PUBLICATIONS 6/2018

# Efficient deployment of satellite navigation systems in Finland. Action plan 2017-2020

MINISTRY OF TRANSPORT
AND COMMUNICATIONS

**Ministry of Transport and Communications**

## Vision
Wellbeing and competitiveness through high-quality transport and communications networks

## Mission
The Finnish Ministry of Transport and Communications seeks to promote the wellbeing of our people and the competitiveness of our business.
Our mission is to ensure that people have access to well-functioning, safe and reasonably priced transport and communications networks.

## Values
Cooperation

LIIKENNE- JA VIESTINTÄMINISTERIÖ


Date of publication
12 April 2018


Title of publication

**Efficient deployment of satellite navigation systems in Finland. Action plan 2017-2020**


Author(s)

Seija Miettinen, Senior Adviser
Seppo Öörni, Senior Adviser
Olli Lehtilä, Senior Officer



Commissioned by, date

Publication series and number

**Publications of the Ministry of Transport and Communications 6/2018**

ISSN (online)
ISBN 978-952-243-550-7
URN URN:ISBN:978-952-243-550-7
Reference number

Keywords
satellite navigation, positioning, location data, Galileo, GPS, small satellites, New Space

Contact person

Other information



Abstract

Along with digitalisation, satellite navigation has become an important part of our everyday life. For example, the operation of power and communication networks and transport services requires satellite positioning and accurate timing. The satellite navigation sector is indeed growing and, in 2017, the European Commission estimated the value of the satellite navigation sector at over EUR 70 billion. With the growth of automated transport and the development of 5G and IoT, the market value is estimated to rise to about EUR 195 billion by 2025. Europe is undergoing an important phase in the development of satellite navigation as the Initial Services of Galileo, the European Global Navigation Satellite System (GNSS), have recently been introduced and the system is expected to be in full operation in 2020. Over the past few decades, Finnish experts and Finnish expertise have been part of several space and satellite projects. In addition, the first satellites of our own have been developed over the past few years and Finland is indeed becoming a new operator in the satellite markets.

This Action plan describes the current state of satellite navigation systems and how they are deployed in the different sectors of our society, especially in automated transport. At the same time, it describes the current model of Finnish space administration and the pressure to reform it. At the end of the Action plan, 17 concrete measures are proposed to promote the deployment of satellite navigation especially at a national level. The Action plan is part of one of the key projects in Juha Sipilä's Government Programme: A growth environment will be created for digital business operations. The work has been carried out by listening to a wide range of actors in the sector.

The Action plan aims to ensure that satellite navigation systems are deployed in all sectors of society in all of Finland. Its key goals in terms of the future are the following: making Finland one of the leading countries in the deployment of satellite systems and enhancing the preconditions for the current high quality of space research in Finland, enhancing the deployment of satellite data in business activities and service provision, ensuring the quality of positioning and the deployment of satellite navigation systems in all Arctic regions, promoting the deployment of small satellites, and determining the need and possibilities to establish a space administration in Finland.

KOMMUNIKATIONS-
MINISTERIET

| | |
|---|---|
| | Publikationsdatum<br>12.4.2018 |

Publikation

**Effektivt utnyttjande av satellitnavigering i Finland – åtgärdsprogram 2017–2020**

Författare
Seija Miettinen, ledande sakkunnig, trafikråd
Seppo Öörni, trafikråd
Olli Lehtilä, överinspektör

Tillsatt av och datum

| | |
|---|---|
| Publikationsseriens namn och nummer<br>**Kommunikationsministeriets publikationer 6/2018** | ISSN (webbpublikation)<br>ISBN 978-952-243-550-7<br>URN URN:ISBN:978-952-243-550-7<br>HARE-nummer |

Ämnesord
satellitnavigering, positionering, positionsinformation, Galileo, GPS, små satelliter, New Space

| | |
|---|---|
| Kontaktperson | Rapportens språk |

Övriga uppgifter

Sammandrag
I och med digitaliseringen har satellitnavigering blivit en betydande del av vår vardag. Bland annat de tjänster som betjänar elnäten, telekommunikationsnäten samt trafiken och transporterna kräver satellitbaserad positionering och exakt tidsinformation. Marknaden för satellitnavigering växer och Europeiska kommissionen har uppskattat att marknadens värde är över 70 miljarder euro 2017. Som ett resultat av utvecklingen inom automatiserade transporter, 5G och IoT väntas siffran stiga till 195 miljarder euro 2025. I Europa befinner vi oss nu i ett viktigt skede i utvecklingen av satellitnavigering: de första tjänsterna i det europeiska globala Galileo-satellitnavigeringssystemet har just tagits i bruk och avsikten är att hela systemet ska fungera fullt ut 2020. Finländare och finländsk kompetens har under de senaste årtiondena varit delaktiga i ett stort antal rymd- och satellitprojekt. Dessutom har man i Finland under de senaste åren för första gången utvecklat egna satelliter och vårt land är på väg att bli en ny aktör på satellitmarknaden.

I detta åtgärdsprogram beskrivs nuläget i fråga om satellitnavigeringssystem och utnyttjandet av dem på olika samhällsområden i Finland, särskilt inom automatiserade transporter. Samtidigt beskrivs den nuvarande modellen för rymdförvaltningen i Finland och det förändringstryck som riktas mot den. I slutet av åtgärdsprogrammet presenteras 17 konkreta åtgärder för att öka utnyttjandet av satellitnavigering särskilt på det nationella planet. Åtgärdsprogrammet är ett led i det spetsprojekt i statsminister Juha Sipiläs regeringsprogram som siktar på att skapa en tillväxtmiljö för digital affärsverksamhet. Programmet har beretts på bred bas i samråd med branschen.

Målet med åtgärdsprogrammet är att säkerställa att olika system för satellitnavigering utnyttjas inom alla sektorer i hela Finland. De centrala målen med tanke på framtiden är att lyfta upp Finland till täten bland de länder som utnyttjar satellitsystem, att stärka verksamhetsbetingelserna för den nuvarande högklassiga inhemska rymdverksamheten, att öka utnyttjandet av satellitinformation inom affärsverksamheten och vid tillhandahållandet av tjänster, att säkra kvaliteten på positioneringen och utnyttjandet av satellitnavigeringssystem i arktiska regioner, att främja utnyttjandet av små satelliter och att utreda behovet av och möjligheterna att grunda en rymdförvaltning i Finland.

MINISTRY OF TRANSPORT AND COMMUNICATIONS

| | |
|---|---|
| | Julkaisun päivämäärä<br>12.4.2018 |
| Julkaisun nimi<br>**Satelliittinavigointijärjestelmien tehokas hyödyntäminen Suomessa - toimenpideohjelma 2017–2020** | |
| Tekijät<br>Seija Miettinen, johtava asiantuntija, liikenneneuvos<br>Seppo Öörni, liikenneneuvos<br>Olli Lehtilä, ylitarkastaja | |
| Toimeksiantaja ja asettamispäivämäärä | |
| Julkaisusarjan nimi ja numero<br>**Liikenne- ja viestintäministeriön julkaisuja 6/2018** | ISSN (verkkojulkaisu)<br>ISBN 978-952-243-550-7<br>URN URN:ISBN:978-952-243-550-7<br>HARE-numero |
| Asiasanat<br>satelliittinavigointi, paikannus, sijaintitieto, Galileo, GPS, piensatelliitit, New Space | |
| Yhteyshenkilö | |
| Muut tiedot | |


Tiivistelmä

Digitalisaation myötä satelliittinavigoinnista on tullut merkittävä osa tavallista arkeamme. Esimerkiksi sähköverkkojen, tietoliikenneverkkojen sekä liikenteen palvelujen toiminta edellyttää satelliittipaikannusta ja tarkkaa aikatietoa. Satelliittinavigoinnin markkinat ovatkin kasvussa ja Euroopan komissio on arvioinut niiden arvoksi vuonna 2017 yli 70 miljardia euroa, jonka odotetaan kasvavan automaattiliikenteen, 5G:n ja IoT:n kehityksen vuoksi 195 miljardiin euroon vuoteen 2025 asti. Euroopassa eletään tärkeää vaihetta satelliittinavigoinninkehityksessä, sillä eurooppalainen globaali Galileo-satelliittinavigointijärjestelmään on juuri otettu käyttöön ensimmäiset palvelut ja sen on tarkoitus olla täysimääräisessä käytössä vuonna 2020. Suomalaiset ja suomalainen osaaminen ovat olleet mukana lukuisissa viime vuosikymmenten avaruus- ja satelliittihankkeissa. Lisäksi viime vuosien aikana Suomessa on kehitetty ensimmäistä kertaa omia satelliitteja ja valtiostamme onkin kehittymässä uusi toimija satelliittimarkkinoille.

Tämä toimenpideohjelma kuvaa satelliittinavigointijärjestelmien nykytilaa sekä niiden hyödyntämistä yhteiskuntamme eri osa-alueilla, erityisesti automaattiliikenteessä. Samalla kuvataan Suomen avaruushallinnon nykymallia ja siihen kohdistuvia muutospaineita. Toimenpideohjelman lopuksi esitetään 17 konkreettista toimenpidettä, joilla pyritään edistämään satelliittinavigoinnin hyödyntämistä erityisesti kansallisella tasolla. Toimenpideohjelma on osa Juha Sipilän hallitusohjelman kärkihanketta: Rakennetaan digitaalisen liiketoiminnan kasvuympäristö. Työ on tehty laajasti alaa kuullen.

Toimenpideohjelman tavoitteena on varmistaa satelliittinavigointijärjestelmien hyödyntäminen koko Suomessa yhteiskunnan kaikilla sektoreilla. Keskeisimmät tavoitteet tulevaisuutta ajatellen ovat: Suomen nostaminen kärkimaaksi satelliittijärjestelmien hyödyntämisessä ja nykyisen korkealaatuisen kotimaisen avaruustutkimustoiminnan edellytysten vahvistaminen, edistää satelliittitiedon hyödyntämistä liiketoiminnassa ja palvelujen tarjonnassa, varmistaa paikannuksen laatu ja satelliittinavigointijärjestelmien hyödyntäminen kaikkialla arktisilla alueilla, edistää piensatelliittien hyödyntämistä ja selvittää tarve ja mahdollisuus perustaa Suomeen avaruushallinto.

# Contents

In this Action plan satellite radionavigation includes positioning and time data as well as the services needed for their utilisation. During the preparation of this Action plan, the Geospatial data study is also being prepared for which reason this Action plan does not deal extensively with location data, which is often shown with maps. With regard to automated transport, it is of key importance that positioning and maps are up to date and reliable.

# 1. Introduction

As society has become digitalised, satellite navigation has become an important part of our everyday lives. For example, the operation of power and communications networks and transport services requires satellite positioning and accurate timing. In addition, satellite positioning is utilised in many other areas of everyday life, such as in the monitoring of people with dementia and prisoners. In 2017, the European Commission estimated the current value of the satellite navigation sector at over EUR 70 billion. Smartphone services account for the majority of this sum.

The efficient utilisation of satellite navigation was incorporated into Sipilä's Government's key project **Creating a growth environment for digital business operations**. The objective of the key project is to make Finland a favourable operational environment for digital services and digital-based business models. Work to develop the digital growth environment is carried out under the lead of the Ministry of Transport and Communications (herein after MTC).

The Government-appointed space advisory board has drawn up a national space strategy for 2013–2020 to facilitate the realisation of national objectives. The strategy has been taken into consideration when preparing this Action plan. Finland's needs in the global operating environment set the premise for developing Finland's space sector, and the strategy outlines the primary development objectives in the fields of space activity Finland is active in and which are funded from the Government budget.

The vision for the National Strategy for Finland’s Space Activities 2013–2020 is for Finnish actors to represent the world's leaders in space science, data-based business and their utilisation in society by the time the strategy period comes to an end. The strategy outlines four extensive key projects, whose main aim is to develop Finnish research expertise and the competitiveness of companies especially in the Arctic region and the utilisation of open data. Within this Action plan, the Arctic region is understood to be more extensive than the region north of the Arctic Circle. This area covers the whole of Finland.

Internationally-speaking, in 2016, the European Commission published the Space Strategy for Europe, which has also been taken into account in the preparation of this Action plan. The Space Strategy for Europe states that space technology, space data and space services have become essential and that the most broad-scoped opportunities facilitated by space solutions and data have yet to be utilised.

In order to utilise the significant opportunities space has to offer, the European Commission has determined that Europe must work together and keep at the forefront utilising all available skills, expertise and investments. In 2017, Finland drafted the Act on Space Activities, which will promote the development of new space innovations and business opportunities.

Europe is undergoing an important phase in satellite navigation as the Initial Services of Galileo, the European Global Satellite Navigation System (GNSS), have just begun operating. The plan is to have the system fully operational by 2020. The Galileo satellite navigation system is the first system intended entirely for civilian-use, and it is expected that its deployment will improve the efficiency of business in Europe and thus also in Finland.

## 1.1 Objective of the Action plan

The objectives of this Action plan include:

1. guaranteeing the utilisation of satellite navigation systems and the quality of positioning throughout Finland in all of society's sectors as well as to encourage every administrative branch to draw up a plan for the utilisation of satellite navigation
2. making Finland one of the world leaders in the utilisation of various satellite navigation systems and in the provision of location data services in the Arctic region
3. promoting the utilisation of satellite data in business and in the provision of services
4. promoting the utilisation of small satellites and improving the operating conditions for Finnish high quality space research
5. determining the need and possibilities for establishing a space administration in Finland The objective is not to establish a new agency, but activities could be centralised with one existing actor.

# 2. Current status of satellite navigation systems

## 2.1 GPS, Galileo, GLONASS, BeiDou and EGNOS

Of Global Navigation Satellite Systems (GNSS) the ones that are currently fully operational and continuously modernised are the American GPS and Russian GLONASS. The European Union's Galileo and China's BeiDou are in their deployment phase, which means that some of the systems' functionalities are already in use. Galileo is expected to be fully operational in 2020, and BeiDou is currently expanding from a local system into a global navigation satellite system by 2020. At the moment, BeiDou is fully operational locally in China and its surrounding countries. India (IRNSS) and Japan (QZSS) are developing local satellite navigation systems.

The European Geostationary Navigation Overlay Service (EGNOS) is a satellite-based augmentation system that supplements the GPS system's operations for users in Europe. In the future, the augmentation system is to also cover Galileo's signals. Initially, the system was to also help the GLONASS system, but this was discarded.

Numerous satellite navigation systems and their supporting systems together facilitate an endless number of uses and services in the areas of positioning, navigation and accurate timing. The accurate timing refers to time synchronisation in areas that require the exact time such as banking, telecommunications and the supply of energy. In the area of research as well as in practical work in matters related to land surveying and geodesy the shared use of a satellite navigation system will decrease measurement uncertainty and facilitate more accurate and reliable measurements as well as new methods and applications. Finland's coordinate system has been based on satellite observations by FinnRef ground stations since 1998.

New GNSS systems and the modernisation of existing ones increase the number of satellites and frequencies available so much that location and time determination are more effective even in the most challenging conditions, such as in street canyons and forests, more efficient than today, when there are only GPS or GPS and GLONASS satellites. However, satellite positioning is not available everywhere such as indoors and in tunnels, which means the need to combines other location determination technologies to satellite positioning remains.

A global satellite navigation system that works in general is achieved with 18 to 30 satellites. Satellite-based augmentation systems have been developed to supplement satellite navigation with the help of ground stations, computer centres and other satellites. The systems in question monitor GNSS satellite signals and factors that influence GNSS signals very carefully at ranging and integrity monitoring stations. On the basis of these measurements, the corrective data and reliability estimates for positioning can be calculated, which are then sent to the user via satellites that are on geostationary orbits. Satellite positioning is based on precision timing: the travel time for the signal can be determined by calculating the difference between the transmission time for satellite-sent radio signals and their reception time. This will determine the distance between the satellite and the receiver. Four distance measurements help in determining the receiver's 3D position coordinates in the global coordinate system as well as the time difference between the receiver clock and the time logged in the satellite system. This will help in achieving PNT (Position, Navigation, Timing).

## 2.2 European Galileo and EGNOS programme services

Development of the European Galileo programme began in 2003. In December 2016, the Commission adopted its first declaration on the services provided by the Galileo programme. There are currently 18 satellites in orbit, of which 15 are fully operational, the services of two satellites which are on the wrong orbits can be utilised in part and one is not in use. A further four satellites are to be launched by the end of 2017. The aim is that the Galileo programme will be fully functional and in force in 2020, at which time there should be 24 satellites and some spare satellites in use. The Galileo programme is the first satellite positioning system entirely intended for civilian use, and it will ensure Europe's independence from other satellite systems and improve Europe's operational reliability.

The EGNOS programme was adopted in 2009. The EGNOS service produces the corrective adjustments for positioning on the basis of observations made at 39 RIMS stations, and the data is transmitted via three geostationary fixed satellites. Geostationary fixed satellites are visible in Finland at low angles of elevation, which presents challenges for the availability of corrections. Finland's only RIMS station is located in Virolahti. Problems in the quality of EGNOS corrections have been observed in northern and north-eastern Finland. This is because a sufficient number of RIMS stations being unable to detect satellites rising from the east, meaning the correction does not apply to them. Disruptions in the ionosphere caused by the activeness of the sun can also require higher location accuracy than average in corrections at higher latitudes. The Commission has promised to four new RIMS stations, one of which would be located in Kuusamo. The new station in Kuusamo would significantly improve the reliability of overall positioning and serve air traffic in particular. At the moment, the Commission and the GNSS Agency are assessing the technologies with which RIMS stations will be equipped. From Finland's perspective, Kuusamo's RIMS station should be based on ENGOS V3 technology. It is believed that this technology will solve Finland's quality problems.  This new technology could be in use sometime between 2023 and 2025.

The Galileo programme provides access to an Open Service (OS), a Commercial Service (CS), a Public Regulated Service (PRS) and a Search and Rescue Service (SAR). The quality and availability of the OS and CS are described in Table 1.

The commercial service's service level is determined by the service operator within the limitations of the Galileo system. Galileo's service description sheet[1] from 2002, on the other hand, describes the minimum performance for distance measurement satellites using one or two frequencies, which cannot however be directly turned into accuracy performance assessments. The GNSS Agency has also recently published the first performance report for the open service, which states that horizontal and vertical positioning errors (95%) are significantly better than their target values i.e. 3.56 m and 4.12 m.

| *Service* | | *Open Service* | | *Public Regulated Service* |
|---|---|---|---|---|
| *Abbreviation* | | *OS* | | *PRS* |
| *application* | | | | |
| Frequencies (number of) | | 1 | 2 | 2 |
| Coverage: | | Global | | Global |
| Accuracy of horizontal positioning (m) | | 15 | 4 | 6.5 |
| Accuracy of vertical positioning (m) | | 35 | 8 | 12 |
| Timing accuracy (ns) | | - | 30 | 100 |
| Service Availability% | | 99.8 | | 99.5 |
| Integrity available | | No | | Yes |
| Alarm limit | level | - | | 20 |
| | altitude (m) | - | | 35 |
| Alarm delay (s) | | | | 10 |
| Atmospheric correction | | Yes | Yes | Yes |
| Year of deployment | | 2016–2018 | | 2018-2020 |

**Figure1: Goal accuracy of Galileo's Open Service and Publc Regulated Service**

[1] http://ec.europa.eu/transparency/regdoc/rep/1/2002/EN/1-2002-518-EN-F1-1.Pdf

### 2.2.1 Galileo's Open Service

The Open Service (OS) is accessible to users free of charge and produces positioning and timing data for satellite navigation mass applications. The Open Service ensures that satellite navigation systems operate globally, regardless of the availability of a single system. Galileo also increases the number of satellites, its positioning is more reliable and it provides improved accuracy. However, the Open Service does not provide information on the integrity of the system.

Galileo offers three signals at nearly the same frequencies and the same way as the GPS system, so it is easy to manufacture Galileo-compatible locators for smartphones, navigators, cameras and other positioning devices. It has been estimated that inexpensive devices that use one frequency can achieve a horizontal positioning accuracy of at least 15 metres and a vertical positioning accuracy of 35 metres. Positioning that utilises two frequencies achieves a horizontal positioning accuracy of 4 metres and a vertical positioning accuracy of 8 metres.

The Galileo programme's Open Service contains a navigation message authentication feature (OS-NMA), which makes it possible for users to be certain that the service's navigation signal is really from the Galileo satellites. Authentication reduces the possibility of external parties intentionally interfering with the satellite positioning receiver so it shows incorrect time or location data. Authentication will be deployed in 2018, and this will be open to everyone, free of charge. In order for it to be possible to use authentication, the receiver must support the feature and a public encryption key be installed to it. The use of authentication is not mandatory. The Galileo receivers function even when they are not able to process authentication data. Other GNSS systems do not include an authentication feature that is available for all users, meaning this a notable strength for the Galileo system.

The time signal for the Open Service could be used to facilitate the synchronisation of various systems and applications, such as ICT systems and banking systems.

### 2.2.2 Galileo's Commercial Service

The Commercial Service (CS) supports applications developed for professional and commercial use. These offer better and more accurate positioning than the Open Service. A service promise is to be given for the Commercial Service covering availability and interruptions in service, the length of these interruptions as well as the practices related to their elimination. The service is transmitted by operators, who purchase the right to use the signal from the Galileo operator together or separately from open signals. The service is a global one.

The Commercial Service provides two significant improvements compared to the Open Service:

- more accurate geographical location determination, "high-resolution CS" and
- a more efficient authentication capacity "authenticated CS".

These can be delivered to users independent of one another. Data that facilitates high resolution travels with the Galileo satellite signal and is subject to a charge. The objective is to achieve a positioning error of less than one decimetre. At its simplest, an authenticated CS can use the OS's authentication capacity, but the separate encrypted codes sent in the CS signal provide additional protection against counterfeit signals. The encrypted codes make it possible to identify signals sent from Galileo. Users must pay a fee for encryption keys for the codes.

### 2.2.3 Galileo's Public Regulated Service

The Public Regulated Service (PRS) is reserved exclusively for users authorised by public administration. The service offers signals with strong encryption for applications that require service continuity in normal conditions, during disruptions and in exceptional circumstances. The service is encrypted and designed to operate reliably in spite in attempts at interference and distraction. The service includes solutions that filter interference the technical specifications of which are kept confidential. Use of the service requires that the receiver is able to decode the encrypted signal.

The service is primarily intended for use by the authorities, and to support applications that are strategic and critical for society. Typical users include the police, rescue services, border control, customs and the defence forces and actors who play key roles in the provision of logistics that influences energy supply, telecommunications, banking activities or society's vital functions. The service is to function in all conditions.

The availability of the service is controlled by authorities appointed by the European Union. Authorities from EU Member States are responsible for the distribution of devices. Nationally, the Ministry of Transport and Communications makes decisions on the user groups who are authorised to use the PRS. The national PRS authority grant access rights. In Finland this authority is the Finnish Communications Regulatory Authority. The national PRS authority's areas of responsibility also include the administration of PRS devices and seeing to supervision, key administration as well as export supervision in the case of industry.

### 2.2.4 Galileo's Search and Rescue Service

The Search and Rescue Service (SAR) picks up emergency signals from the alarm transmitters and transmits messages to the COSPAS-SARSAT system's search and rescue service. COSPAS-SARSAT is a global rescue system which steers emergency signals from the transmitters of located ships, aircrafts, emergency buoys, etc. automatically via satellites to the nearest search and rescue organisations.

The Galileo system's satellites will receive and transmit emergency signals. When at full operating capacity, the system's satellites cover the entire Earth at all times and are able to also transmit return message on the reception of an emergency message.

The Galileo SAR service will further improve the status of those who currently use the COSPAS-SARSAT with regard to the coverage of the service and accuracy of the emergency transmitter's positioning, particularly in the north. The acknowledgement message in the form of a return signal is also a notable improvement to the quality of service. This will inevitably increase the willingness of people to utilise the service, in particular for recreational and tourist purposes, thus improving the safety of mobility in Finland.

### 2.2.5 EGNOS's Open Service

The EGNOS programme's Open Service was deployed in 2009. The accuracy of Galileo's positioning can in future be improved when using corrective data from EGNOS or some other support service. Today, EGNOS only improve the accuracy of GPS, but in the future the system will also be able to do so for Galileo positioning. In good signal conditions EGNOS can provide an accuracy of approximately one metre.

### 2.2.6 EGNOS's Safety of Life Service

The satellite-based EGNOS support system's safety of life service (SoL) has been available in Europe from 2011, when it was approved for use by air traffic. In the near future, the service will also be extended to maritime transport. The Safety of Life Service is mainly a safety critical service and is only related to ensuring immediate safety for human life. The service aims to ensure the safe use of the positioning system and warns system users of system disruptions such as the malfunction of a satellite or another part, which can weaken the accuracy of positioning. Signatures can be added digitally to messages in the service, which will ensure that the receiver can be certain of the authenticity of the message.

The service warns the user, when the system should not be used for navigation. The integrity of the system is even more important than its positioning accuracy. This means that the different parts of the system must function flawlessly. When there is a possibility that the accuracy of positioning has been compromised above a certain limit value, the service sends a warning to the user. The limit values are set separately for horizontal and vertical positioning accuracy for different user groups.

### 2.2.7 Timetable for the implementation of Galileo services

The test use of Galileo's Open System and Search and Rescue System began in December 2016. Test use of the Public Regulated Service will begin in 2018 and the service will be fully operational by the end of 2020.  All the services should be deployed in phases by the end of 2021.

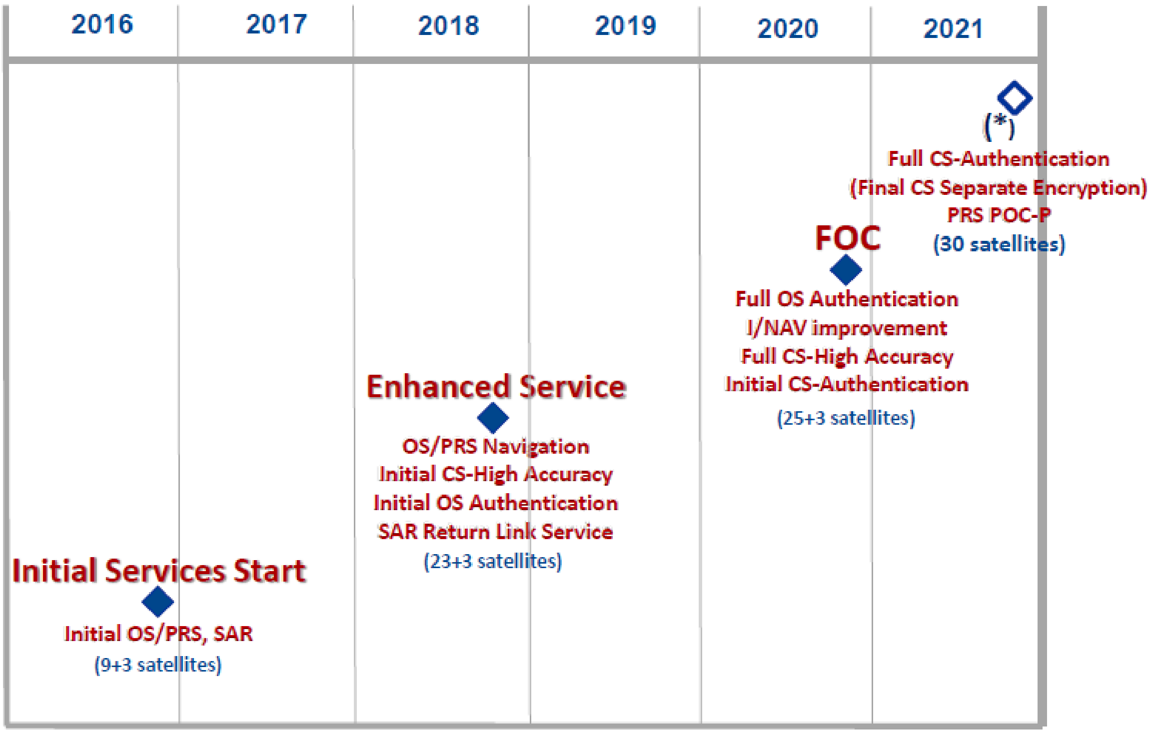


**Figure 2: Timetable for the implementation of the Galileo programme. European Commission, Galileo FOC Programme Roadmap, 12 December 2016.**

## 2.3 Challenges related to satellite navigation systems

### 2.3.1 Coverage problems affecting North European satellite navigation systems

Satellite navigation programmes and their associated support systems do not perform optimally at high latitudes and especially in the Arctic region in particular in determining vertical positioning. This is due to the satellite constellation i.e. the way satellites are situated on their orbits. However, Galileo provides a somewhat better coverage in higher latitudes than GPS, whereas GLONASS provides the best possible coverage due to its highest inclination angle. There are problems with geostationary navigation systems (EGNOS) in Northern Europe, because the satellites that send support signals are poorly visible in norther areas and the good reception is not possible.

Services provided by EGNOS, the support system for satellite navigation, are available in Central Europe, but for the time being not all services are available in Northern Europe (e.g. LPV200). The greatest problems with coverage have been observed in Finland (see Figure 3 below). Coverage problems mean that the service cannot be utilised in Finland for example in air traffic.

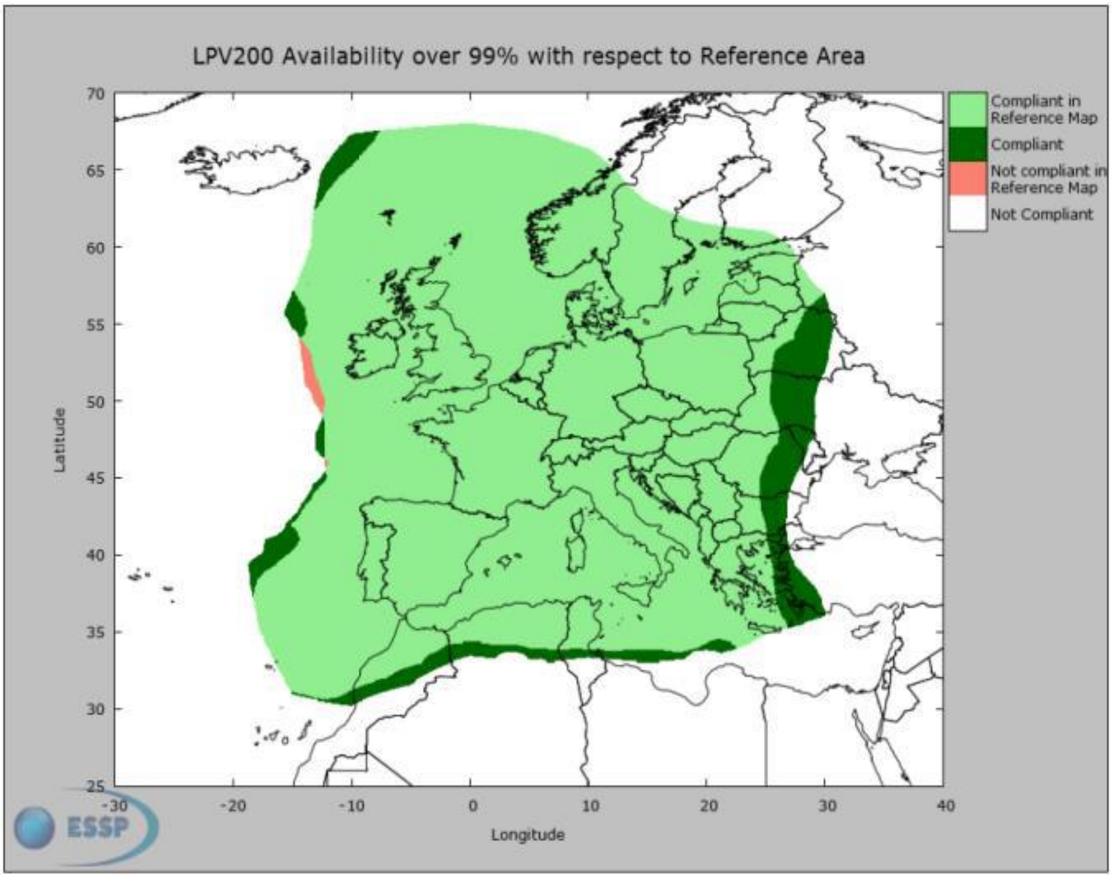


**Figure 3: EGNOS coverage problems in Finland (January 2017, GNSS Agency)**

### 2.3.2 Interference and jamming

Satellite navigation signals, like other radio frequency signals are susceptible to both unintentional interference and deliberate jamming. However, this problem is particularly challenging and more difficult to resolve in satellite navigation, as satellite navigation signals are very weak in strength after traveling from space to Earth and are therefore prone to interferences. Sources of satellite navigation interference include the he free electrons created by the sun's UV radiation in the ionosphere, which angle the satellite signal and various terrestrial systems that interfere with the progress of the satellite signal. The free electrons in the ionosphere interfere with signals especially when the sun is at its most active in eleven year cycles, but temporary solar storms can also cause significant interference to the progress of satellite signals and cause errors in distance measurements between the satellite and the user.

The most common unintentional terrestrial sources of interference sources are electric devices near the reception point. In addition, various types of RF transmissions may affect the reception of satellite navigation. For this reason, it is very important to place the fixed satellite navigation receiver antennas correctly, avoiding electromagnetic interference to electronic and radio devices. The quality of the satellite navigation receiver will also have a significant impact on how susceptible it is to interference. It is also good to be aware that when malfunctioning any radio device can radiate on the wrong frequency jamming other radio systems. This will require the case by case investigation and elimination of radio interference. Intentional jamming is carried out with devices that deliberately send a radio frequency signal sufficiently effectively and with such signal characteristics that prevent or hinder the monitoring of satellite navigation signals in certain areas or deliberately send misleading signals to the receiver. If the FinnRef positioning service is used to support positioning, the service can help in identifying interference and jamming. The service can make it possible to create a quality instrument for satellite positioning in Finland.

New frequency bands and positioning codes that are not as susceptible to interference have been planned for satellite navigation systems that are being modernised. The frequencies of signals have also been taken into consideration in Galileo and susceptibility to interference when planning codes. In the future, numerous modernised satellite navigation systems will be in shared use meaning that it will be increasingly difficult to jam all the available frequencies at the same time.

### 2.3.3 Support Systems

Satellite positioning provides outdoors location determination in global coordinate system. Its accuracy varies depending on environmental factors and the reception technology in use as well as depending on possible aiding systems or reference networks. Satellite signals are often too weak to be received indoors or for example in tunnels, which means that supplementing technology is needed for positioning. Tall buildings in urban areas hinder the progress of satellite signals. Other supporting and parallel positioning technologies will be needed alongside satellite positioning systems so that for example navigating the progress of a pedestrian from the outdoors to the indoors can be seamless, accurate and easy. Aiding navigation technologies include inertial navigation technologies[2] and wireless positioning methods, Wireless positioning methods include positioning based on a mobile mast signal (e.g. 4G),methods based on the measurement of wireless LAN signal strength (e.g. WLAN) positioning based on  Bluetooth technology,  remote sensor positioning based on RFID chips ultrasound and infrared positioning and time-delay positioning based on ultra wideband signals (UWB). Other aiding positioning technology include cameras and fixed physical locations equipped with sensor reflectors.

### 2.3.4 Preparedness

As Finnish society has experienced general technological progress and digitalisation, it has become very dependent on the usability of reliable timing and positioning data.  Just like any other radio system, satellite navigation is not available everywhere and at all times. Especially the operating capability of the police and rescue authorities suffers if satellite-based positioning data is not accessible. Telecommunications networks, banking systems and many other functions that are significant to a fully functioning society will cease or work properly without the highly accurate time signal that most often originates from satellites.

These days, the GPS system is used for time and location data. In the future Galileo Public Regulated Service (PRS) will strive to ensure that critical actors can receive satellite signals even in poor conditions

## 2.4 Location data from the perspective of privacy and protection of personal data

[2] Inertial navigation is based on the measurement of acceleration.

Regulation that applies to location data has been fragmented into a number of provisions. The applicable regulation depends on whether information processing includes the processing of personal data (according to either general or special legislation) electronic communication or data related to geography and infrastructure. The abundance of regulation has is in part related to the fact that at the level of fundamental rights, location data is linked to privacy protection, protection of personal data, freedom of movement, freedom of expression and the principle of public access to information possessed by the authorities.

Personal data includes all information related to an identified or identifiable natural person. An identifiable person is natural person, who can directly or indirectly be identified for example on the basis of identifying data such as their name or even their location. Location data is thus personal data, of it can be linked directly or indirectly to a natural person.

The processing of personal data is provided for in the Personal Data Act. On 25 May 2018, this will be replaced by the European Union's General Data Protection Regulation. The processing of all personal data necessitates grounds for processing pursuant to personal data legislation. Grounds for processing can include permission from the registered party or a law provision. When personal data is processed, the controller must see to it that the registered party's rights are released and that the controller fulfils the statutory obligations prescribed to it. Information security and data protection must be guaranteed. Additionally, it must be ensured that personal data is only used for purposes that are compatible with the intended use. If the information is to be used for other purposes, the registered party must provide permission for this or the special conditions for processing must be enacted into legislation.

Special legislation that applies to a specific sector has also been laid down on the processing of personal data. Special legislation has been laid down on transport and intelligent transport. Below is a description of the Commission's activities related to C-ITS systems. Legislation on electronic communication contains special provisions on the processing of person data. The legislation applies to communication carried out with those electronic communication services that are commonly used and available. Provisions on location data in electronic communication applies to communication service providers as well as added-value service providers. Key statutes that apply to electronic communications have been collected in the Information Society Code and regulation is based on the Directive on privacy and electronic communications. The Commission has announced that it will examine the directive on the basis of the EU's information security reform and in January 2017 it submitted a proposal that the directive be replaced by a regulation. It would be a significant reform if regulation applied to all communication service providers in a technology-neutral manner.

The provisions in the Information Society Code that apply to the processing of personal data are not usually applied to satellite positioning, because satellite positioning does not utilise public communication networks. If these definitions change along with new EU regulations, this may also have an impact on the processing of personal data in satellite positioning. Positioning itself happens with a positioning device that receives a navigator signal calculates the location, direction and speed of the device on the basis of this. The collection of data happens in the positioning device and satellites do not process location data. Also other processing of personal data may be carried out on the positioning device, if it has the necessary features, or the data can be moved from the positioning device to another device or service.

However, the mobile network and wireless local area network can be used for the transmission of location data and to support positioning. Positioning devices often transmit information via public communications networks. Positioning data is usually relayed over the mobile network to various services and applications, and it is usually an essential part of the service. In addition, for example positioning systems in mobile phones generally use satellite positioning data as well as positioning data that can be accessed via public communications networks. Telecommunications networks provide a parallel positioning method, for example, indoors or they may provide assistance, which allows a faster start to positioning or improved accuracy of positioning. In such cases, the data protection rules for electronic communication data providers and added-value service providers apply. As a rule, in any other case general personal data legislation applies.

Geographical data differs from location data. Geographical data refers to all information that contains a direct or indirect reference to a certain place or geographical area. Regulations that apply to geographical data predominantly applies to the availability of such data from public materials and registers. Geographical data has not as a rule been considered personal data. However, location data can be linked to individual people in which case it is personal data. In this case, general personal data legislation applies, if there are no special provisions on the matter.

On 31 November 22016, the European Commission published a Communication on the strategy on interactive intelligent transport systems (ITS-C). The strategy states that the protection of personal data and privacy is a deciding factor in the successful deployment of automated vehicles equipped with an interactive network connection.  Users must be able to rely on it that their personal data will not be treated as merchandise and that they can effectively track how and for what purpose their information is used. Satellite positioning is used to locate vehicles and location data can in principle be considered personal data, because they are related to the identified or identifiable natural person via the vehicle's identifying data. For this reason, the implementation of the C-ITS must comply with applicable data protection legislation.

As part of the C-ITS Platform project, the Commission, together with public and private actors is looking for solutions to problems related to the ITS deployment issues, so that the first services could be introduced in 2019. One area that requires solutions are issues related to data and privacy protection. The C-ITS Platform will complete its work in September 2017 after which the Commission will decide on any further actions. The Intelligent Transport System Directive 2010/40/EU (ITS Directive) also makes it possible for the Commission to adopt delegated legislative acts that are binding to Member States. In its C-ITS strategy, the Commission stated that it will consider the use of delegated powers to ensure the implementation of the information security regulation in the C-ITS sector.

## 2.5 Systems that supplement satellite navigation systems and parallel systems and in particular systems that serve automated transport

### 2.5.1 Communication networks and other technologies

More than one method is used for determining the geolocation of automated vehicles. These methods include data transfer methods (e.g., ITS-G5, WiFi, UWB, Bluetooth or LTE), cameras, radars and physical landmarks. The location is produced through the fusion of the location data produced by them.

There is more need for communication between vehicles as road traffic is becoming increasingly automated. Cooperative Intelligent Transport Systems (C-ITS) allow vehicles to communicate on their own movements or relay information about traffic conditions. Vehicles can send information about their own location on a continuous basis and use outside information services through the mobile communications network infrastructure that they are connected with. Vehicles can communicate with each other directly or through communications networks.

Air navigation can be based on one or more systems and sensors. As a rule, depending on the flight phase and the equipment available to the aircraft, a satellite navigation system or ground-based radio navigation equipment are used as the primary system. The systems on board the aircraft, such as inertia systems and the gyro compass, can also be used. Traditional ground-based navigation equipment operating analogically on the basis of radio signals include Distance Measuring Equipment (DME) and the Instrument Landing System (ILS), which will remain in used at least until the 2030s. VHF Omni-directional Range (VOR) has already been largely replaced by satellite-based systems. In addition to the ground-based infrastructure and satellite navigation systems, navigation is also supported by radar control.[3]

Navigation systems relying on ground-based infrastructure are used in rail traffic. This technology is expected to remain in use until the end of the 2030s. Radar and radio systems, visual safety systems, pilots and printed nautical charts are still used in maritime traffic in addition to satellite navigation. Potential uses of a broad range of different technologies are examined as part of the development of autonomous ships.

### 2.5.2 Utilisation of earth observation data in automated transport

Different types of information, including open and free-of-charge earth observation data, is available as part of the Copernicus earth observation programme of the EU. Exploiting its broad potential is still in its early stages, which means that only a small part of the full programme impact is known. Combining earth observation data with detailed terrestrial observations as well as weather and conditions models will produce the best possible information on traffic conditions. When this information is used in automated transport, consideration can be given to the impacts of weather and damage to transport infrastructure on an up-to-date basis. This will significantly improve the safety of automated transport. Satellite navigation and information on traffic conditions can help to anticipate the challenges on the route in real time. This applies to all modes of transport. As a result, the existing traffic information systems can be expanded, especially in road transport. Even though the information is already used in maritime and air traffic but information tailored to the needs of different users assumes more importance as it is more often available and more extensively accessible.

### 2.5.3. Services that correct positioning

Corrective measurements for satellite positioning are not only produced by geostationary satellites (EGNOS in Europe), but also by commercial operators in the form of differential corrections Corrections are standardized and in use to improve accuracy and reliability. In addition to its fundamental role as the basic network of the national coordinate system, FinnRef network also provides open data and differential correction services on which private companies, too, can build their own services and generate added value. In addition, FinnRef facilitates a secured service for the State's critical functions (i.e. the Defence Forces, the

[3] Today's aircraft have ILS, DME and VOR as standard equipment. VOR is likely to be replaced by GNSS and DME. DME will probably be used as backup for GNSS for many years to come.

security sector and taxation). Data can also be used for research in either national or international projects.

The most accurate positioning and navigation applications use a carrier phase measurements and regional support services, such as RTK (Real Time Kinematic) NRTK (Network Real Time Kinematic). In Finland, the commercial NRTK service is offered by Geotrim Oy and Leica Geosystems Finland via a national network of approximately 100 ground stations. The National Land Survey of Finland (hereinafter the NLS) is currently developing the FinnRef positioning service. In its first stage it will provide the positioning accuracy required by the NLS's own deliveries to its properties. This will be made possible by 40-50 ground stations the construction of which will be completed by 2019.

PPP technology (Precise Point Positioning) is developing rapidly and as multisystem technology and receivers are becoming less expensive, it will be able to challenge in the next few years traditional DGNSS (Differential Global Navigation Satellite System) technology, offering decimetre-level navigation accuracy in real time. There are already companies providing correction services based on geostationary satellites (such as OmniStar and TerraStar), which allow DGNSS and PPP solutions to be used in global scale. It is also probable that PPP corrections will be sent with Galileo's CS. This would significantly improve the availability of corrections in Finland. The FinnRef positioning service can speed up the launch of the PPP service

### 2.5.4 Small satellites

Along with traditional satellites small satellites have now also opened up possibilities for smaller countries, such as Finland, for companies, and for individual research institutes as paths to near space. Whereas a traditional large satellite weighs approximately 500 kilograms, nanosatellites which are one version of small satellites weigh 1 to 10 kg. They also cost a fraction of the price of a large satellite. In spite of its size, the payload of a smaller satellite is almost as good as that of a larger satellite. In fact, space provides new and unique commercial opportunities for Finnish industries, *startup* companies and space researchers. According to Tekes, there are about 80 Finnish companies that design satellite instruments, structures and software or use satellite data in their business.

In addition to traditional research organisations and equipment and application suppliers, the opportunities offered by the New Space Economy are also attracting new operators to the sector in Finland. New Space activities often involve new operators that are commercially oriented and independent of the state. New Space provides an easier and less expensive access to space through such platforms as small satellites. In New Space also means using space applications for non-research purposes. The activities may involve the provision of everyday positioning and telecommunications services as well as the production of more accurate information on conditions.

In fact, Finland is becoming a new operator in the small satellite market. Before manufacturing satellites of their own, Finnish operators have been involved in many European space projects over the past few decades, even though the focus in the Finnish participation has been on space research and earth observation (EO) and not on positioning. Finland is ideally placed for manufacturing small satellites, from nanosatellites weighing a few kilos to microsatellites of 100 kilos because producing mobile phones required similar mentality and expertise. Aalto-1 and Aalto-2 are the first demonstrations of Finnish small satellite expertise. In addition to indigenous small satellites, Finnish-made products have also been sent to space on board ESA's earth observation satellites and space probes as well as on EU's Sentinel earth observation satellites[4]. These have accounted for most of the space equipment manufacturing in Finland.

Small satellites can be used for measuring a broad range of different matters and locations. For example, detailed information on car park utilisation rates, agricultural operations and aircraft movements can be collected by using small satellites. Small satellites can also be used for measuring atmospheric properties and for monitoring climate change and, as part of these, for monitoring conditions in the Arctic (such as the ice situation). Small satellites utilise GNSS and they are equipped with GPS receivers allowing them to indirectly locate such targets as aircraft and ships. However, small satellites can only be effectively used for such purposes as guiding autonomous vehicles if more of them are launched to space. For example, it is estimated that 60 small satellites are needed to ensure continuous global radio coverage. GNSS positioning data may contain errors arising from such factors as ionospheric deviations but small satellites may be able to correct some of these inaccuracies by providing corrections. It is estimated that the inaccuracies concerning the GNSS positioning data on Finland could be corrected by sending about 30 small satellites to space.

Autonomous vehicles and vessels will play an increasingly important role in all modes of transport in the future, which means that comprehensive geographical and positioning data will be needed for automated transport. These goals can only be met if there is a GNSS-based changeover from multisystem single-frequency to dual-frequency equipment. In the future, small satellites can assist GNSS is such work as relative positioning in relation to the environment and surrounding vehicles. Constellations of small satellites could also be built into independent

[4] Sentinel satellites are the most important part of EU's Copernicus earth observation programme, which used to be known as Global Monitoring for Environment and Security (GMES).

satellite positioning systems.[5] As small satellites are closer to the Earth than GNSS satellites, the signal would be stronger, making it more fault-tolerant and allowing it to penetrate urban and indoor environments more effectively.

### 2.5.5 Telecommunications satellites

Telecommunications satellite connections provided by commercial operators are used for such purposes as for relaying companies' data connections, for internet connections, for relaying television programmes and for telephone connections. Many of the satellites are located on geostationary orbits but the operators of such satellites as Iridium and Globalstar offer speech and data services over satellites at lower orbits. An example of a novel service on the market is the service provided by the OneWeb satellite operator, which aims to offer quick data connections using low-orbit satellites. The aim of the operator in question is to build a network of 648 satellites, which is expected to be deployed in 2019.

Despite these novel services, the most common consumer-oriented telecommunications satellite application in Finland is the reception of television programmes using geostationary satellites. According to Statistics Finland[6], 5.7 per cent of all Finnish households have a dish antenna allowing the reception of satellite broadcasts. Satellite television provides a broad range of different television programmes relayed by a large number of satellites. Because Finland is a northern country, geostationary satellites have a low elevation angle in our country, which means that such obstacles as trees or hills can block the reception.

All operators currently offering commercial satellite telecommunications services in Finland are foreign companies.

# 3. Finland's space administration

## 3.1 Space programmes and organisations in which Finland is involved

At EU level, Finland is a partner in the Galileo and EGNOS programmes as well as in the Copernicus earth observation programme. It is also a member of the European Space Agency (ESA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), both of which are intergovernmental bodies. The purpose of ESA is to develop space technology,

[5] Reid, Tyler, Orbital Diversity for Global Navigation Satellite Systems, Ph.D. Dissertation, Stanford University, May 2017, http://web.stanford.edu/group/scpnt/gpslab/pubs/theses/TylerReidThesis2017.pdf

[6] Statistics Finland, 2017: http://www.stat.fi/til/kbar/2017/03/kbar_2017_03_2017-03-27_kuv_012_fi.html

space research and the utilisation of space. Its work covers research and the development of practical applications that are relevant to the monitoring of the environment and the Earth's climate, navigation and telecommunications. EUMETSAT is responsible for European weather satellites, which these days form the most important global meteorological observation system. The EU, ESA and EUMETSAT work in close cooperation because ESA is responsible for the construction and technology of all European satellites.

The Galileo and EGNOS programmes of the EU are steered by the European GNSS Programmes Committee, which comes under the European Commission. All Member States (including Finland) are represented in in the committee. The European Commission has, by means of statutes and agreements, delegated space development to ESA and the terrestrial segment and signal services to GSA. Finland is represented in the governing bodies of the latter organisation. In the administrative committees of the Galileo programme, Finland is represented by the Ministry of Transport and Communications and the Finnish Communications Regulatory Authority. The administration of the Copernicus earth observation programme is leaner than that of the Galileo programme. In the Copernicus Committee, Finland is represented by the Finnish Meteorological Institute. In the decision-making bodies of ESA’s operating sectors, Finland is represented by the Ministry of Economic Affairs and Employment and Tekes, which have delegated some of the tasks to space research institutions.

The budget of the Galileo programme for the period 2014–2020 is about EUR 7 billion and that of the Copernicus programme about EUR 4 billion. Finland’s annual contribution to the Galileo programme is EUR 15 million and to the Copernicus programme EUR 8.6 million. EU's Horizon 2020 framework programme has a budget of about EUR 1.4 billion and Finland’s annual contribution is about three million. The administrative measures and membership fees pertaining to Finland's EUMETSAT membership are managed with the resources of the Finnish Meteorological Institute in the administrative branch of the Ministry of Transport and Communications. In 2017, the EUMETSAT's membership fee was 7.2 million euros. The Ministry of Transport and Communications has also provided EUR 7.1 million for the Finnish Meteorological Institute's national satellite data centre in Sodankylä between 2010 and 2017. The Finnish ESA membership fee of EUR 19.8 million for 2017 is the responsibility of Tekes and the Ministry of Economic Affairs and Employment. The ministry is responsible for basic funding (obligatory payments, including membership fees), which total about EUR 3.3 million. Within the framework of its annual authorisations, Tekes is responsible for the participation fees for ESA's programmes, which total about EUR 16.5 million each year. A large proportion of the fees and charges paid to ESA are channelled back to Finland as research projects and industrial orders.

In the early years of the 2000s, the Finnish space industry was involved in the construction of the first four Galileo satellites, receiving subcontracting work of about EUR 8 million. However, there were no Finnish companies in the consortium winning the contract for the larger satellite series following the first series. The focus in the space equipment and technology research in Finland is currently on other space sectors. In 2017, ESA launched the Navigation Innovation and Support Programme (NAVISP), to which Finland contributes a total of EUR 1.5 million. In Finland, the leading public sector actors in the satellite positioning research coordinated by ESA and EU are the Finnish Geospatial Research Institute (FGI) of the National Land Survey of Finland (NLS) and the Tampere University of Technology.

## 3.2 Finland's current space administration

Finland's current space administration is based on a decentralised model, where each administrative branch is responsible for its own area of responsibility in the following areas as is listed below. The Space Committee coordinates Finland's space sector activities. Space sector activities in Finland are mostly the responsibility of the Ministry of Economic Affairs and Employment because space matters are primarily seen as an industrial and business issue. The ministry also has access to Tekes's space expertise as well as the budget allocated by Tekes and the Ministry of Economic Affairs and Employment for space activities. However, the ministries are responsible for developing and utilising their own administrative branch's space activities. The Ministry of Economic Affairs and Employment is responsible for formulating the national positions for the space issues discussed in the EU's Competitiveness Council, and the Minister of Economic Affairs represents Finland in the EU and ESA ministerial meetings discussing space issues. In the supreme ESA body (ESA Council), Finland is represented by Tekes and the Ministry of Economic Affairs and Employment. Tekes also serves as the secretariat of the Finnish Space Committee and coordinates Finland's participation in ESA programmes.

In 2014, at the initiative of the Ministry of Transport and Communications, an authority was established in the Finnish Communications Regulatory Authority to prepare and then to administer the Galileo Public Regulated Service (PRS) on a national basis. The powers of the PRS authority are also incorporated in the Finnish legislation (Information Society Code). The Finnish Communications Regulatory Authority has established cooperating groups between administrative branches to prepare the introduction of the PRS service. In addition to the wider issues concerning the PRS service, the PRS authority is also responsible for a number of other safety matters in the field of satellite navigation outside its powers through memberships in international committees and working groups.

In the administrative branch of the Ministry of Transport and Communications, the administration of satellite frequency issues and the issuing of radio licences to Finnish satellites are the task of the Finnish Communications Regulatory Authority, which is responsible for Finland’s frequency administration at national and international level. The satellite frequency administration is managed in the same manner in such countries as Sweden, Norway, Denmark and Estonia. Finland's decentralised space administration, which was established when Finland joined ESA, is shown in Figure 4.

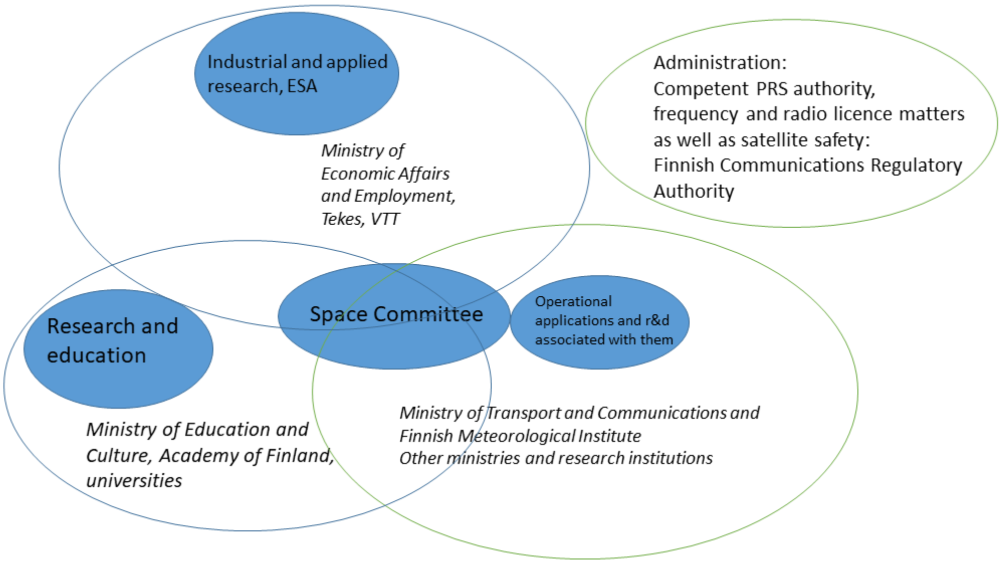


**Figure 4: Finland's decentralised space administration**

Until now, the main task of the Finnish Space Committee has been to discuss Finnish opinions submitted to ESA in which the focus has been on the construction of the space infrastructure. Development of satellite earth observation and the development of satellite positioning have also been discussed in the committee. Each administrative branch has been responsible for the use of the signals sent by the satellites in its own work. Finland also takes part in space activities in the EU, in which there has been progress in many fronts in recent years. This has also meant more administrative work. Figure 5 below shows the participation of different authorities in the work of international space organisations. In the EU, space matters are discussed at ministerial level in the Competitiveness Council and the Transport Council. In addition to taking part in the work of space organisations, Finland also participates in the preparation of satellite frequency issues in the working groups coming under the International Telecommunication Union (ITU) and the Electronic Communications Committee (ECC).

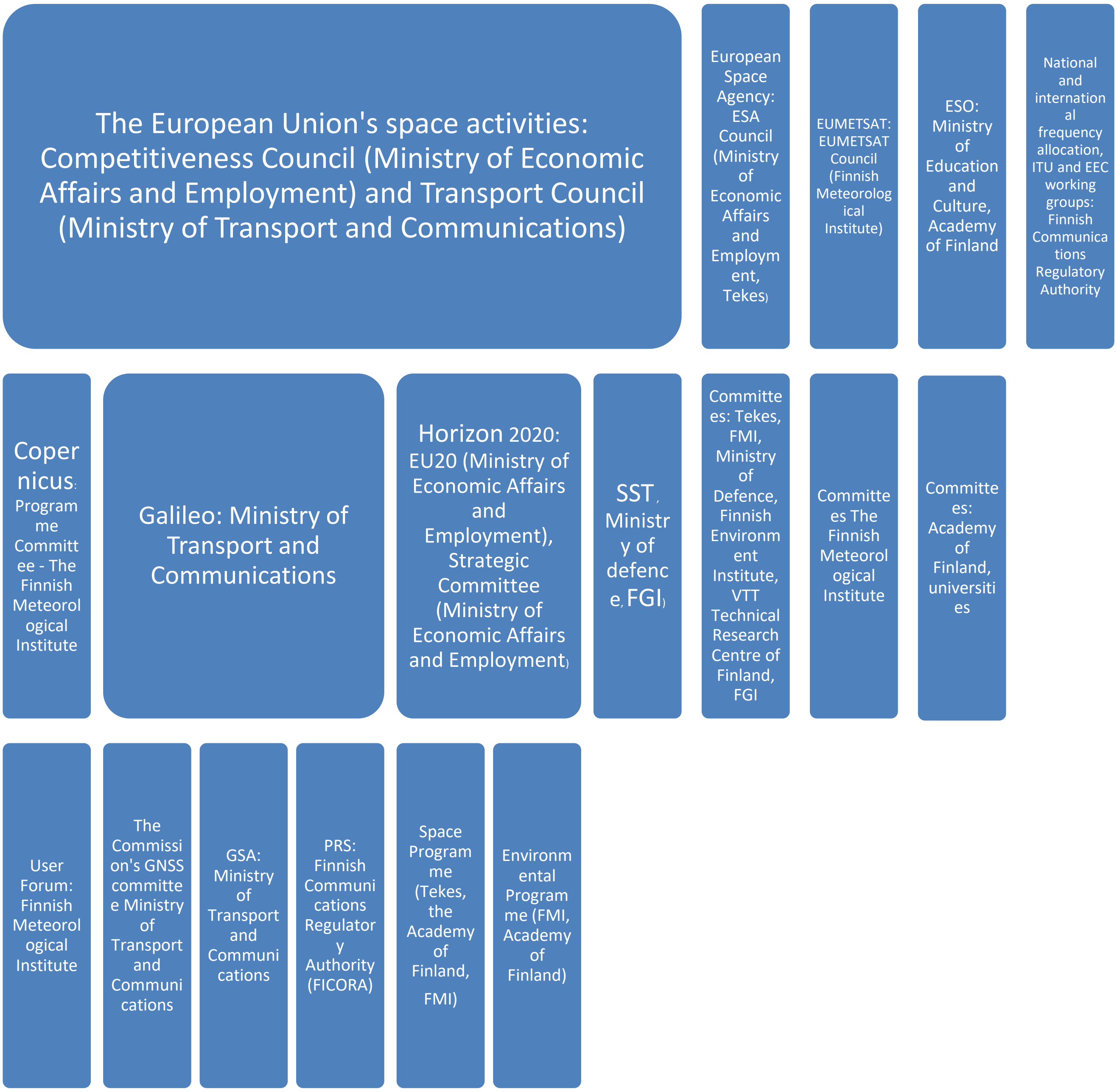


**Figure 5: Finland's representation in European space organisations**

Gradually, Europe's two major space projects, Galileo and Copernicus, are in full use. The aforementioned new business model, the New Space Economy is now becoming established alongside large space projects. This will mean that areas of focus and influence of the Finnish space administration will shift to the exploitation of space, and the utilisation of satellite produced signals will become more emphasised. The development and use of the two major European projects are key to ensuring European innovativeness and the launching of new commercial opportunities at national level as part of the New Space Economy.

### 3.2.1 Benefits of centralized space administration

During the preparation of the Action plan, a number of parties proposed that Finland should have a centralised space administration in which all space activities, such as scientific space and earth research, satellite mapping, satellite positioning and the space industry (including the rapidly growing New Space Economy) could be brought under a single administration and the existing decentralised system could be abolished. The aim would not be to establish a new agency, but the activities could be centralised under an existing actor. If the space sector was centralised under a single actor, it could be in a better position to promote the development and construction of satellites as well as the utilisation of satellite systems.

A centralised space administration would also bring the following benefits:

1) more effective management and coordination of the space sector (more effective coordination would benefit the societally important use of radio frequencies, air space management, and the data accumulated during the operations); preparation and implementation of Finland’s strategic space programme would be easier in the future (the current national space strategy, prepared by the Finnish Space Committee, covers the years 2013 to 2020),
2) agile and flexible administration that is able to react to changing situations and provide a smooth path for space development projects,
3) one stop shop principle (different actors are provided with space information and services on a centralised basis),
4) better operating prerequisites for the New Space Economy and it would also be easier for growth companies to access an expanding new market,
5) more effective promotion and introduction of global technology, product and service innovations in different applications, such as automated transport.
6) securing availability of data, by ensuring that Finland has access to data produced by satellites (this relates to satellite positioning and the EO sector),
7) better visibility and impact of Finland's space sector internationally and nationally,
8) more effective channelling of funds from ESA’s financing mechanism back to Finland and more effective focusing of national funding instruments
9) on the development of space research and training and on the development of small satellites, and
10) long-term development of the space sector and ensuring the continuity of the sector.

Many EU countries (such as Sweden, Norway and Austria) have a centralised space administration. However, in a number of countries (such as Sweden, Norway, Denmark and Estonia), satellite frequency administration is the responsibility of a national frequency administration authority (similar to the Finnish Communications Regulatory Authority). It is also of utmost importance in Finland to ensure effective planning and administration of frequencies for satellite traffic in the future in order to secure uninterrupted functioning of Finnish radio systems (satellite and terrestrial systems), and to ensure that the Finnish radio systems do not interfere with the radio systems of other countries.

It is essential to consider the correctly timed availability of frequencies for Finnish satellites in the planning of the tasks and responsibilities in the centralised space administration so that small satellites can also be used in the future.

## 3.3 Administration of satellite frequencies and radio licence procedures

In satellite operations, frequencies are used for such purposes as controlling satellites from the Earth and for producing satellite information (with the help of radar and other technology) and for sending the information to the Earth. For this reason, frequency issues are relevant to all satellites, including radio navigation satellites and small satellites. Frequency planning and international agreements provide a basis for the smooth functioning of satellites and their ground stations. The Radio Regulations of the International Telecommunication Union (ITU), which comes under the United Nations, lay out procedures for the agreement on the use of satellite frequencies (frequency coordination and notifications and registrations in the Master International Frequency Register) and provide guidelines for the use of these procedures. In Finland, satellite frequency administration and ensuring compliance with the procedures laid out in ITU's Radio Regulations are the responsibility of the Finnish Communications Regulatory Authority.

The possession and use of the radio transmitters carried by Finnish satellites requires a radio licence issued by the Finnish Communications Regulatory Authority if the agreement on the frequencies has been concluded in the name of Finland. In addition to granting radio licences, one of the most important tasks of a frequency administrator is the protection of Finland's satellite resources including public radio satellite resources and over land radio traffic from new foreign satellites as well as ensuring that there are suitable frequencies for Finnish satellite systems so their use does not cause disruptions to other services in Finland and elsewhere.

The ITU Radio Regulations are updated approximately every four years at the World Administrative Radio Conference. During the time between these conferences, necessary research and the review of compatibility are carried out in international working groups (ITU and CEPT subcategories) in which the Finnish Communications Regulatory Authority and the Finnish interest groups are involved. Typically, the frequency bands assigned for satellites overlap with other terrestrial systems, most commonly with radio link and radar bands. As frequency bands are becoming crowded, satellite operators compete for new frequencies and their terms of use with other services such as 5G.

# 4. Utilisation of satellite navigation systems

## 4.1 Satellite navigation systems market overview

In 2014, the global volume of space activities was approximately 230 billion euros. The manufacture of satellites, their launch into space and their operation accounted for 90 billion euros of this sum. The net turnover for the application market, which predominantly comprised the broadcasting of TV programs, satellite positioning devices and services, was 140 billion euros. Satellite positioning applications and terminal equipment accounted for approximately 60 million euros of this sum.

According to the 2017 market report for the European GNSS Agency (GSA)[7], sales of satellite positioning devices and augmentation services will grow at an annual rate of 6.4 per cent between 2015 and 2020. Added-value services are expected to grow 20% between 2015 and 2020. In 2017, the global market for satellite positioning services totalled EUR 70 billion. Boosted by the rapid growth of automated transport, 5G, smart cities and IOT, the turnover of GNSS added-value services is expected to reach EUR 195 billion by 2025 (Figure 6).

Global turnover by revenue type

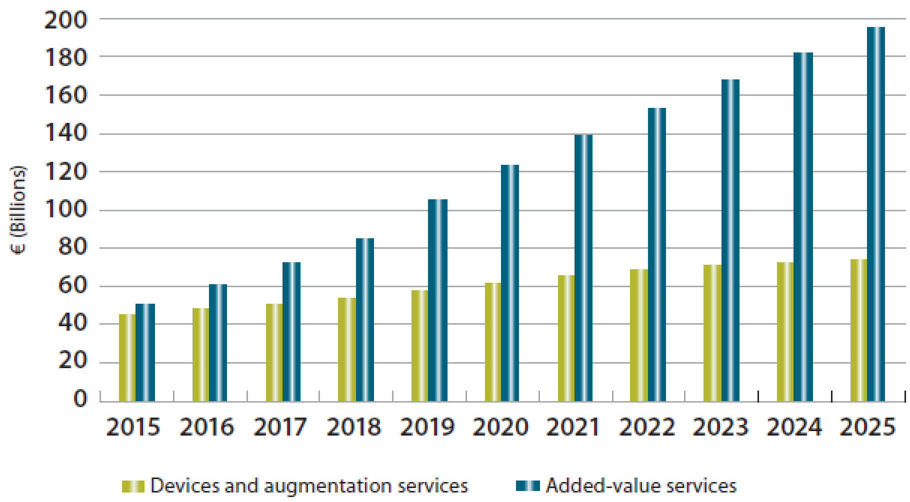


**Figure 6: Devices and augmentation columns show market trends for GNSS receivers and equipment and services directly supporting them. The columns for added-value services describe all services that create added value for services by using GNSS technology.**

[7] GNSS Market Report 2017: https://www.gsa.europa.eu/system/files/reports/gnss_mr_2017.pdf

**These services can include navigation services and smartphone applications.**

According to the market report, there were 5.8 billion GNSS devices in the world in 2017 and the total will reach eight billion (one device/person) in 2020. There are 5.4 billion smartphones in the world and nearly all new smartphones include satellite positioning. Road traffic devices total 380 million. Road traffic applications account for 50.0 per cent and smartphone and table applications for 43.4 per cent of the global turnover of satellite navigation systems (Figure 7).[8]

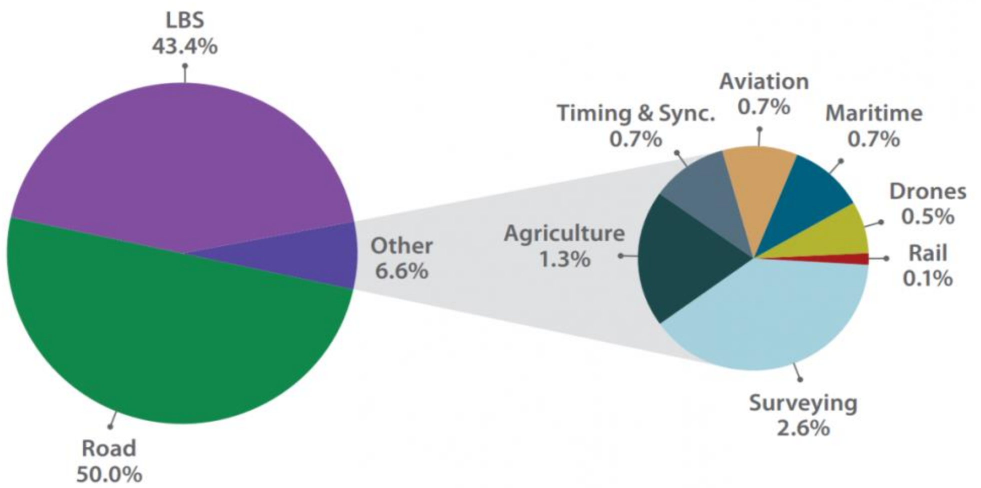


**Figure 7: Breakdown of the total satellite navigation turnover by sector 2015-2025**

Europe accounts for EUR 17 billion of the turnover of satellite navigation services (25% of the world total). This includes road traffic navigation (such as the navigation equipment offered by the Dutch company TomTom), maritime and air navigation, land survey navigation (such as the Swiss Leica equipment), agricultural navigation equipment, location-based software services (such as applications using satellite positioning in smartphones) and accurate timing (used in such services as electricity distribution). Figure 8 below shows the breakdown of the GNSS turnover by region and country.

[8] GNSS Market Report 2017: https://www.gsa.europa.eu/system/files/reports/gnss_mr_2017.pdf

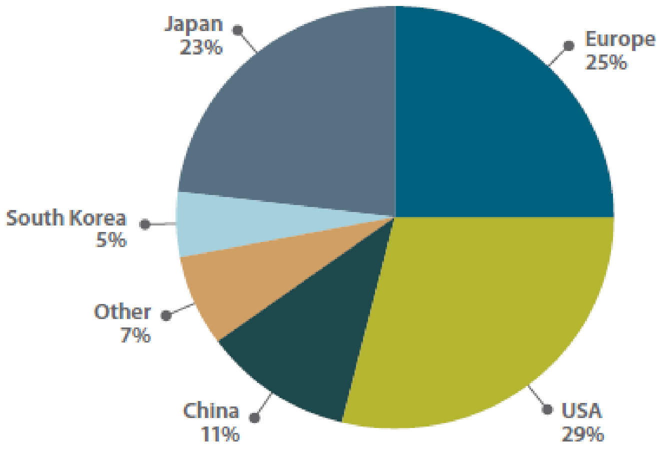


**Figure 8: Comparison of the entire GNSS sector's turnover by area and country.**

### 4.1.1 Value of Finnish space and satellite navigation market

According to Tekes, there are about 90 operators in Finland that are engaged in the development of space technology applications. There are dozens of satellite navigation companies in Finland, including u-Blox (positioning electronic circuits), HERE (maps), Reaktor (small satellites), Iceye (small satellites), Mobisoft, Aplicom and Paetronics (vehicle management), Beaconsim (simulators), Alpha, Positron and SSF (pseudolites, which can replace satellite signals in such places as container ports and open-cast mines), Suunto and Sports Tracking Technologies (sports), Tracker (tracking of hunting dogs) and Vaisala (measurement equipment and systems).

The combined turnover of the Finnish companies producing satellite navigation systems and equipment is at least EUR 300 million. It is, however, difficult to give the total number and turnover of the companies using satellite navigation systems in their business operations. Between 6 and 7 per cent of the European Union GDP (EUR 800 billion) is directly connected with different types of satellite navigation. The total refers to all those situations that rely on satellite navigation. It can also be concluded from the European Union GDP that about six per cent (about EUR 15 billion) of Finland's GDP is dependent on satellite positioning.

In an impact assessment conducted by Tekes, Finnish companies were asked whether their products, services or processes would function without space technology. Of the hundreds of respondents, 25 per cent said that their products or services would not work without space technology. When expressed using economic indicators, this means that the space technology is part of a sector that provides a basis for a turnover of at least EUR 22 billion, more than 40,000 jobs and exports worth EUR 13 billion. This is about 20 per cent of all Finnish exports.

Satellite navigation systems can provide a boost to the development of autonomous ships, which is attracting growing interest in Finland, and they can also open up new markets for Finnish-built autonomous vessels. This trend may also help to create new services for automated transport. PRS and CS service business can also be expected to grow in the near future.

## 4.2 Logistics

Satellite navigation and positioning have a wide range of potential applications in logistics, including real-time tracking of vehicles. When the location of the vehicles is known, transport and route plans can be changed at a short notice. This is often necessary in the distribution and collection of small-size cargo where situations frequently change. Tracking of individual consignments and packages can also be arranged on a real-time basis. Real-time tracking of shipments is also in the interest of the customers who often want to check the progress of their own orders. Real-time monitoring of shipments and estimated timetables provided at a short notice are part of the Just on Time approach in which correctly time shipments reduce the need for intermediate storage, make production processes more efficient and improve customer service. In today's logistics, predictability and reliability are often more important than speed and for this, in addition to information about one's own location, real-time and positioning-based information about traffic congestion and disruptions as well as on weather and road conditions are needed. In future logistics, in which new operating models (such as crowdsourcing) will be applied, satellite positioning will play an increasingly important role.

Round timber transports for the forest industry are largely based on satellite positioning. When the forwarder brings the timber from the forest, the driver marks the location of the stack electronically, using satellite positioning. The persons coordinating the transports use the stack information, plan the transports and relay the details to the transport companies and their vehicles. The vehicle drivers locate the stacks on the basis of geographical data and the navigator giving the location of their vehicle. The details of the collection of the timber and the route to processing are relayed to transport planners and can be viewed on the basis of the information provided by the driver and the geographical data on the vehicle. Similar systems are also used in fuel transport and in the collection of milk from agricultural producers.

Combining satellite positioning with electronic consignment notes helps to make the steering and monitoring of shipments more efficient. In that case, it is not necessary to save the details of the goods for tracking purposes as they are

already in electronic form. At the same time, the likelihood of errors is reduced and the information is correct and always up to date.
Satellite navigation will also improve the safety and security of deliveries. When valuable items and especially when dangerous goods are transported, the location of the shipment should be known on a real-time basis. In the transport of dangerous goods, the properties and location of the substances should also be known to the rescue authorities so that proper measures can be taken in accidents or thefts. At the same time, these arrangements also necessitate strict data security so that the geographical data or the details of the cargo do not end up in wrong hands.

In maritime traffic, real-time positioning data combined with other information makes it possible to optimise traffic flows and routes of individual vessels. The events concerning port visits and cargo handling can also be anticipated and rationalised on the basis of up-to-date positioning data. In fairway maintenance, the accurate geographical data provided by satellite navigation is used for such purposes as checking the depth of the fairways and the location of safety devices.

In road traffic logistics applications, location data is relayed to traffic centres in accordance with the transport control needs and nowadays also in accordance with the customers' needs. At the same time, GPS navigators have become more common and they are also attached to trailers and containers. Satellite positioning is widely used in transport planning and optimisation as well as in vehicle tracking and it is also used to collect information on driving habits.

Tachographs, which are obligatory in heavy vehicles, and the digital tachographs, which became mandatory in May 2006, do not include a GPS navigator as an obligatory component but devices equipped with GPS are available in the market. A logistic information system and a wireless ip connection are more important than the device itself as they allow the organisation to incorporate the terminal device tracking the vehicle into its own information system.

## 4.3 Automated transport

Automated transport applications of different levels are largely based on the information produced by their support and background systems. Accurate positioning is vital to the development of automated transport as a whole because positioning plays a crucial role in decision-making in autonomous systems.

Positioning of autonomous vehicles is based on absolute and relative positioning[9]. Absolute positioning is based on an HD map, vehicle sensors, network-based

[9] http://gpsworld.com/expert-advice-sensor-fusion-for-highly-automated-driving/

positioning and GNSS satellite positioning. Relative positioning is based on the information produced by cameras, measuring devices and optical sensors. The purpose of relative positioning is to determine the relationship of the object to be positioned with other objects in its surroundings.  Inertia measuring devices, distance measuring instruments and laser scanners are the most important relative positioning devices in automated transport.

The key issues in the decision-making systems of automated transport are the location, direction and speed of the vehicle in the traffic environment and its relationship with other objects in the traffic environment. Forecasts of the movements of other objects are also needed. For this reason, autonomous traffic solutions cannot solely be based on absolute GNSS decisions and relative positioning decisions are also needed. Almost all automated transport solutions rely on fusion positioning, which combines the information produced by GNSS solutions and relative positioning solutions. The fusion positioning information provides the systems making autonomous decision with the primary data on the basis of which the decision-making algorithms can give the commands required for controlling the vehicle (such as the position of the vehicle on the road, its speed and direction as well as the distances of other objects).

By far the most difficult problem from the perspective of the positioning systems is autonomous driving in city traffic. This is because the key requirement is to achieve a reliable positioning accuracy of less than 10 cm, irrespective of any physical obstacles. At the moment the prevailing assumption is that currently used GNSS solutions, such as GPS, Galileo and GLONASS are basically inadequate for accurate positioning, especially in autonomous driving in city traffic.

To some extent, interruptions in satellite positioning can be compensated for by using inertia measurements and odometry (travel and speed measured from wheels). These solutions are used in positioning in such places as tunnels. Relative positioning methods can also be supported with landmarks, which can be natural or artificial (such as transponders embedded in the road).

Physical conditions and operating logic vary a great deal between different modes of transport, which produces both challenges and opportunities for the various position determination solutions.  In sea areas, accuracy requirements are not quite as stringent as they are in road traffic, but, on the other hand, the weather will pose greater challenges for both reliability and accuracy. Moreover, in maritime traffic, unreliable data transfer connections make it more difficult to support the positioning systems.

In rail traffic, too, the accuracy requirements are less stringent than in road traffic and this mode of transport also runs on fixed tracks. At the same time, however, satellite positioning systems used in rail traffic must be supported by other relative positioning methods because the positioning signal may disappear for long periods of time in such places as tunnels. In aviation, positioning is primarily based on the information produced by GNSS systems and radio navigation solutions. As in rail traffic, there are no accuracy requirements of a few centimetres.

## 4.4 Utilisation in road traffic

**Current status**

The number of services based on positioning is quickly growing. There are already numerous applications in use in road traffic such as road tolls, eCall (European emergency call system), the digital tachograph, parking services and various public transport or travel chain services. The benefits of positioning should not, however, be solely examined from the perspective of traffic and logistics services because the greatest potential lies in the combination of different services. The user's location is a key factor in the combination of services. Positioning can be used as a basis for combined services in mobility, trade and marketing. For example, when moving, the user can continuously receive information on special offers and manage different types of purchases.

At the moment, the European Electronic Toll Service (EETS), which is interoperable throughout the European Union, is not used in any EU Member State. However, there are about 200 different electronic toll systems and some of them are based on satellite positioning. One of these interoperable electronic road toll systems is based on the use of GNSS. In spring 2017, the European Commission presented a programme, in which the aim is to phase out time-based road charges (vignettes) and to change over to distance-based charging. The aim is to create a system with EU-wide interoperability. Individual Member States would be able to decide on the introduction of the system in their territory. The aim is to reduce traffic congestion and pollution. A driver would only need one contract and one terminal device in the EU area.

The two graphs below show the spread of the eCall system over the next twenty years (Figure 9). The green graph shows the percentage of new vehicles using the eCall system, in accordance with the longest possible type approval period. With a type approval period of 15 years, it can be assumed that 15 years from now, all new cars will have the eCall system. In that case, 38 per cent of all cars would be equipped with the eCall system. There are also estimates in which the percentage of eCall cars of all cars has been calculated on the basis of an eight-year type approval period and assuming that the eCall system will be retrofit in 20 per cent of all existing vehicles. In that case, 31 per cent of all cars would be equipped with the eCall system.

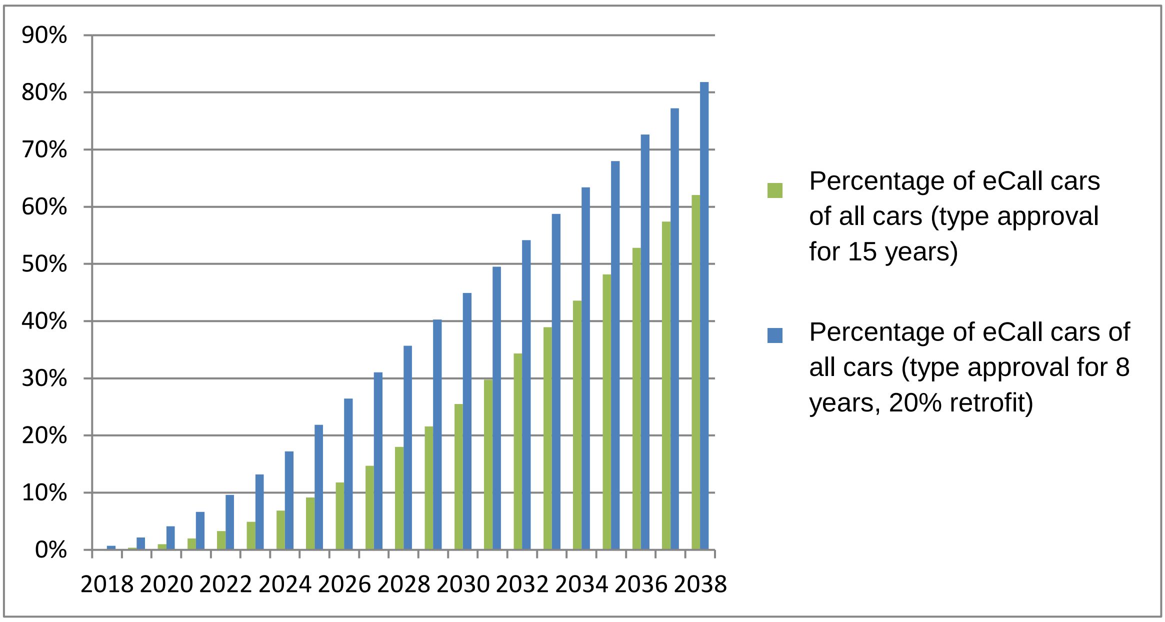


**Figure 9: Estimated percentage of eCall cars of all cars in 2018-2038**

An increasing proportion of heavy vehicles is equipped with digital tachographs, which are based on satellite positioning (Figure 10), and this trend is comparable with the spread of the eCall system. It is estimated that in twenty years from now, in 2037, about 60 per cent of all heavy vehicles will be equipped with digital tachographs. This estimate is based on the fact that all new vehicles registered after 1 June 2019 will be equipped with a digital tachograph. A digital tachograph is not required in heavy vehicles registered before that date.

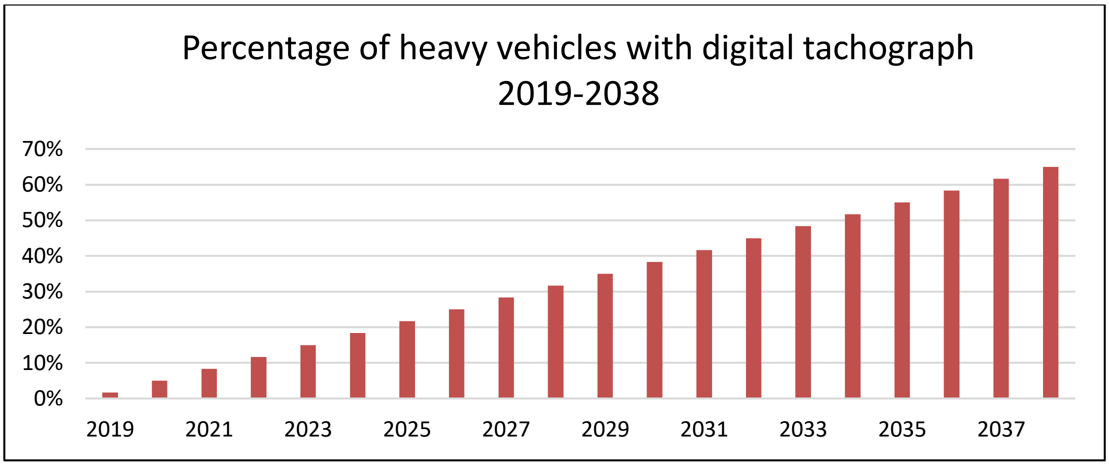


**Figure 10: Estimate on the deployment of a digital tachograph in heavy transport vehicles (more than 7.5 tonnes).**

Positioning will assume an increasingly important role in the future as traffic and the transport system are becoming more digitalised and accurate location data will be the most important common data denominator. This applies to transport and road planning, construction, management and maintenance of the transport infrastructure well as transport management. In these areas, more accurate and reliable positioning is required. In addition to a road infrastructure supporting automation (control points, road markings, data transfer beacons and base stations), multisensor fusion and digital map descriptions, SLAM (Simultaneous Localization And Mapping) solutions based on artificial intelligence will probably also be used. Together with RTK-GNSS positioning, these will probably form the basis for the positioning solution for autonomous driving and other demanding road traffic applications in the future.

**In the future**

There will be more use of automation in road traffic as systems supporting drivers are becoming more widely available. Many of them, such as the lane keeping assist and parking assist are based on the use of accurate vehicle location data. Vehicles are in contact with each other and the surrounding infrastructure, creating a networked, interactive and real-time intelligent transport system (C-ITS), in which the accurate location is a basic requirement for a safe and reliable system. The first 13 networked mobility services with EU-wide interoperability will be introduced in 2019. They will have a particularly positive impact on road safety and most of them will function with the existing GPS positioning accuracy. The next seven services will help to improve vehicle navigation in urban areas and in them the positioning accuracy requirements are higher than in the first 13 services. However, in most of them, too, GPS positioning accuracy is adequate.

Even though the services still rely on GPS positioning accuracy, Galileo and EGNOS services are becoming increasingly important in the future. In fact, in its proposal on amending the directive on electronic road toll systems, the European Commission proposes that in the future, vehicle equipment relying on satellite positioning should be compatible with Galileo and EGNOS systems.

Networked and increasingly automated driving will gradually become a single system and it is estimated that by the year 2030, vehicle capabilities and the transport environment are ready for automated transport on roads and in cities. In that situation, tracking is in real time, satellite positioning accuracy requirement is less than 10 cm and the data transfer capacity must be significantly higher than today. Satellite positioning must be accompanied by a signal correction service and solutions that ensure privacy protection and data protection. Transport infrastructure must be digitised and accurate digital maps required in autonomous driving must be available. Satellite navigation must also function indoors and in tunnels, which requires solutions for indoor positioning. It is also predicted that all new vehicles will be part of the internet of things by the year 2025. Mobility is become increasingly servitized. Many of the new services function in real time and serve the users from door to door. This means that it must be possible to track the user and the vehicle in different parts of the travel chain so that a seamless service chain can be ensured.

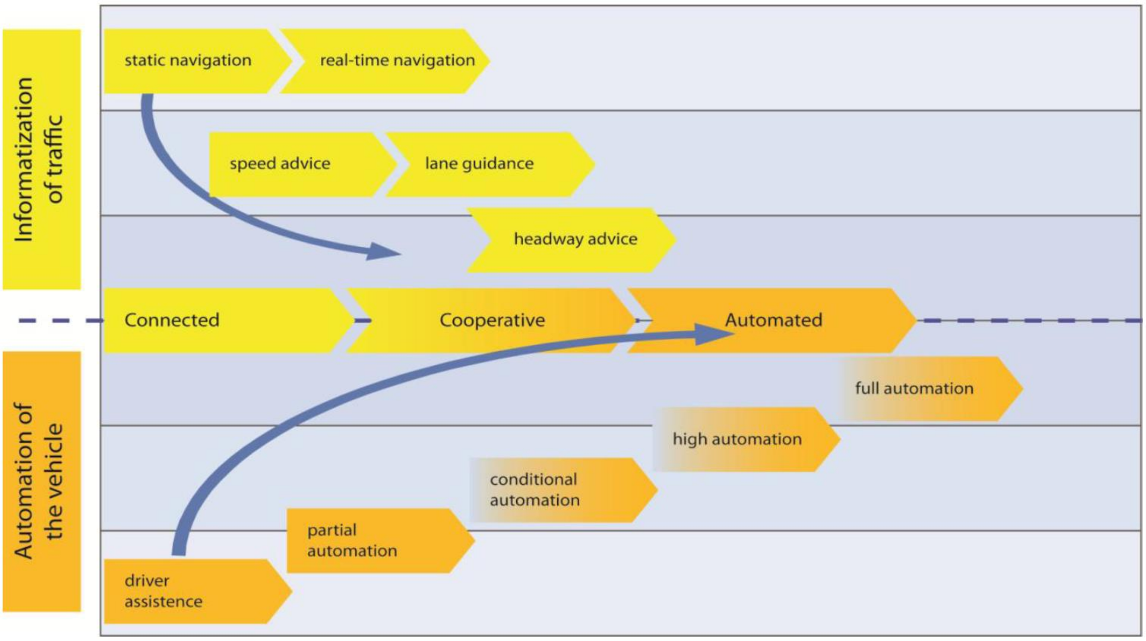


**Figure 11: Development of automation in road traffic**

Before automated driving can become more common, privacy issues, data protection issues and system security issues associated with it must be solved. The European Commission is examining possible solutions as part of the C-ITS project and it will present its proposal for technical solutions and possible special legislation at the end of 2017.

## 4.4 Utilisation in rail traffic

### Current status

Satellite positioning is used for producing train travel location data. These days the majority of trains are equipped with GPS tracking device that transmit location data using GPRS radio technology to timetable systems from where the data the data can be accessed by officials and the public in various ways. In Finland, VR has introduced the Junat kartalla (trains on the map) service and an interface service providing real-time location data.  The Junat kartalla service, which was launched in 2011 and updated in 2017, relies on GPS positioning and real-time location data supplied by the Finnish Transport Agency.

In 2019, the Finnish Transport Agency will publish train GPS location data as open data, offering them for use to service providers.  This location data, enhanced through satellite positioning, will also be available to passenger information systems and mobile applications  GPS positioning is used in track inspection services and the updating of the key characteristics of rail infrastructure maintenance.

### The future and the European Rail Traffic Management System ERTMS

The European Rail Traffic Management System (ERTMS) and the European Train Control System (ETCS) are technological solutions that the EU has adopted in an effort to make the use rail traffic and infrastructure more efficient. Over the past few years, both the European Union Agency for Railways (ERA) and the European GNSS Agency (GSA) have drawn attention to the potential of satellite positioning and automation in train control systems.

Three levels of train control are under development: The most advanced of the levels is ERTMS level 3, which is based on satellite navigation. ERA has launched negotiations with rail operators interested in ERTMS level 3 on how satellite positioning in train control could be promoted through cooperation in rail traffic. It has been estimated that the track and rolling stock investments required for ERTMS level 3 would ultimately be less costly than the investments required for level 1. Achieving cost savings would require entirely new technological solutions that have not yet been productised or commercialised.

Tests with Europe's first satellite-based train control system began in February 2017. In the project, suitability of satellite technology to train control is tested on the Italian island of Sardinia. In summer 2017, Finland prepared a national implementation plan for at least 15 years for equipping its rail network with the updated national train control system by the year 2038. The currently used technology is largely similar to ERTMS level 1. The aim should be to move directly to ERTMS level 3 so that intermediate level investments could be avoided and satellite navigation could be used.

## 4.4 Utilisation in maritime transport

### Current status

Traditionally, using satellites in maritime transport has mainly involved the utilisation of positioning satellites in vessel navigation and the positioning of emergency messages sent by ships. An automatic positioning device is obligatory on vessels used in maritime traffic coming under the regulation of the International Maritime Organization (IMO). Especially in open sea, the location of ships and navigation is practically always on the basis of the location and time data provided by positioning satellites. To facilitate the monitoring of individual vessels and the overall traffic situation, the positioning data determined by the ships is also relayed to control centres. This is particularly important in emergencies and when the vessel is in need of other assistance. The systems used for relaying positioning data include the Automatic Identification System (AIS) and the Global Maritime Distress and Safety System (GMDSS).

In addition to maritime radio and data transfer systems, there are also other telecommunications systems and services to support positioning and to relay location data. These include mobile phone networks and wireless local area networks near the coast and telephone and network systems based on telecommunications satellites in open sea. Satellite positioning is also extensively used outside the maritime traffic regulated by IMO (fishing vessels and pleasure boats) and the positioning receivers have developed into multi-purpose navigation and data processing systems based on electronic nautical charts and data communications connections. Fishing boats operating in EU waters must observe reporting obligations under which they must give their accurate position electronically. This means that in practice these vessels must be equipped with satellite navigation receivers.

According to a questionnaire for pleasure boaters conducted by Taloustutkimus in 2012, nearly all active boaters use printed nautical charts for navigation, while 80 per cent of them also use map plotters or navigation software as an information source supporting printed charts. About one half of all respondents did not update their nautical charts but instead used the free-of-charge ‘Notices to Mariners’ service of the Finnish Transport Agency providing information on changes in nautical charts and fairways.

Assist systems improving the accuracy and reliability of the positioning data are also often used to support satellite positioning systems. Assist systems send data supplementing GNSS systems through a separate data transfer channel. EGNOS and the differential GPS systems, both of which are satellite-based, are the most commonly used assist systems in maritime traffic. The positioning and navigation data produced with satellite navigation is verified on the vessels with radar data and data produced by other shipborne sensors and with the help of the traditional visual navigation.

All navigation devices used by vessels in professional maritime traffic must be approved by IMO. IMO has recently approved functional requirements for Multi-System Shipborne Radionavigation Receiver. As the name suggests, the device can use several different navigation systems based on different principles in different combinations. With the device, it is possible to use several different GNSS systems or their assist systems simultaneously without the need to determine separate functional IMO requirements for each combination of navigation systems. The hope is that this will facilitate the introduction of new systems (such as Galileo and EGNOS) speeding up joint use of different systems and, consequently, improve the reliability and quality of navigation data.

**In the future**

Increasing automation of maritime traffic and the introduction of autonomous and remote-controlled vessels mean that in the future, data transfer systems must be highly readable. Data transfer systems relay location, condition and route data of remote-controlled vessels and vessels making extensive use of automation, and they also rely signals required for the control and steering of the vessels from land stations to ships. The reliability, adequacy and coverage of the data transfer systems of remote-controlled vessels as well as cyber security will play a key role in the management of maritime traffic risks in the future.

Vessels and ports will become increasingly automated. In the future, vessel and port devices will become networked as part of the general IOT trend, which will require additional capacity in maritime traffic data network and satellite systems. Increasing vessel automation will help to prevent and reduce dangerous situations arising from human activity, to comprehensively monitor vessel functions and to optimise routes so that emissions and fuel consumption can be reduced. Ships can also be supplied with more electronic information assisting navigation. For example, with the existing technology, it would already be possible to produce phase observation corrections, which allow real-time calculation of 3D location data using shipborne receivers at an accuracy of up to a few decimetres. This would support satellite navigation systems and make it possible to determine accurate vessel location vertically. At the same time, accurate vessel 3D location data, combined with exact details of the fairway depth profile would allow real-time examination of the vessel's draught, maximisation of cargo and the use of deep fairways so that fuel consumption can be reduced. However, providing vessels with a reliable, continuous and standardised data transfer connection that has adequate capacity and coverage is the main challenge in this field and the area where more development work is required.

Finland has strong expertise and experience in maritime industries and the ICT sector, which will provide us with a solid basis for being one of the first countries introducing automated maritime traffic and autonomous and remote-controlled vessels. In autumn 2016, an ecosystem project for autonomous maritime traffic was launched in Finland. The goal in the Tekes-lead project is to create the world’s first autonomous shipping products and services as well as a viable ecosystem by 2025. Leading companies in the sector, such as Rolls Royce, Wärtsilä and ABB as well as a number of innovative ICT companies are the parties to the ecosystem. The project is being coordinated by DIMECC Oy. As part of the ecosystem, a test area for automated shipping and autonomous and remote-controlled vessels is in the process of being established in Finland.

## 4.4 Utilisation in aviation

### Current status

The International Civil Aviation Organization (ICAO) has prepared a performance-based navigation concept the aim of which is to achieve globally harmonised navigation methods in which satellite positioning systems play a central role. In order to encourage the introduction of these methods, the European Aviation Safety Agency (EASA) has drawn up regulations and guidelines supporting the activities. The European Commission is in the process of drafting an implementing regulation under which operators must introduce PBN methods intended for flight phases in the coming years. Finland has already met most of these requirements.

Finland has been one of the European pioneers in the introduction of aviation satellite navigation. Flying methods allowing GPS-based navigation are already in use at all Finnish airports and most of the instrument flights in Finland are flown with aircraft equipped with GPS receivers. These methods have provided a basis for free routing of aircraft and environmentally friendly continuous ascent and descent approaches.

All Finnish airports can be approached using a GPS-based system. However, the runway-specific ground equipment system (ILS) is used for most landings as it is more accurate than GPS-based systems. Receivers using a satellite-based augmentation system (SBAS) allow European-wide access to positioning data verified using the EGNOS system. Joensuu Airport is the only Finnish airport with EGNOS capability. The Finnish Border Guard used EGNOS-based navigation in its aviation activities.

Today, air traffic control uses the information provided by secondary radars to locate aircraft and the radar service also serves as a support and backup system for satellite-based navigation. Emergency transmitters sending location data to the rescue coordination centre via satellites are used in search and rescue operations

### In the future

Additional benefits can be achieved by making use of the capabilities of the EGNOS system. By using the system in certified aircraft, aerodromes and heliports can be made more accessible in poor weather conditions and flight routes can be optimised with regard to noise and the environment. In some cases, the system can also make investments in ground equipment unnecessary. However, in practice this would require a higher-performance EGNOS system in the Finnish territory and aircraft with a significantly more comprehensive capacity to use the system. At the moment, only a small percentage of all commercial aircraft have

EGNOS capability and the EGNOS service level LPV200, which corresponds to the currently used landing ground equipment, is not yet available in all parts of Finland.

In the near future, before the introduction of the LPV200 approach flight method, Finnish airports will introduce APV SBAS approach flight methods, which already provide a basis for satellite-based approaches in Finland within the framework of the EGNOS system. APV SBAS methods allow sufficiently low approach minimums, which means that there will gradually also be more demand for the methods in heavier aircraft and they will become accessible to general aviation.

The accuracy of satellite positioning permitted by the SBAS system can be further improved with the airport-specific ground-based augmentation system (GBAS). It will allow higher accuracy and smaller operating minimums for all runways at an airport, using a single system. The technology is, however, still at a development stage. The introduction and benefits of the Galileo system will be based on the use of dual-frequency and multi-constellation receivers. The standards for them are being drafted and the introduction will probably start between 2020 and 2025.

In the future, air traffic control radars can be replaced with such tools as satellite navigation systems based on time data, which use the positioning data sent by the aircraft. Accurate time data is critical to the functioning of the systems.

Unmanned aviation will increase and drones will be used more extensively for commercial purposes in the coming years, which will open up new opportunities in the sector. Satellite positioning is essential when unmanned aircraft are flown without maintaining visual contact to them.

## 4.8 Utilisation in official activities

An encrypted PRS service that is solely intended for authorised users will provide selected authorities with more certainty in the use of time and location signals and for producing reliable data on the prevailing conditions. It will be more difficult for criminals to interfere with the positioning capacity of the police or customs officials during criminal investigations and emergency assignments. Weapons systems and other time-based and location-based functions of the defence forces will become less sensitive to intentional interference.

In the future, rescue and security authorities will increasingly rely on mobile units and movable units that are either autonomous or remotely controlled and that contain monitoring and detection sensors. Accurate real-time location data is critical to this operational capability. In connection with observations and investigations, accurate and verifiable location and time data is critical with regard to the verification of observation and monitoring information. Autonomous operations would be impossible without accurate and reliable positioning.

The needs of the security and rescue authorities (police, border guard, rescue services, emergency response centres) mainly concern regionally comprehensive and reliable positioning of terminal equipment and, consequently, personnel and units, indoors and outdoors. Accurate positioning requires correct, up-to-date and easily available geographical data. For example, as drones are becoming more common, stricter requirements will be set for positioning accuracy.

The positioning time stamp is also essential, particularly with regard to the analyses carried out afterwards. Uninterrupted availability, resilience and reliability of the services are critical to the security and rescue authorities.

## 4.9 Utilisation in agriculture and land surveying

### 4.9.1 Agriculture

The aim in the use of satellite positioning in agriculture is to optimise the use of arable land.  Ordinary agricultural work performed using tractors always involves overlaps because the farmer wants to ensure that there are no unkept sections that may be hit by diseases. Overlaps account for about ten per cent all work on arable land. Simply by minimising overlapping work, farmers can minimise fuel consumption, environmental impacts and field compaction.

Combining existing and new data is key to achieving improvements.  Satellite images produce information about such matters as biomass, while drones can provide detailed maps of arable land. By using combined data, farmers can make decisions on such matters as the need for fertilisation, which in turn will have an impact on costs and environmental loading, and check that agricultural subsidies are correctly used.

In Finland, agricultural parcels are small and the GPS guides available for assisting agricultural work and their repair services are expensive.

### 4.9.2 Land surveying

The National Land Survey of Finland (NLS) has used satellite positioning since the mid-1980s. The FinnRef positioning service of permanent GNSS stations forms the basis of Finland’s national grid coordinate system. FinnRef is in the process of being expanded.

In practice, all measurements required for land surveys are made as network real time kinematic (RTK) measurements, except for a small number of measurements in difficult terrain. NLS has also started using satellite measurements in the updating of the topographic database in recent years and changes in the terrain are collected directly to the terrain computer using a GNSS device and a distance measuring instrument.

The introduction of more advanced measuring software and technologies as well as improvements in satellite positioning systems have provided a basis for the use of RTK measurements. The new and more frequent signals of the positioning satellites facilitate measurements in difficult terrain (tree cover). RTK measurements have led to significant efficiency improvements in terrain work carried out as part of land surveying. The introduction of Galileo will lead to an increase in the number of positioning satellites (GPS, Galileo, GLONASS, Beidou) and they will provide adequate measuring capacity for nearly all conditions. This will also mean more effective measurements as part of land surveying.

NLS is developing the FinnRef positioning service by increasing the number of base stations between 2017 and 2019. A denser network will help in the maintenance of coordinate and elevation systems. The FinnRef positioning service is also used in many areas of research. NLS also offers a universally available FinnRef positioning service free of charge at an accuracy of 0.5 metres. As the FinnRef network is made denser, the positioning service is also undergoing improvements and NLS will start using the service in its own operations in 2019.

The FinnRef positioning service also produces added value for the users of GNSS systems. It is used for continuous monitoring of the impacts of land uplift and the movements of tectonic plates on the Finnish coordinate system. The FinnRef positioning service is part of the European-wide GNSS network used for maintaining the European coordinate system, the use of which is obligatory under the INSPIRE directive of the EU. Especially the measurements carried out at the Metsähovi research station of NLS Geospatial Research Institute are used in the maintenance of the global coordinate system, calculation of the orbits of GNSS satellites and the determining of the Earth's position. Without these measurements, the GNSS system could not function in its current form.

## 4.10 Use in location-based software and content services

Nowadays, smartphones, tablets, smartwatches and auto navigators are widely used for navigation and positioning. There are countless mass-market smartphone applications using satellite positioning. The applications involve different types of navigation, social media, sports and entertainment (geocaching, PokemonGo, etc.) Virtual reality services with game industry and professional applications are becoming increasingly popular and they require accurate location data for smooth functioning.

There are also many applications for official and business use, which can boost logistics efficiency and ensure that help will arrive quickly to accident sites. In addition to power consumption, such qualities as availability, speed and reliability of the positioning features are important for these services in smart devices.

Usability of smartphones can be improved by utilising more than one satellite constellation. According to the GNSS market report published in 2017[10], a growing proportion of the more expensive smartphones are supported by more than one constellation (such as GPS+GLONASS). The first smartphone with integrated Galileo capability was introduced in 2016. Providing smartphones with an option for more than one constellation may also lead to a situation where they can replace low-priced receivers and applications intended for professional use.

Many smartphones use assisted positioning (A-GNSS), which speeds up access to the satellite positioning solution (TTF-Time to First Fix). In this method, satellite positioning is assisted by providing the smartphone with such data as the satellite orbit information using a ground-based telecommunications network. Positioning can be speeded up as it is not necessary to get this slow-moving data from satellites (full downloading of the GPS calendar and orbit information takes 12.5 minutes). Alternatively, the mobile device may send its own data to the base station, which determines the location and returns it to the mobile device. In both cases, the location solution can be made in slightly poorer conditions that if only satellite data was used. The speed of the determining of location data is also affected by the terrain. In urban areas, such factors as blind spots between high-rise buildings may cause delays in the determining of the location data.

In addition to A-GNSS, other device sensors and networks, such as wireless local area networks (WLAN) can also be used in indoor spaces. WLAN positioning can be used for locating patients in hospitals, tracking shopping carts in shops and for guidance in museums and airports if these areas have a WLAN network.

## 4.11 Utilisation in time synchronisation

Measurement standard institutes and chronology laboratories produce the coordinated universal time (UTC(k)) for the use of society. The official time observed in different countries is usually based on the UTC time produced by

[10] European Global Navigation Satellite System Agency, ‘GNSS Market Report, Issue 5 (2017), https://www.gsa.europa.eu/2017-gnss-market-report

national measurement standard institutes and Finland, this is the responsibility of VTT Technical Research Centre of Finland Ltd (hereafter VTT). In fact, it makes sense to use coordinated universal time as the source of system synchronisation as UTC is maintained by 72 national measurement standard institutes and chronology laboratories.

Satellite navigation systems can produce time data for a large number of different purposes at low cost. However, this time does not, as such, meet the metrological or statutory traceability requirements. Likewise, the risks concerning the reliability and uninterrupted availability of the service often prevent the direct use of time obtained from satellite systems and telecommunications networks for critical applications. It should be particularly noted that the Galileo System Time is a combination of several UTC implementations and it does not as such meet the metrological or statutory requirements concerning UTC traceability. In the United States, the GPS system is considered to meet the traceability requirements but there is no clear interpretation at European level. This is because the US Naval Observatory is not a metrology institute and it is not a party to the mutual recognition agreement. In both cases, the traceability requirements can be met by means of a monitoring receiver or a network or receivers. The time produced by them is compared with an UTC implementation and the measured time difference is relayed to the user.

The need for the precision, availability and reliability of timing depends on what it is being used for. The simplest need is for non-critical synchronization of clocks, which can be carried out by means of the Network Time Protocol (NTP). A substantially more accurate time synchronisation (for which the time obtained from satellite navigation systems is typically not adequate) is needed for the synchronisation of telecommunications and power network measurements and control, time stamp services, electronic commerce, digital television and radio broadcasts, and passive radar systems. In addition to an accuracy of a few microseconds, these applications often also require traceability and verifiability. In order to achieve sufficient reliability, multisystem and dual-frequency reception, T-RAIM (Time Receiver Autonomous Integrity Monitoring) function, integrity monitoring and possibly also parallel time synchronisation are required in critical applications (see 2.3.2 Interference and jamming). The highest level of accuracy is required in research applications where the aim is to achieve an accuracy of a few nanoseconds.

Accurate time synchronisation methods will become increasingly important in the future:

- 5G data communications networks of the future will make more effective use of frequencies. 5G networks will use interference removal methods, denser base station networks and multi-antenna technology and they all require accurate synchronisation methods.

• The management of the next-generation substations will be based on the digital transfer of measuring and protection data. This will set new demands for the reliability of timestamps. The time obtained through satellite systems is not sufficiently reliable for critical applications, which require parallel synchronisation methods.

• In passive radar systems used in aviation, the aircraft is located by time-stamping the time when its signal is received by the positioning network receivers. In this case, network synchronisation will have a direct effect on the accuracy of positioning. The application is critical and requires reliable synchronisation methods.

• The European Securities and Markets Authority (ESMA) has issued 28 technical standards, which are implemented by means of the markets in financial instruments directive. Standard RTS-25 requires the traceable timestamping of events.

Time synchronisation is critical for the security of supply in energy generation, transfer and distribution systems, data and communications systems, networks and services, financial services, transport and logistics, water supply, infrastructure construction and maintenance, food supply, healthcare and industries.

# 5. Actions

**1. Determining the need and possibilities for establishing a space administration in Finland** The assessment will be carried out by the Ministry of Transport and Communications in cooperation with the Ministry of Economic Affairs and Employment and other central actors.

**2.** Influencing the EU at all levels so they take steps to resolve the EGNOS coverage problem in Finland and to get the same Galileo and EGNOS services in Finland as are already available in Central Europe. Engaging in cooperation with Member States who have the same coverage problems. These include in particular Norway and Sweden, as well as Romania, Cyprus, Italy, Spain and Portugal as well as possibly the Baltic countries. Finding a resolution to the EGNOS coverage problem will be included in Finland's programme for its EU Presidency in 2019. The Ministry of Transport and Communications, the NLS's Finnish Geospatial Research Institute and Trafi are responsible for these measures.

**3. Updating the national aviation navigation strategy**

Updating the navigation and recording device strategy published by Trafi in 2012. Satellite navigation is seen in this strategy as a key facilitator of development. As performance based navigation is introduced more extensively, satellite navigation will become even common than previously. Some of the traditional radio navigation equipment can be gradually withdrawn from service and radars can be replaced with new systems. The Ministry of Transport and Communications and Trafi are responsible for these measures.

**4. Railways**

1) Draw up a report on the possible deployment of ERTMS level 3. The report will assess the transition from existing automatic train protection (ATP) directly to ERTMS level 3, which utilises satellite navigation. The objective of the report will be to assess the pros and cons, and the costs of transitioning to ERTMS level 3 as well as the timetable for the transition's implementation. The pros and cons must be compared specifically to ERTMS level 1 and the pros and cons of Finland's current system. The Finnish Transport Agency and Trafi are responsible for these measures.

2) Drawing up a report on the possibilities of using satellite positioning to prevent level crossing accidents. The Finnish Transport Agency and Trafi are responsible for these measures.

**5. Promoting satellite navigation in the Arctic Council**

1) Examine the **challenges facing Arctic navigation**, including those facing satellite navigation (coverage problems in the north and north-east) and solutions to them. The results will be utilised in international and EU-level work to influence decision-makers. The Ministry of Transport and Communications, the Finnish Transport Agency and the NLS's Finnish Geospatial Research Institute are responsible for these measures.

2) Promote parallel use of different satellite navigation systems (GPS, Galileo, GLONASS and BeiDou) in terminal equipment, applications and services. Device manufacturers and the sector's market are responsible for these measures.

3) Test the potential of satellite navigation and the national FinnRef positioning service as well the functioning of the physical and digital road infrastructure solutions in automated transport in Arctic regions. The Finnish Transport Agency, Trafi and the NLS's Finnish Geospatial Research Institute are responsible for these measures.

4) Create a pilot project to examine the potential uses of the Galileo signal in the monitoring of the ionospheric weather in the aurora borealis region, which will facilitate the relaying of information on prevailing conditions to Arctic shipping using a long-range HF (high frequency) link. The Finnish Meteorological Institute and the Ministry of Transport and Communications are responsible for these measures.

**6.** Prepare a Government resolution on the national implementation of the PRS service of the Galileo satellite navigation system in Finland. The Ministry of Transport and Communications and Ficora are responsible for these measures.

**7.** Draw up a real-time image of Finland with GNSS signals of varying quality and coverage. The implementation, actors and timetable all depend on the securing of the ESA's funding.

**8.** Examine how assist data enabling accurate vertical GNSS positioning can be relayed to ships in Finnish waters and the Baltic area reliably and without interruption. The Finnish Transport Agency is responsible for the measures. The NLS's Finnish Geospatial Research Institute supports the activities.

**9.** Influence the development of the next generation Galileo programme taking into account the objectives Finland has set for satellite navigation. The Ministry of Transport and Communications, the NLS's Finnish Geospatial Research Institute and the Ministry of Defence/Defence Command are responsible for these measures.

**10.** Examine how satellite navigation competence and expertise can be guaranteed in the future. The Ministry of Transport and Communications, the Ministry of Education and Culture and the Finnish National Agency for Education are responsible for these measures.

**11.** Examine how satellite navigation is utilised in the traffic management of various modes of transport as well as in automation using Trafi's traffic lab and draw up a plan for making information available for added-value services. Trafi and the Finnish Transport Agency are responsible for these measures.

**12.** The promotion of GNSS awareness

1) Promoting awareness of the possibilities provided by the Galileo and EGNOS systems The Ministry of Transport and Communications, the Finnish Communications Regulatory Authority and the NLS's Finnish Geospatial Research Institute are responsible for these measures.

2) Promoting the spread of multisystem and multifrequency receivers This will improve the accuracy, reliability and continuity of positioning. Device manufacturers and the sector's market are responsible for these measures.

3) Making an effort to get the GNSS Agency to organise a Galileo Hackathon in Finland. The Ministry of Transport and Communications and Ficora are responsible for these measures. The NLS's Finnish Geospatial Research Institute supports the activities.

**13.** Time synchronisation

1) The Ministry of Transport and Communications and the Ministry of Economic Affairs and Employment are making an effort to influence the GNSS Agency's and the ESA's activities, which can be used to develop the Galileo system so that the time it transmits can be utilised globally in services that legally require traceability to UTC. Traceability is needed for example by actors within the scope of the financial instrument market as well as other time stamp producers. The Ministry of Transport and Communications and the Ministry of Economic Affairs and Employment are responsible for these measures.

2) Developing new solutions for the utilisation of time transmitted by satellite systems specifically Galileo, in Finnish services that legally require traceability to UTC. Supplement the functionality of the FinnRef positioning service so it covers the transmission of the national UTC in Finland. VTT Technical Research Centre of Finland Ltd is responsible for these measures. The NLS's Finnish Geospatial Research Institute supports the activities.

**14**. Draw up a pilot project on the shared use of advanced time transfer protocols for satellite navigation systems and telecommunications networks in time synchronisations projects critical to society, such as information and communications systems, power networks and aviation. VTT Technical Research Centre of Finland Ltd is responsible for these measures.

**15.** Determine how to utilise NLS's FinnRef positioning service network. Determining the conditions needed for establishing a FinnRef location correcting service based on FinnRef positioning service network data and made open for everyone free of charge and in this way create favourable conditions for new business ideas. Additionally, it will also be determined what measures will be needed to make the service suitable for full capacity use also by safety and rescue authorities. The Ministry of Agriculture and Forestry, NLS's Finnish Geospatial Research Institute, the Ministry of Defence, the Ministry of the Interior and the Ministry of Transport and Communications are responsible for these measures.

**16.** Developing national expertise in the detection and tolerance of interference and jamming. Promoting cyber-security related to international positioning satellites. The Ministry of Transport and Communications and Ficora are responsible for these measures.

**17.** Supporting the development of new space sector business and the utilisation of small satellite activities by for example drawing up a New Space roadmap. The Ministry of Economic Affairs and Employment, the Ministry of Transport and Communications and Tekes are responsible for these measures.

## Abbreviations

AGNSS, Assisted GNSS positioning (based on numerous satellite navigation systems)
AIS, Automatic Identification System, system for the identification of maritime vessels and the transfer of their location data
Beidou, China's satellite positioning system (also called Compass)
COSPAS-SARSAT, SAR Satellite, global rescue system (COSPAS is from the Russian name)
CS, Galileo Commercial Service, Galileo's commercial positioning service
DGPS, Differential GPS
EGNOS, European Geostationary Navigation Overlay Service, Europe's Satellite Based Augmentation System (SBAS)
FOC, Full Operational Capability, the Galileo system's utilisation phase
Galileo, a satellite navigation system that Europe is currently developing
GBAS, Ground Based Augmentation System
GLONASS, Global Navigation Satellite System, Russia's global positioning system
GNSS, Global Navigation Satellite System
GPS, Global Positioning System, the United States' global positioning system
GSA, European GNSS Agency
IRNSS, Indian Regional Navigational Satellite System, satellite navigation system that India is currently developing
LBS, Location-based services
NMA, Navigation Message Authentication
OS, Galileo Open Service, open positioning service
PNT, position, navigation, time
PPS, Precise Positioning Service, GPS positioning service for military use
PRS, Public Regulated Signal, Galileo's signal reserved for use by authorities
The Galileo system's public regulated time and positioning service
QZSS, Quasi-Zenith Satellite System, a satellite navigation system that Japan is currently developing
RNSS, Radio Navigation Satellite System (same as GNSS)
RTK-GPS, Real-Time Kinematic GPS
SAR, Search and Rescue Service (special emergency message transmitter service in Galileo)
P BAS, Satellite Based Augmentation, System
SoL, Safety of Life service in EGNOS
VOR, Very high frequency Omni-directional radio Range