Galileo, the European GNSS, and to novel maritime AI-based navigation. The KPIs for publications, citations and obtained external funding illustrate this.

The FGI-Navi also performs research for the Finnish government and for the Finnish Military. Some of this work is classified and therefore not covered by KPIs concerning publications and citations.

It is considered important that the FGI-Navi maintains the focus on research related to robust and resilient PNT and to new positioning methods such as e.g., new sensor technology and LEO-based satellite navigation. **It is recommended that FGI-Navi consider, under the umbrella of resilient PNT, to focus on effects of the Earth's ionosphere exerted on satellite signals, given the location of Finland in the high-latitude region. It is also recommended, in combination with collaborative sensing and robust PNT in all environments, to explore collaborative computing for PNT, as well as cooperative navigation.**

## 5 Role in Networks and Collaboration: Activity and Leadership

The move of FGI headquarters to the Otaniemi campus area has been strategically successful. The new modern working environment offers spaces for internal collaboration. The external collaboration especially with Aalto University has increased and carries even more potential to be exploited. NLS has signed a strategic MoU with Aalto in 2017. The collaboration with teaching, utilizing joined premises and shared positions could still be further developed in a more systematic and strategic manner.

FGI is a member of the UNITE Flagship consortium funded by the Academy of Finland. The UNITE is an innovative cross-disciplinary community combining the topmost competencies within the forest sciences with geospatial technologies, sensor innovations and gamification. The FGI carries a cornerstone role within the flagship and the consortium offers a superb platform for high impact applications for the FGI's research.

### 5.1 FGI and Centers of Excellence

Centers of Excellence (CoE) are highly competitive research programs for selected areas and long term funding opportunities. The funding is offered by the Academy of Finland and always monitored by Scientific Advisory Boards (SABs), which scientifically review the progress made and give recommendations for a new period. From 2014 to 2020 the FGI hosted the CoE Laser Scanning Research (LaSR) with Prof. Juha Hyyppä as leader and Principal Investigator and surprised the professional geospatial community with excellent results. The high expectations of the AoF were more than over-fulfilled - this CoE produced not only excellent research output, but also positioned the Academy as a research promoter in Laser Scanning worldwide. Thus, Finland has become a leading nation in this area. This was impressively demonstrated by the 30+ professorships (with 17 new professors, 8 visiting professors, 6 honorary professors), 25 new Masters of Science, 400+ journal papers and 24 finished PhDs. The Technology Transfer program resulted in 8 start-up companies. It also demonstrated the great inter-collaboration potential of FGI: Besides FGI also the University of Oulu, the University of Helsinki, and Aalto University contributed with complementary and related subject areas. The FGI has become No. 1 of the public research institutions in Finland, in terms of citations and research quality [9].

**The Panelists know very well about the difficulties to attract another CoE with FGI as leader, but highly recommends to observe the research topics and apply whenever there is an opportunity.** Some potential and relevant topics might be: (1) Integration of Ground Penetrating Radar (GPR) and Digital Twins of Cities - Needs for Monitoring Critical Infrastructures; (2) The Finnish Geospatial Ecosystem and Climate Modelling - Looking in the 2030s; and (3) The Metsähovi Observatory - A Hub in Earth Sciences for Worldwide Services.

## 5.2 FGI and International Geospatial Organisation, Mobility

The FGI is engaged in the work of many international bodies, the list of organizations is long and includes many organizations at international level, such as the International Union of Geodesy and Geodynamics (IUGG) and the International Association of Geodesy (IAG), at European level, such as the EuroSDR and EuroGeographics, and at the Nordic level such as the Nordic Geodetic Commission (NKG). Further, the FGI is actively engaged with the United Nations; both in the Committee of Experts on Global Geospatial Information Management (UN-GGIM) and with the United Nations Office for Outer Space Affairs (UNOOSA). Active participation in such international collaboration is beneficial for the FGI in providing good opportunities for building up international networks with other researchers while at the same time promoting research done by the FGI. For the individual researcher the engagement in the organizations provide opportunities for observing international trends which can lead to new research ideas and careers. **It is recommended that the FGI continues to take active part in such international cooperation, and also continue to show leadership, by taking on positions as president, secretary general, commission chairs etc.**

Mobility of researchers is another field where the FGI is very active. This works as a two-way process in that the FGI is both encouraging its own researchers to spend time at other research institutes or universities, and at the same time is receiving researchers visiting from abroad. The mobility is very high and has a positive effect in contributing to the personal development of the individual FGI researchers, as well as to the continued development of the FGI as an internationally recognized research institute. **It is recommended that the mobility of researchers at the FGI is maintained at least at the current level.**

## 5.3 FGI and Location Innovation Hub

The establishment of the Location Innovation Hub (LIH) together with 27 partners and 20 other organizations, is an important example of FGI/NLS taking leadership and playing an important role in both national and international networks and partnerships. The goal of the LIH is to expand the use of geospatial data – location-based data – in services, new business and technologies, and produce new benefits for society based on them.

The Ministry of Economic Affairs and Employment selected Finland's candidates and the European Commission selected LIH as one of the four digital innovation hub networks. These networks will act as service hubs to accelerate digital investments and digitalisation in the private and public sectors. LIH will commence operations in 2023.

LIH will strengthen Finland's capabilities in the use of geospatial data by bringing specialists in the sector together and providing technological and business support for using geospatial data. LIH will also broadly build geospatial data testing platforms, ranging from indoor positioning to test environments for autonomous vehicles, as well as digital test data. In addition, it will develop geospatial data expertise in the fields of AI and cybersecurity. LIH will also provide networks in Europe and beyond.

**It is recommended that FGI utilizes and invests in the excellent opportunities for new business and various needs in society - notably climate change and urbanization challenges, which arise from the establishment of the Location Innovation Hub.**

## 6 Foresight and Innovativeness (preparedness to meet challenges of the future)

The challenges of the future are differentiated according to proposals by international bodies into: Geospatial Data Management, Geospatial Data Developments and Geospatial Data Research. In a second part we recommend FGI and NLS to focus on the most relevant topics for the next 5–10 years.

### 6.1 Geospatial Challenges of the Future

According to the recent discussions at the United Nations Global **Geospatial Information Management (M)** (UN-GGIM) Expert Group meeting in New York, 1. to 5. August 2022 new use cases have been identified which should be explored for a sustainable future of healthy communities and also to fulfill the UN Sustainable Development Goals 2030. In particular, topics such as Geodetic Reference Frames, Integrated Geospatial Information Framework (IGIF), Geospatial Information for Sustainable Development, Integration of Geospatial, Statistical and other related Information, Application of Geospatial Information to Land Administration and Management (LAM), Geospatial Information and Services for Disasters, Marine Geospatial Information, Policy and Legal Framework, Implementation and Adoption of Standards for the Global Geospatial Information Community, Collaboration with the UN Group of Experts on Geographical Names.

The World Geospatial Industry Council has discussed and proposed (Side Event UN-GGIM, New York 2022) the following new topics for **geospatial data/information developments (D)**: the Metaverse/Virtual or Augmented Reality (XR), Smart Infrastructures, Smart Cities, Autonomous Vehicles, Virus Control and Management, Traffic Management, Industrial Manufacturing, Gamification, Mining, Smart Agriculture, Smart Energy, Healthcare Applications, Product Development, and Highly Complex Assets (Airports, Seaports).

**Geospatial Data Research (R)** is for a long time subject of the scientific international bodies like the International Association of Geodesy (IAG), The Federation Internationale de Geometre (FIG), the International Society for Photogrammetry, Remote Sensing and



Spatial Sciences (ISPRS, and the International Cartographic Association (ICA). These bodies are also observers at the annual UN-GGIM meetings and contribute to several UN-GGIM working groups. In addition there are others, like the International Union of Geodesy and Geophysics (IUGG) and the Digital Earth Society. Summarizing some hot topics of geospatial science are given as follows: Geodetic Reference frames and its harmonization, the Genesis mission, Global Navigation Satellite Systems with more than 100+ satellites for navigational and differential services, cooperative navigation, Very Long Baseline Interferometry (VLBI) and crustal movements, Earthquake monitoring and analysis, precise (cm) geoid determinations at land and sea, quantum geodesy and its impact onto instrumentation, Satellite Laser Ranging for precise orbit determinations (incl. space debris monitoring), Artificial Intelligence for geodetic applications, Statistical Inference, Bayesian statistics, robotics and automation, Machine Learning and image processing (optical satellites, airborne photography, close range photography), Convolutional Neural Networks for image and point cloud interpretations, hybrid sensor integration for airborne imaging, Synthetic Aperture Radar (SAR) and Radar Interferometry, laser scanning (airborne, terrestrial static and mobile), mobile mapping, Simultaneous Localization and Mapping (SLAM), Ground Penetrating Radar, time series analysis for satellite imaging, airborne photography and laser scanning, Digital Twin generation, Digital Building Models (BIM), volunteered data updates and GIS, new cartographic reference systems, real-time mapping, AI and geographic data interpretation, interactive mapping, OpenData visualization and policies, OpenScience for geospatial applications, Interactive Computer Graphics, and many more.

In addition to these global issues of geospatial R&D&M there are regional challenges to be monitored and controlled, such as the Scandinavian land uplift, regional climate change analyses and simulations, and urban planning violations.

## 6.2 The Future of FGI's Research & Development (maintaining scientific competence)

FGI has demonstrated in the past that it knows very well the ongoing discussions in geospatial R&D&M at an international level. With the NLS merger it can focus on its main portfolio being R&D - the management part is more or less NLS business. But as given in the introduction there is room left for improving the KPI impact of NLS/FGI wrt geospatial knowledge infrastructure, i.e. Finland should come close to the rank of the top nations.

There is no doubt, FGI has also in the future to fulfill national tasks, such as maintaining the high quality of the leveling network and gravity measurements (absolute and relative), due to the Scandinavian land uplift, and to perform precise (cm) geoid determinations.

Here it also complements metrology experiments and calibrations, for which it has a long and successful history. With the new antenna at Metsähovi it can control classical uplift parameters by VLBI experiments. In addition FGI has proven that forestry monitoring, harvesting and single tree management can rely on laser scanning (airborne, UAVs, terrestrial) and it shall continue being a leader of the National Laser Scanning programme at present and from 2026 onwards. The UAV lead in the AoF cluster should be continued with the same spirit as in the past - this is needed also for the society (military, police, disaster management). The OpenGNSS services will provide access for the Finnish society and therefore it is recommended to follow the international developments and implement updates in Finland. It is expected that in a few years from now, every smartphone can deliver cm precision for the position  $x,y,z$ , which opens new horizons for volunteered geodata updates and processing. The OpenData visualization and management (of geodata) supporting the HPC applications shall also be continued and strengthened.

In addition to the national tasks FGI is famous for its curiosity-driven R&D. Two good examples are demonstrated by the Laser Scanning and UAV clusters. When FGI started this R&D about 15 years ago nobody would have foreseen the societal impact of this work. Today it represents necessary toolkits for meeting societal requirements.

## 7 Research Environment

The FGI research and support staff appreciate the working and research environment very much. There is a good atmosphere, very good facilities and support, no unhealthy competition. After the pandemic, many staff members still work remotely. Likewise in many other organizations, some staff members appreciate this flexibility while others indicate that it goes at the cost of the community feeling.

### 7.1 Research Support

Each department has at least one project coordinator, there are two information specialists and one person for EU support, IT and communication/outreach support is centralized at NLS. Overall, staff appreciates that support is in general good and sufficient, and also the support staff feels that research staff knows how to find them and use their services. Specific issues that came forward:

- IT support from NLS should take into account that researchers may have different needs, and security demands of NLS put undesirable restrictions. In particular, use of the LINUX operating system should be better supported.
- Role and responsibilities of project coordinators should be clearly defined and communicated.
- It is recommended to have an overall support coordinator at FGI level. Currently, there are bottom-up initiatives, for instance, between project coordinators of different departments, but no one is responsible.
- There is only one person for EU support, mainly focussing on exploring opportunities and networks. Given the increasing importance of EU funding, this is a very limited resource and a risk in case the person leaves (losing know-how). It is advised to have more people take this as part of their responsibilities. In addition, there is a need to extend the task to grant writing support as well.

## 7.2 Career Paths

Policies are in place for tenure professorships, but with very limited number of positions. Research scientists generally agree that it is unclear what the career prospects are, also considering different profiles, and a general concern is that most research scientists only get short term contracts for many years. This brings uncertainty for the staff members. Solution is not to give contracts for project duration, since this would not be fair for staff members working on multiple short-term projects. It should be noted that the current policy involves a risk for FGI as well, since people may leave before projects end. Recommendations:

- develop a consistent policy on career paths in FGI, both in terms of promotion and fixed-term and permanent contract.
- work career development plans with individualized annual agreements, which should also include training and coaching

## 7.3 PhD Program

Many research scientists at FGI are pursuing a PhD, even though they are not hired as 'PhD students'. The PhD research has often a secondary priority or is accomplished in combination with the research projects that they are working on. The latter is not perceived as a problem in terms of the topics and research objectives. However, the lack of a clear and consistent PhD policy for all PhD students has the disadvantage that it is highly dependent on the supervisor and/or research group leader how well PhD students are guided, supported and encouraged to finish their PhD in a reasonable time frame. Recommendations:

- introduce a general PhD policy on supervision, training, agreements on duration, 'free' time to work on PhD
- make an agreement with Aalto on participation of PhD students in their PhD program

## 7.4 Recruitment Challenges

FGI is an attractive institute to work in, but is facing challenges in hiring and keeping skilled research staff. Main reason is the high competition in the job market for the broad field of engineering and science relevant for FGI (geo-information, remote sensing, electrical engineering, mathematics, computer sciences, physics, etc.). On the other hand, this also brings opportunities:

- be visible in bachelor and master programs at Aalto (and other universities) by offering or contributing to courses → agree on systematic teaching activities
- offer a good program for Summer students
- increase visibility in collaboration with communication department, highlighting that current staff members are very passionate about their work

## 7.5 Diversity

The gender balance and diversity in general are appreciated. Majority of staff members are male, but this is logically explained by the larger number of male students in relevant master programs. The working environment at FGI is very international, which is considered very positive, and there are no concerns regarding language or cultural diversity.

At NLS, staff is mainly Finnish, and as a consequence their HR department and information on intranet is not well prepared for international staff. Recommendations:

- HR services at NLS should be better informed about hiring procedures for international staff
- develop an onboarding package for international staff members, which assists them with administrative procedures in general and also informs them about NLS/FGI policies and rules (e.g., how to apply/register leave, what to do in case of illness)

## 7.6 Inter-departmental Collaboration

The four research departments have a clear identity, and share a good amount of themes that allow for synergies and collaboration. Examples: strategic research areas, AI, digital twins, autonomous driving. Staff and research group leaders indicate that collaboration is possible and there are no barriers, but at the same time there are no clear incentives to do so. Recommendation:

- more incentives to collaborate on certain themes, which could be both top-down (regular meetings with research group leaders) and bottom-up (organize seminars, brainstorm sessions, workshops).

## 8 Suggestions and Recommendations for Further Development of FGI's Research and Expert Work

In the following the International Evaluation Panel summarized suggestions and recommendations, based on studying the presented documents, own experiences and the interviews. Here we differentiate with regard to the addressees: the Ministry of Agriculture and Forestry (MAF, MMM), the National Land Survey (NLS) and the Finish Geospatial Research Institute (FGI):

### 8.1 To the Ministry

- The ministry should be congratulated for a successful merging process of FGI and NLS which has created resilience to the FGI operations and finances, and has opened extended support services while letting research at FGI to flourish.
- The role of FGI within NLS as a unique international level research institute requiring a certain level of dynamics in operations should be guaranteed.
- FGI is carrying out a lot of research in collaboration with or having impact to other ministries beyond the ministry of Agriculture and Forestry (e.g. ministries of Transport and Communications, Environment and Defence). This important and high impact role of FGI should be articulated more visibly and supported financially beyond MAF budget funding.
- The long-term operations with adequate staffing and regular instrument upgrades of the Metsähovi Geodetic Research Station should be guaranteed and cannot rely too much on the FIRI infrastructure funding from the Academy of Finland.

## 8.2 To the NLS

- While standardizing and developing the administrative procedures within NLS the unique role of the FGI as an academic-like research institute should be taken into account. FGI requires, for example, more support for its international staff for the HR processes and specialized support for ICT (e.g. support for Linux and more finessed security considerations for research purposes).
- Open data policies and practices should be considered at the NLS organizational level.
- Continuous high-level external funding would allow the FGI to move towards more permanent positions and longer temporary appointments beyond what is allowed by the budget funding. The NLS could consider carrying the associated financial risk at a higher institutional level.
- NLS could consider initiating an internally funded PhD program within the whole organization.
- MAF, NLS and FGI should discuss the option of a secondment of one Finnish researcher to the newly established United Nations Center of Excellence “Geodetic Reference Systems” in Bonn, Germany, to contribute substantially and to get first-hand knowledge for further developments of geospatial reference systems in Finland.

## 8.3 To the FGI

- The forthcoming FGI research strategy should take into account the global challenges and introduce FGI’s research impact on them.
- FGI should establish an international advisory board to support the management in the implementation of the strategy.
- The operations of the unique Metsähovi Geodetic Research Station should be prioritized.
- The continuous external funding at high-level would allow more permanent positions and longer temporary appointments beyond budget funding with controlled financial risk at the organizational level.
- The career paths should be made more transparent and communicated clearly to staff and be consistent within different departments.
- FGI should have a clear PhD student policy and strategy throughout the organization.
- There should be more incentives for and visibility of internal collaboration (between departments).

- The project management capacity and systems should be uniform throughout the organization. The work of project coordinators should be coordinated to enable benchlearning between research groups.
- The EU project support is subcritical and should be strengthened.
- The coordination of applications for external funding could be coordinated aiming for fewer but bigger projects.
- The opportunities offered by the new LUMI supercomputer as well as the enhanced capabilities for data management should be exploited.
- There should be a strategy and procedures to fully utilize the potential and capabilities of the FGI staff for academic teaching at the universities.
- There is an unused potential to utilize the know-how at the universities (especially Aalto) for critical capabilities e.g. in artificial intelligence and signal processing.
- FGI is excelling in a number of high impact research papers and citations. However, it should be communicated clearly also within the FGI that there are other KPI's for high impact work as well.
- FGI could be more proactive in creating ecosystems with SME companies to share ideas and problems.
- FGI is encouraged to increase the number of part-time Professors of Practice positions with specific focus areas with Finnish universities.
- In certain cases the China collaboration should be viewed not only from the security perspective but also from ethics perspective.
- FGI has started a lot of new things. Also strategic discontinuing should be considered.
- FGI should develop a strategy to better communicate in a Citizen Science sense and for Public Understanding of Science needs.



## 9 Conclusions

The FGI is a unique research institute of high quality and impressive impact, not only in Finland but also worldwide. Finland can be proud of having maintained for more than 100 years this institution, with scientific freedom and autonomy. We think that the best policy for the MAF and NLS would be to let the institute evolve in accordance to its inner dynamics and societal needs. It will also in the future contribute to actual challenges like the Scandinavian land uplift, crustal movements and dynamics, forest inventory, the harmonization of European geodetic reference systems, Digital Twins of cities and landscapes, GNSS services of all kinds (positioning, navigation and timing), and OpenData, OpenSource and OpenScience (OpenX) to meet the expectations of a continuously changing environment and society. This mix of geospatial problems to be solved will definitely require an institution like FGI to get first-hand scientific results and information important for politicians and decision makers. It is our strong belief that the activities of FGI and its inherent potentials present a clear asset to the Finnish society. May our suggestions and recommendations help to find the optimal structures and processes within the MAF, NLS and FGI to guarantee a great 2030 future of FGI.

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## Appendices

1. Terms of References, MAF
2. Resumes of the International Evaluation Panel Members

## Appendix 1 - Terms of reference

**Ministry of Agriculture and Forestry, Finland**  
**8 June 2022**

### **International evaluation of Finnish Geospatial Research Institute FGI**

#### **TERMS OF REFERENCE**

##### **Introduction**

- Finnish Geospatial Research Institute FGI is a part of National Land Survey of Finland (NLS)
- FGI/NLS was established in 2015 by merging former Finnish Geodetic Institute (FGI) (established in 1918) with NLS
- FGI/NLS belongs to the administrative sector of the Ministry of Agriculture and Forestry
- FGI conducts innovative research and expert work within the field of spatial data
- FGI has around 150 staff ( around 100 man years of research)
- FGI is based in Espoo, Otaniemi campus area
- FGI manages Metsähovi research infrastructure in Kirkkonummi
- FGI has four research departments and one research support service group
- Previous evaluation in 1998
- Major changes in the operation environment in the last 20 years: funding landscape, organization structures, technological development – new evaluation of FGI is needed
- More information: [www.fgi.fi](http://www.fgi.fi)

##### **Scope of the evaluation**

- Quality of research and expert work
- Societal impacts and relevance to society: public sector, private companies, citizens
- Activity and leadership in research collaboration and networks
- Foresight and innovativeness

(Organizational matters are not in the scope of the evaluation)

### **Outcomes of the evaluation**

- Description of FGI's strengths, weaknesses, threats and opportunities
- Suggestions and recommendations for further development of FGI's research and expert work

### **Guiding questions**

#### Quality of research and expert work

- How does research project portfolio and scientific activities match FGI's research strategy?
- How does FGI's scientific competence compare with similar (European) institutes?
- Which areas/topics are the most important for maintaining scientific competence in the future?

#### Societal impacts and relevance

- How well the present research project portfolio and expertise of FGI matches the demands of society?
- Does FGI's research have untapped potential for new business opportunities, products, services and/or other applications?
- How does FGI's societal impacts and relevance compare with similar institutes?

#### Collaboration and networks

- How does collaboration and networking activities match with FGI's research strategy?
- How does FGI's collaboration and networking activities compare with similar institutes?
- How could FGI's collaboration and networking activities be improved?

#### Foresight and innovativeness

- What is the level of foresight of FGI's research strategy?
- Does FGI's research produce novel approaches and innovations?
- How could FGI's foresight and innovativeness be improved?

### Organization of the evaluation work

- The evaluation is assigned by the Ministry of Agriculture and Forestry (MMM), contact person is Research Director Mikko Peltonen
- The evaluation will be conducted by a team of esteemed experts representing various disciplines relevant for geospatial research and with background in comparable research institutes in Europe and in Finland, as well as experts representing FGI's knowledge users from Finland and Europe
- The evaluation panel members are:
  - Keijo Hämäläinen (Chair of the evaluation panel), Rector, University of Jyväskylä
  - Dieter Fritzsich, Professor Emeritus, University of Stuttgart
  - Anna Jensen, Process Coordinator, Danish Property Assessment Agency/Consultant, AJGeomatics
  - Sandra Verhagen, Professor, Delft University of Technology
- The evaluation will be facilitated by Juho Hellsten and Leena Sukselainen, FGI
- The evaluation report drafts will be viewable only by the facilitator and the evaluation team, and the final draft will be shared with FGI's management team for correcting potential misunderstandings
- The final evaluation report will be public

### Timeline

- The evaluation work is expected to be finished by the end of January 2023 (tbc)
- The full set of written background material will be provided for the evaluation panel by the end of August 2022 (some material will be available earlier)
- The evaluation will be conducted mainly off-site, and through facilitated tele-meetings and interviews of stakeholders.
- A two-day site visit will be organized for the evaluation panel in October-November 2022
- The evaluation panel can use virtual meetings (e.g. Teams) for discussion and preparation of the evaluation report

## Appendix 2 - Resumes of the International Evaluation Panel Members

A short resume of each of the international panel members is provided in the following.

### **Keijo Hämäläinen, Panel Chair**

- Rector of the University of Jyväskylä, Finland (2017- )
- Professor of Physics (2002- )
- Vice-Rector of the University of Helsinki (2014–2017), Dean of the Faculty of Science, University of Helsinki, (2010–2013)
- Chair of the board of the Universities Finland UNIFI (2020–2021)
- Member of the board of the Finnish Innovation Fund SITRA (2020-)
- Member of the board of the Finnish Cultural Foundation (2021-)
- Member of board of the Finnish Research Impact Foundation (2022-)
- Chair of the Federation of Finnish Learned Societies (2015–2018)
- Chair of the Publication Forum steering group JUFO (2015–2019)
- Member of the Finnish Research Infrastructure Committee of the Academy of Finland (2014–2022)
- Council, Scientific Advisory or Evaluation Panel Board member in various international research organizations e.g., ESRF (France), DESY (Germany), MAX-IV (Sweden), SSRL (USA), Spring-8 (Japan)

### **Dieter Fritsch, Panel Member**

- Emeritus Professor, University of Stuttgart, Germany (2016) and Consultant
- Professor of Photogrammetry and Surveying, Univ. Stuttgart (1992–2016)
- Rector of the University of Stuttgart, Germany (2000–06)
- Vice-Rector of the University of Stuttgart (1998–2000), Dean of the Faculty of Civil Engineering & Surveying, University of Stuttgart, (1994–1996)
- Vice Chair of the Board of Trustees, German University in Cairo (2016-)
- Vice Chair of the United Nations GGIM Private Sector Network (2016–2022)
- Member of the Advisory Board Center of Excellence Laser Scanning at FGI (2013–2021)
- Vice President Research EuroSDR (2009–13)
- Member Board of Directors Leica Geosystems, Heerbrugg, Switzerland (2002–06)

- Member of the Apple University Education Forum, Cupertino, USA (2006–12)
- More than 480 publications in Photogrammetry, Remote Sensing, Laser Scanning, GIS, GNSS, Computer Vision, Computer Graphics and Statistical Inference, Supervisor and Co-Supervisor of more than 100 PhD students

#### **Anna B. O. Jensen, Panel Member**

- Chief consultant, Danish Property Assessment Agency, Denmark (2020-)
- Owner and senior consultant, AJ Geomatics, Denmark (2006-)
- Guest professor, KTH - Royal Institute of Technology, Sweden (2018–2021)
- Professor and Head of Division, Division of Geodesy, KTH - Royal Institute of Technology, Sweden (2014–2018)
- Part time associate professor, Technical University of Denmark (2006–2012)
- Associate Professor, Technical University of Denmark (2003–2006)
- Specialist, National Survey and Cadaster, Denmark (1995–2003)
- President, Nordic Institute of Navigation (2019-)
- Danish representative. European Commission, WG on Galileo Commercial Service (2018–2020)
- Chair, Nordic Geodetic Commission, WG on Future Positioning Services (2018–2020)
- Swedish representative, European Commission, WG on Galileo Commercial Service (2014–2018)
- Member, European Space Agency, GNSS Scientific Advisory Committee, GSAC (2008–2012)
- Experiences with teaching and supervision at all university levels (B.Sc., M.Sc. and Ph.D.) as well as business professionals.
- Experiences with research and development in GPS/GNSS-based positioning and navigation, atmospheric effects on satellite signals, sensor integration, geodetic reference frames, coordinate transformations, height systems, adjustment theory, geodata quality, land surveying, laser scanning, GIS, relative gravity measurements, space technology, space policies, EU tendering etc.

#### **Sandra Verhagen, Panel Member**

- Associate Professor at Delft University of Technology, Netherlands (2007- )
- Postdoctoral researcher at Delft University of Technology, Netherlands (2005–2006)
- President of Commission 4 “Positioning and Applications” of the International Association of Geodesy (2007–2011)



- Visiting research fellow at the GNSS Research Centre of Curtin University, Perth in Australia (2012)
- (co-)PI in various projects funded by NWO, KNAW, EU, ESA and the Australian CRC SI (2013-)
- PhD, Delft University of Technology Thesis: The GNSS integer ambiguities: estimation and validation (2005)
- Research interests focus on carrier phase ambiguity resolution and quality control for real-time kinematic GNSS applications. She received a research grant (VENI) from the Technology Foundation of the Dutch Science Association for her research proposal “Next generation Global Navigation Satellite Systems: carrier phase ambiguity resolution as the key to challenging new applications”
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