

Business in satellite navigation



*An overview of market developments
and emerging applications*





Executive summary 1

Introduction

Satellite navigation technology is increasingly used in almost all sectors of activities. Its high-performance standards already make it an essential tool for very demanding professional, commercial and scientific applications. It is now becoming part of a more general concept – that of “infomobility”- where users receive information tailored to their needs, and pertaining to their precise location.

Converging factors have favoured this remarkable expansion. The proliferation of communication networks and geographic information systems, together with the overall decrease of cost, size and power consumption of satellite navigation receivers have driven the market towards high-volume consumer applications. The public sector also plays a major role by constantly improving satellite navigation systems and setting up a regulatory framework, which maximises the use of satellite navigation services to increase safety and efficiency of all types of transport modes.

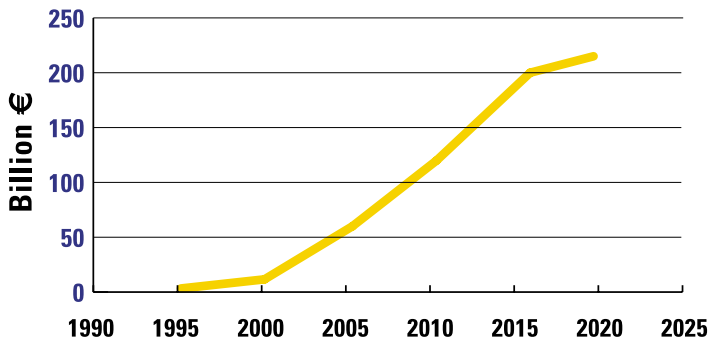
This paper examines how Global Navigation Satellite Systems (GNSS) technology has evolved over the past years and allowed for

expansion into a wide range of sectors. It provides existing market examples as well as a sample of commercial products that have emerged recently. It analyses the factors that are driving the emergence of hundreds of applications in various domains such as aviation, maritime, communications, leisure, timing, science, agriculture. It makes an assessment of the economic importance of all activities generated by this technology, either at the level of manufacturers for the production of receivers, or at the level of system integrators for the development of novel applications and value-added services. The main outcome of this analysis is that the market is on the brink of an even wider expansion of applications, representing a huge economic gain in terms of industrial products and services provision, as shown in Figure 1.

In this context, the European contributions to satellite navigation infrastructures, known as EGNOS and GALILEO, are fundamental: they will trigger the expansion of the market by providing decisive positioning performance improvements and will secure safety applications and financial investments by granting services guarantees and clarity regarding liability.

Market evolution: total annual global turnover for satellite navigation

1





Current market situation

The **annual global market growth rate** for satellite navigation products and services has been quite substantial over the past four years, with an **average annual increase of 25%**. In the difficult economic situation of the recent years, very few other markets have shown such a positive trend.

The overall industrial chain for navigation and services is rapidly evolving, moving from stand-alone navigation products to services provision based on a combination of navigation and communication/information technologies.

The average position determination for civil applications has reached levels better than 10 m. As satellite navigation applications expand, companies are demonstrating their capacity to develop new products, to improve their competitiveness through their extensive know-how and eventually increase the market further.

Main market drivers

Ingenuity of manufacturers, service providers and research institutes has allowed for the development of new techniques that further increase system capabilities and open the door to even more applications. Differential satellite navigation techniques, based on code measurements, lead now to metric positioning accuracies, whilst phase measurement techniques reach centimetre or even millimetre accuracy.

European navigation initiatives will further contribute to the rapid evolution of the market, as they will significantly improve performances, initially in 2004 with EGNOS and in 2008 with GALILEO. Particular characteristics of the latter, such as global integrity signals and service guarantees, will

strengthen user and service providers confidence, hence favouring the further development of safety-critical and mass-market commercial applications.

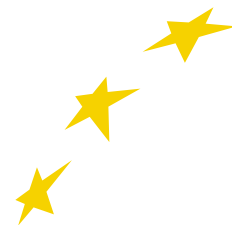
Technological progress (receiver miniaturisation and power consumption reduction), impact favourably upon satellite **navigation receivers** size and cost, with component **prices falling at a rate of 25-30% per year**. Handheld receivers are already being offered at less than €50.

These trends, linked with the constant improvement of other technologies such as Geographical Information Systems or mobile communications networks provide the necessary base to support the use of satellite navigation technology for high-volume consumer applications.

New emerging applications

New developments are expected, based on mass consumer markets for both hand-held and in-vehicle devices, that will accelerate market growth in the following years. Professional and highly demanding applications are increasingly dependent on satellite navigation technologies. Civil aviation is moving towards satellite navigation as a primary means for navigation and the maritime sector is increasingly reliant on GNSS and Differential GNSS for open-ocean as well as harbour and in-land navigation. In the rail domain, these techniques will facilitate train signalling and traffic management, allowing for increase of line capacity and efficiency.

The mass-market is also rapidly evolving, and is spurred by mobile phone development to achieve new types of services combining the users position with all types of data information. Regulation related with locating accurately the position of emergency calls made via wireless



communications (E911 in the U.S. and E112 in Europe) gives a further stimulus. The market is highly competitive and requires manufacturers and service providers to invest development efforts at a very early stage.

Road applications are also a huge GNSS market, with a wide range of applications ranging from "infotainment", through to road tolling and emergency applications. The **number of cars sold every year, 14 millions in the EU in 2000**, gives an idea of the potential size of this market.

Market forecast

Forecast for future global markets and applications for navigation show that this industry is at the beginning of a large expansion, with a **global turnover of €15 billion in 2001, which is predicted to rise to €140 billion by 2015.**

Initially characterised by a strong product-oriented dominance, it is expected that service provision will rapidly play an important role in the satellite navigation market.





1	Executive summary	3
2	Introduction	7
3	Global market forecast	8
4	Overview of the current market	11
5	Emerging GNSS applications	13
5.1	Location Based Services	13
5.2	Road applications	16
5.3	Aviation	17
5.4	Maritime	18
5.5	Rail	19
5.6	Oil and Gas	20
5.7	Precision Agriculture	21
5.8	Fisheries	21
5.9	Survey and marine engineering	21
5.10	Science	22
5.11	Electricity networks	22
5.12	Social	22
5.13	Customs, Justice and home affairs	23
5.14	Leisure	24
6	Assessment of market drivers	25
6.1	Identification of market drivers	25
6.2	Technological trends	26
6.2.1	Receivers technology	26
6.2.2	Geographic Information System	28
6.2.3	Synergies with mobile telecommunication	28
6.2.4	EGNOS and GALILEO differentiators and benefits	29
6.3	Regulation and policy	31
7	Conclusion	33

■	Figure 1: Market evolution: total annual global turnover for satellite navigation	3
■	Figure 2: Overall value-added chain for navigation products and services	7
■	Figure 3: Overall value-added chain	8
■	Figure 4: Annual net turnovers for satellite navigation products	9
■	Figure 5: Annual gross turnovers for satellite navigation products	9
■	Figure 6: Global net turnovers by application in 2001 and in 2015	10
■	Figure 7: Global annual satellite navigation product and services turnovers	10
■	Figure 8: Consolidated view of satellite navigation markets from 1994 to 2001	11
■	Figure 9: Global satellite navigation turnovers in 2001	12
■	Figure 10: Number of mobile phones in use	13
■	Figure 11: Wireless global location-based services turnover	14
■	Figure 12: Driving factors for satellite navigation development	25
■	Figure 13: Decrease in receivers voltage need	26
■	Figure 14: Power consumption reduction trend	26
■	Figure 15: Trend in cost reduction	27
■	Figure 16: Receivers average cost	27
■	Figure 17: Positioning accuracy through GPS	30
■	Figure 18: Positioning accuracy through GPS and EGNOS	30
■	Figure 19: Positioning accuracy through GPS, EGNOS and GALILEO	30



Introduction **2**

Ever since the launch of the first satellite navigation systems for military purposes (GPS in the United States and GLONASS in Russia), companies worldwide have been developing products and services to stimulate and serve a civilian market for positioning technology. From a baseline of professional equipment for surveying and civil engineering, continued innovation in technology has led to huge improvements in the price and performance of equipment. In tandem, entrepreneurs have continued to develop new applications and spawn new businesses to serve growing markets. Today, several thousand companies are already involved in satellite navigation device production and service provision, encompassing a large diversity of markets far outstripping anything that could have been envisaged even ten years ago.

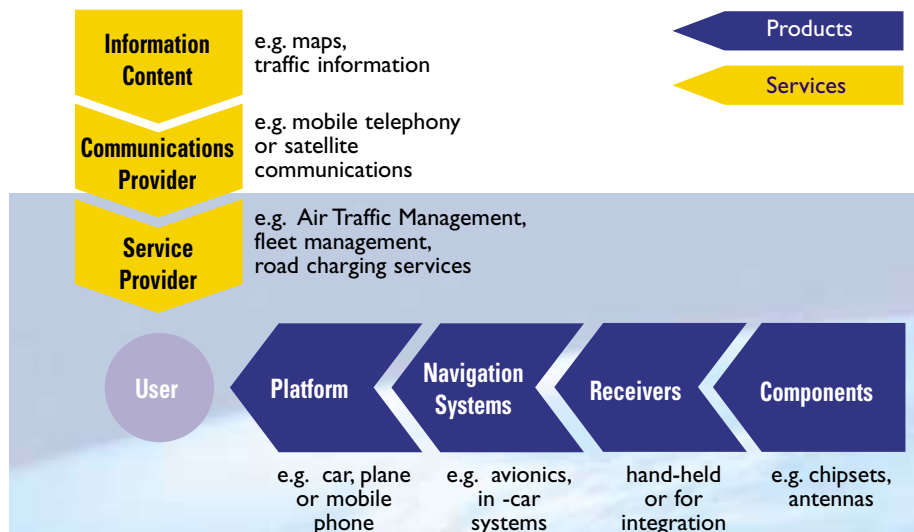
As the market grows in size, it also develops in structure. Starting from an industry that supplied stand-alone navigation

units, the situation has developed to combine both navigation and communication technologies as shown in Figure 2.

Satellite navigation receivers are now commonly integrated into other devices, including in-car navigation systems, fleet management systems, and increasingly also into mobile phones and Personal Digital Assistants (PDAs). The product business is complemented by a rapidly developing service industry that integrates digital mapping, bundled with mobile communications to deliver packaged services to end-users.

Overall value-added chain for navigation products and services

2





Global market forecast **3**

Input information and assumptions have been combined into a comprehensive model, based on the total potential addressable market for each separate application. Market take-up is then estimated and information on current pricing and future trends is used to produce a turnover model. In view of the diversity of the overall supply chain for navigation products and services described in Figure 2, forecasts are made regarding the specific segments of the market, notably:

- “Net turnover” the turnovers directly associated with positioning systems hardware,
- “Gross turnover” the turnovers associated with the entire navigation system in which the positioning system is placed.

The overall conservative predictions for global annual net product turnovers until 2020 are shown in Figure 4. This model indicates a global net turnover of €4 billion in 2001, surging to as much as €25 billion by 2020.

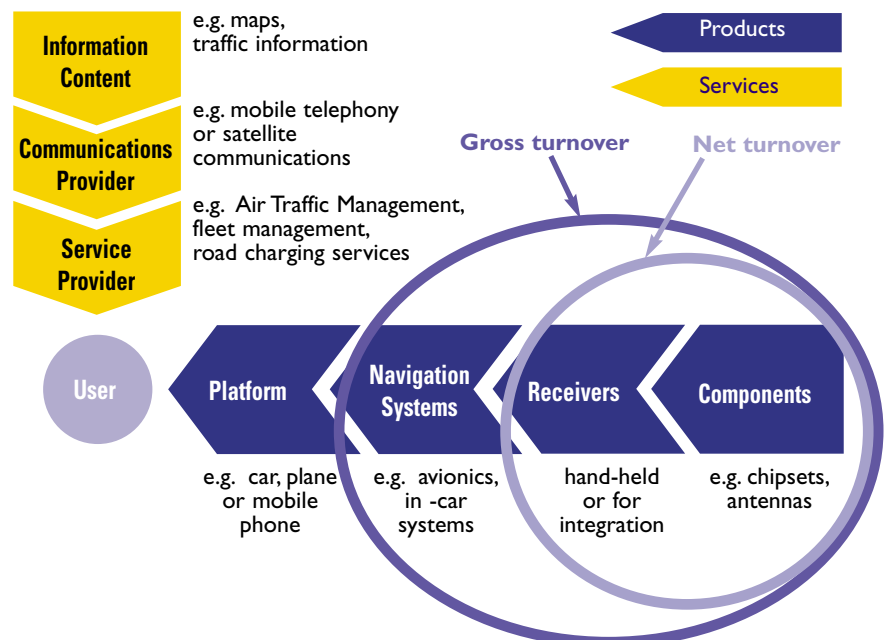
As depicted in Figure 5, the actual gross turnover figure in 2001 totalled €15 billion, with predictions leading to figures as high as €150 billion by 2020.

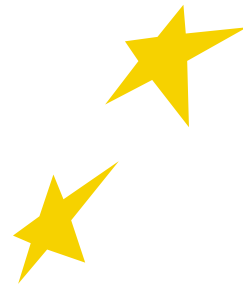
Those figures show that the market characteristics are under evolution: from an important percentage being taken by components and receivers market (basic building blocks) in 2001, it shift towards a more mature and integrated systems market in 2020 (applications turn-key solutions).

This is shown in Figure 3.

Overall value-added chain

3



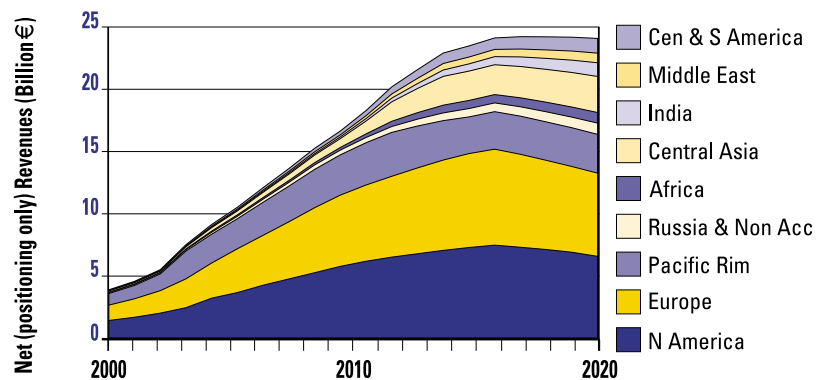


North America, Europe and the Pacific Rim are the dominant markets for the next five years. In fact, these three markets hold in total over 60% of the global market for the entire forecast period. However, after 2007, increased consumer spending in Central Asia and in Central and South America is expected to develop significant markets in these areas. The model incorporates assumptions about declining prices over

time, which are particularly noticeable in the electronics industry. For this reason, once developed markets become saturated and sales are driven by product replacement, declining prices result in reduced overall turnovers in these markets. In practice, entirely new applications and products that have not yet even been envisaged are expected to stimulate future market growth.

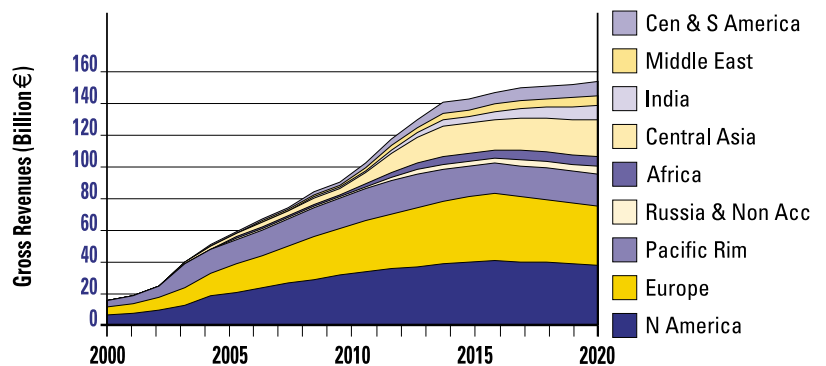
Annual net turnovers for satellite navigation products

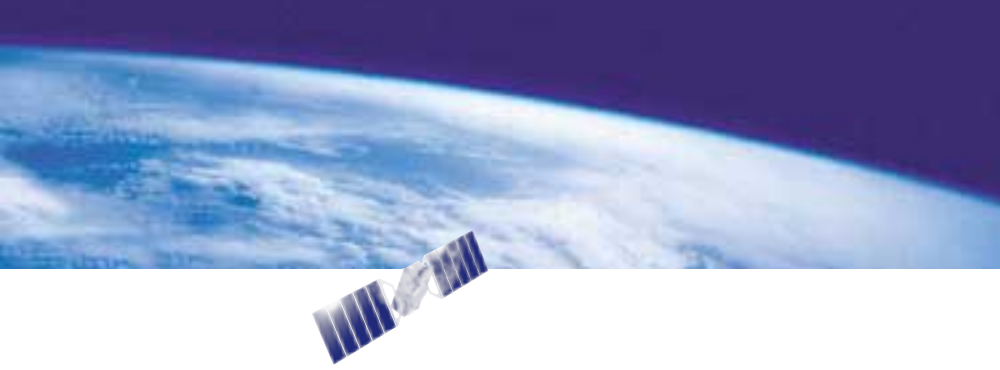
4



Annual gross turnovers for satellite navigation products

5





The breakdown on net turnovers by application is shown in Figure 6. The road telematics market is expected to dominate throughout the period. However there will be an important relative shift from commercial (and professional) to consumer markets, the latter being sustained by the mobile communication developments (advent of 3rd generation UMTS system, emergency services, etc.). Consumer markets account for around 40% of the total today, a figure that will rise to 75% by 2015.

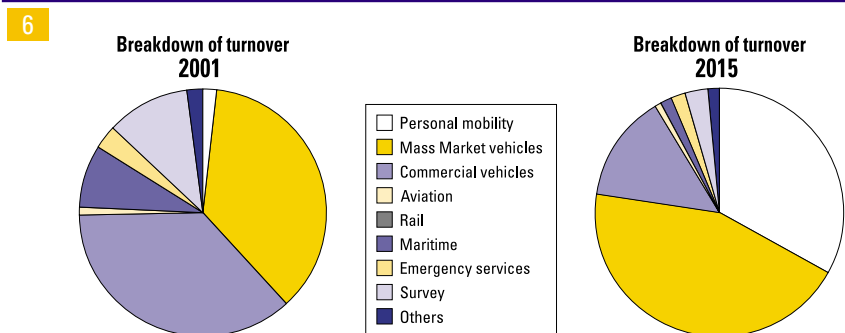
A further significant development expected over the period corresponds to the growth of turnovers associated with services. At present, the product market dominates turnovers, and service turnovers are mostly derived from the commercial fleet

management market. In the consumer automotive market, navigation products are still relatively expensive (in the order of thousands of euro) and the take up of value added services is still relatively low.

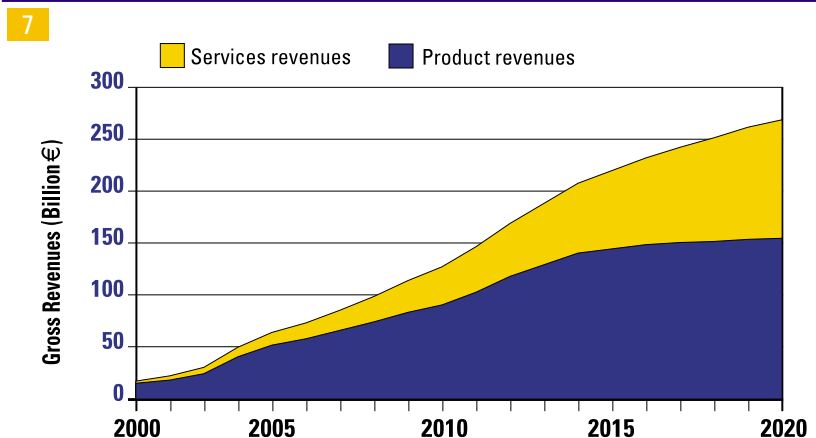
However, as the number of users increases in both mass-market car and hand-held segments, the potential for service turnovers also increases. Economies of scale for suppliers, maturing service offerings and network effects will all combine to increase the value of the service market. The trend is shown in Figure 7.

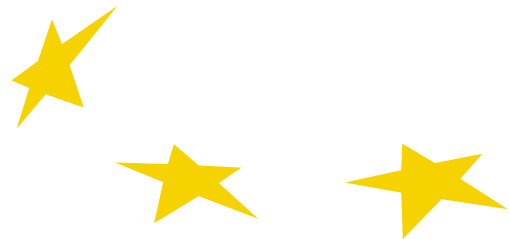
The current service turnovers of €2.3 billion represent 12% of the total market. By 2020, service turnovers will grow to €11.2 billion or 43% of the total market value.

Global net turnovers by application in 2001 and in 2015



Global annual satellite navigation product and services turnovers





Overview of the current market

4

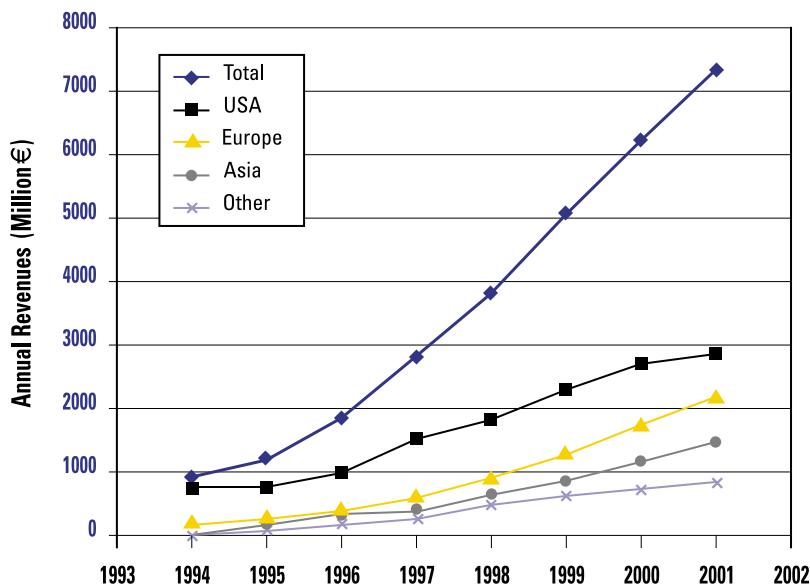
Based on a number of market analysis reports, and on reported sales statistics from leading companies, a consolidated view of the development of the Global Navigation Satellite System market over the past 8 years has been derived. This is shown in Figure 8.

The **global market annual compound growth rate** over the past 4 years averages **27%**, a very high rate compared to most other sectors (e.g. telecommunications). In the 5 years from 1996 to 2000, the proportion of global turnovers derived

from US markets has reduced from almost 60% to just below 40%, showing the expansion of the use of satellite technologies on a world-wide scale. The proportion of turnovers from the main world markets in 2001 is shown in Figure 9. United States companies remain dominant in the supply of products, though this position is beginning to shift. In the 5 years from 1996 to 2001 the share of the global market held by United States suppliers fell from 65% to 50%, indicating the spreading of knowledge and know-how related to these technologies.

Consolidated view of satellite navigation markets from 1994 to 2001

8





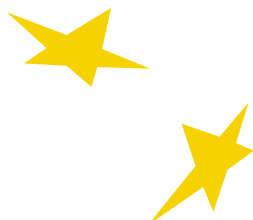
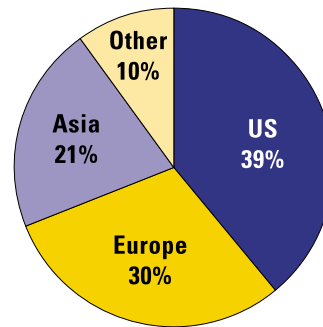
An indicator of the potential trend in the future can be found in the number of patents. Most of the satellite navigation-related patents have so far been taken by Japanese industries (in the range of 3,500), followed by United States companies (1,500). Patents filed by European companies count for less than a third of the

Japanese patents (1,000). In general, the maturity of the market is shown by the fact that the total number of new patents each year is decreasing. It is expected that the advent of GALILEO will boost the patent-filing exercise, opening the door for new opportunities and new GALILEO industrial players.

Global satellite navigation turnovers in 2001

9

Revenue sources for satellite navigation global revenues in 2001



Emerging GNSS applications

5

In this chapter, some applications that have shown very promising developments are presented.

The Location Based Services (LBS) market, with its enormous potential, is first described. In particular, four main LBS categories, i.e. information and navigation services, emergency assistance, tracking services and network-related services, are examined in detail and their expected considerable revenues explained.

Four important transport domains, i.e. road, aviation, maritime and rail are also presented, giving for each sector an insight of the present markets, the possibilities for development and the new markets opened by GALILEO.

Finally, specific applications such as oil and gas and precision agriculture are addressed, in view of the improvements in exploitation techniques made achievable by satellite navigation technologies.

A complete analysis of GNSS applications would include the review of almost all sectors of activity like fisheries, insurance, leisure, water management, environment monitoring, support to people with disabilities, consumer protection, meteorology, science, timing, etc..

5.1 Location Based Services

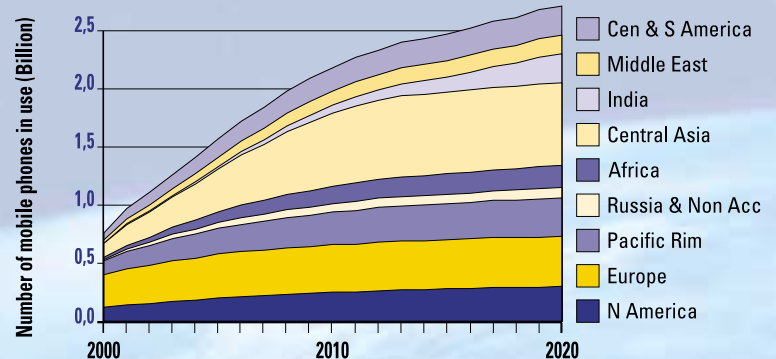
The LBS market is currently segmented into four categories:

- Information and navigation services, which provide data directly to end-users, in particular destination location and criteria for journey optimisation.
- Emergency assistance, which provide the location of mobile users in case of distress and need for assistance.
- Tracking services, which provide location data.
- Network related services, where knowledge of user position improves communication services.

The potential market for LBS applications is enormous, as it is correlated to the expansion of the mobile phone market. This market, which is still growing, reached 860 million subscribers in September 2002. It is estimated that when the growth rate slows down in the European region as the market approaches saturation, it will be followed by a spurt in growth in Central Asia (mainly driven by China), and good growth in India. Market forecasts indicate that 2.7 billion mobile phones will be in use worldwide in 2020. The geographical breakdown can be seen in Figure 10.

Number of mobile phones in use

10





Adding the facility to compute the location of a mobile subscriber will enable telecom operators to focus on a very large market. As depicted in Figure 11, anticipated world wireless LBS turnovers will surge from approximately €1 billion in 2000 to over €40 billion in 2006.

ARC Group announced in a report, published in August 2002, that location-based services will account for over 40% of operators' mobile data services turnovers in 2007.

There are regional characteristics in the LBS market. In Japan, for several years, numerous in-car navigation services have been deployed, mainly for information and guidance purposes. New services based on the implementation of satellite navigation chipsets in mobile phones are already available.

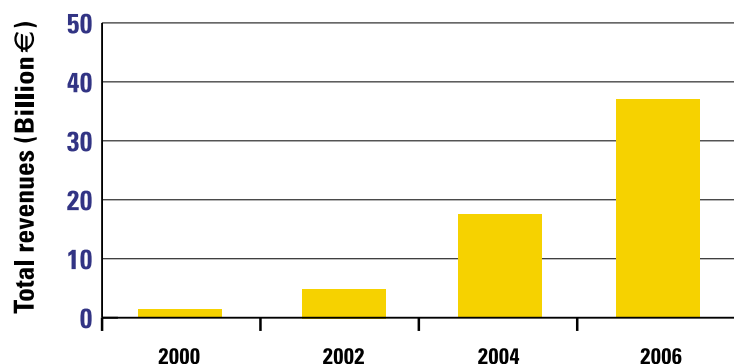
KKDI recently launched a mobile phone service named "GPS Keitai". Among the various services offered, the user can locate himself on a map, ask for personalised information regarding a point of interest (such as restaurants) or a trip (such as directions) but also train or metro timetables. By February 2002, 420,000 mobile phones with integrated satellite navigation functionality had been sold.

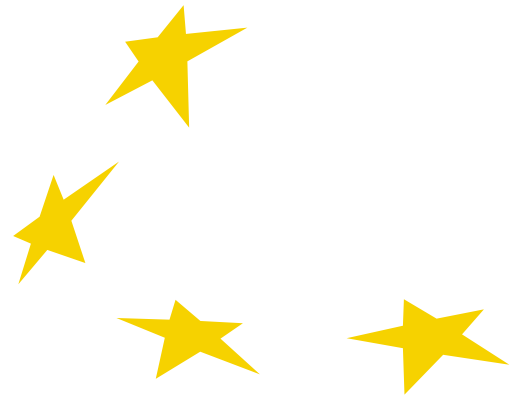
Since June 2002 KDDI, Toyota and Matsushita Electrics are proposing a service that broadcasts a message with precise information related to user location. The service, HelpNet Keitai, based on mobile handsets integrating navigation chipsets, is dedicated to emergency calls. It is offered at a rate of €2.7 per month. It is envisaged to reach 150,000 subscribers by mid 2005.

In the USA, the current location-based market is in a phase of rapid development. Since October 2001, wireless operators must be prepared to conform to the second phase of 911 Emergency Call regulations and provide a service that broadcasts the caller's location data with high accuracy characteristics (50 m for 67% of calls when considering handset-based solutions such as Assisted-GPS).

Wireless global location-based services turnover

11





In September 2002, Intrado Inc. announced that it had teamed with the Greater Harris County 9-1-1 Emergency Network and leading vendors, including Ford Motor Company, to install telematics, i.e. integrated telecommunications and information processing for vehicle systems, in police cars in the Houston area.

In Europe, location-based services are starting to develop. Several applications are now spreading, creating new market opportunities. Emergency services across the European Union receive around 80 million calls every year: 40 million of these are from mobiles and this number is still growing.

By combining satellite navigation tracking and wireless communications, the new telematic systems will offer automatic post-collision notification integrated into the current E-911 emergency networks. In the event of collision, onboard systems immediately transmit alerts along with details such as location, magnitude and number of passengers involved to emergency response centres operated by Cross Country Automotive Services.

Based on the investment required to comply with this regulation, US operators are proposing and deploying more and more commercial LBS for mass market or professional applications.

In July 2002, Wherify Wireless announced that consumers could now order Wherify's satellite navigation Personal Locator for Children. Wherify's GPS Personal Locator for Children sells for some €400, plus a monthly service charge. Wherify is also developing a Personal Locator for Alzheimer's patients, as well as a vehicle locator.

In August 2002, Crimestopper Security Products had developed with Satronics new automated wireless automotive security technology based on satellite navigation. Using phone or Internet interfaces, the system automatically notifies a user when his vehicle has been tampered with or stolen and provides event-specific messages.

In 2002, a directory service was on the market in 1,600 German cities, available through Vodafone. Working off a technology developed by Troy, the service helps people map their evenings out by giving directions to the nearest clubs, cinemas, petrol stations, cash machines, etc..

Webraska offers a service in Britain called "Pub Finder" that provides a list of the nearest watering holes. Once users find a bar, they can inform friends of their location by sending the pub's name and address in a quick text message.

In 2001, SignalSoft and Orange Denmark launched a location-based game called Zonemaster, which is a "battle for land" which takes place in the real world, on real maps, utilising real physical location. Based on a large marketing campaign, the resultant business was very profitable.

In 2002, Telenor Mobil conducted a very positive Pilot Study based on the Friend finder application, with a high level of user satisfaction.



5.2 Road applications

The road sector is a major potential market for GNSS applications. Satellite navigation receivers are now commonly installed in cars as a key tool for providing new services to people on the move such as electronic charging, real time traffic information, emergency calls, route guidance, fleet management or advance driving assistance systems.

By 2010 there will be more than 670 million cars, 33 million buses and trucks and 200 million light commercial vehicles world-wide.

It is estimated that the uptake of GNSS use in this market will occur over the next 5-10 years, with Europe taking the lead in this respect. In 2020, there will be over 450 million cars with GNSS-based navigation systems onboard.

It is expected that in-car navigation systems will be "dual mode", i.e. based on GALILEO and GPS. The average price will tend, as in the computer industry, to stabilise around a minimum value, in this case around €500 (the constant increase in the number of functionality, improvement in man-machine interfaces, etc.). With these assumptions, the total annual gross turnovers from this market will reach €25 billion in 2016.

This trend is based upon the replacement cycle of new cars, with the after-sales market size remaining marginal.

A number of interesting developments in this market will also favour its deployment:

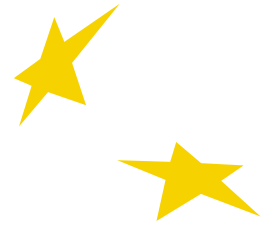
- The availability of route guidance systems that incorporate near real-time traffic information. This type of service is easily expanded to offer other types of location-based services.

- Car manufacturers (Ford, BMW, Renault, Daimler) are diversifying their businesses and are providing, or plan to provide, telematic services to their customers. In some cases, they are forming strategic partnerships to develop and operate such information provision.

Under an initiative of the German government to install a highway toll system for trucks, the ETC consortium (DaimlerChrysler Services, Deutsche Telecom and Cofiroute) is implementing for the end of 2003 a several billion € infrastructure, named "Toll collect", based on satellite navigation services. 600,000 trucks will automatically transmit various parameters as the accumulated number of kilometres, truck weight, number of axles, etc. The centralised toll centre will prepare billing to truck owners. ETC expects yearly earnings in the order of €600 million.

To improve police and emergency centre activities, the DaimlerChrysler TELEAID system determines the location of cars involved in accidents. The system transmits further information, such as personal data about driver or vehicle characteristic, for more efficient intervention assistance.

As toll systems are being implemented in several European countries (e.g. Great Britain, The Netherlands, Austria) for highways, roads or urban areas, adequate accuracy, availability and continuity is required. One hour of loss of signal disruption a year, which corresponds to an availability of 0.9998, would lead to a loss of approximately €400,000 for the Toll Collect system in Germany. GALILEO will bring the necessary performances levels for these applications.



5.3 Aviation

In aeronautical applications, satellite positioning and timing services have long been an additional means of navigation. They provide supplementary service for many flight phases, in leisure flying as well as commercial air transport.

In the European Union, some 5,000 civil aircrafts are currently registered, with an additional 30,000 small private planes in use.

In recent years, scheduled traffic has increased by about 4% per year worldwide, doubling the number of flights within 20 years. Higher navigation accuracy and service integrity are required to allow aircraft separation reduction, allowing for increase of traffic capacity.

EGNOS and GALILEO will assist pilots in all flight phases, from movement on the ground to take-off, en-route flying and landing in all weather conditions, reaching the level of safety that will be required to cope with the continuous increase in the number of flights. GALILEO, with the aid of ground-based local elements, will satisfy the needs for precision approach as defined in the aeronautical standards.

Air traffic controllers need position, heading, speed and time information for the continuous management of all aircraft. Some areas of the world, like in the Canary Islands, lack the appropriate ground infrastructure, including secondary radar and communication links. Standardized transmission of GALILEO navigation data will lead to advanced systems and techniques for safer air traffic monitoring.

All other aviation-related operations, like airport surface movement and guidance control, require precise assistance from air traffic controllers. Airports may have surface radar, but sometimes pilots report taxi movements manually and aircraft are managed using visual aids only. This has led to severe accidents. Satellite navigation and GALILEO in particular will improve operations safety.





5.4 Maritime

Open ocean and inland waterways are the most widely used mode for transporting goods worldwide. A wide variety of vessels move around the world each day.

The European Union merchant fleet is composed of around 10,000 ships with registered tonnage of 1,000 or above. About 25,000 people are employed by the major European Ferry Operators.

The efficiency, safety and optimisation of marine transportation are key issues. Satellite navigation is becoming a fundamental tool for bringing innovation and progress this sector and many other marine activities such as fishing, oceanography and oil and gas exploitation will also benefit from the availability of GALILEO services.

Increased accuracy and integrity, certified services and high availability brought by GALILEO will be applied to leisure boats, commercial vessels and all ships falling under the Safety Of Life At Sea (SOLAS) convention in every phase of marine navigation, i.e. ocean, coastal, port approach and harbour manoeuvres, under all weather conditions.

For marine navigation regulated by the International Maritime Organisation, GALILEO will be an additional means of implementing the regulations on Automatic Identification Systems (AIS) and vessel traffic management systems to increase navigation safety and collision prevention.

All maritime commercial activities are starting to use satellite navigation. In fishing, it helps locate traps and nets. Fleet management, cargo monitoring, and delivery and loading schedules are optimised. Even the location of shipping containers can be

facilitated, and satellite navigation could be used for automatic piloting of barges. Within harbours, a system for information services tailored to each ship's location is being considered.

Handling of containers is crucial for efficient commercial harbour operations. Traffic of goods in European ports reaches 40 million containers a year. Systems are under development to equip containers with standardised positioning devices allowing better logistics operations.

The University of New Brunswick has developed a new satellite navigation guidance system to steer giant port cranes past stationary containers. The cranes' actions are controlled to centimetre level accuracy.

In inland waterways, accuracy and integrity of navigation data are essential to automate accurate manoeuvres in narrow rivers and canals.

The total length of inland waterways in the 15 EU Member States reaches 30,000 km. Goods volume in 2000 was about 125,000 millions of tons per kilometre.

The GALILEO system also contributes to the international search and rescue service, enhancing the worldwide performance of the current COSPAS-SARSAT system. The actual positioning accuracy is rather poor (typically a few kilometres) and alerts are not always issued in real-time. The GALILEO search and rescue service will drastically reduce the Time To Alert (from hour to minutes), and the position of the distress beacon will be determined to within a few metres.



So far restricted to a professional-type user community, there are some 200,000 COSPAS-SARSAT beacons in existence today. It has been shown that the market will rapidly grow to a few million beacons after the advent of GALILEO. In its 20 years of operation, the satellite rescue system has helped save close to 14,000 people worldwide

5.5 Rail

With a network of 150,000 kilometres of lines, general trend in the European railways is the standardisation process of the main subsystems involved in railway operations, in order to reach efficient interoperability. In particular, the European Rail Traffic Management System (ERTMS) is becoming the European standard for train control, signalling and traffic management.

Two layers of ERTMS can rely on satellite navigation: the European Train Control System (ETCS), which deals with train control and protection and the European Traffic Management Layer (ETML) dealing with non safety of life related aspects like traffic management and regulation.

For safety-of-life applications, various consortia have formed to investigate potential opportunities. Gaderos, a consortium formed by several European companies (Ineco, Tifsa, Erri, Thales, Railway safety, GMV, Sener and Aena) proposes rail location units based on satellite navigation technology. Other consortia are seeking interoperability with ETCS or proposing dedicated solution for low density traffic lines. These include Locoprol/Locoloc (Trasys, Alstom, Septentrio, SNCB), Rune (Laben, ViaRail, Ansaldo, Intecs), Integrail (Kayser-Threde, Adtranz, IfEN) or Eco-rail (Technicatome, Alcatel, Teleconsult, Stern & Hafferl, Systra and ST Microelectronics).

Current technologies used for location of rail vehicles and trains in Europe are ground-based solutions, with high equipment and maintenance costs. Use of satellite navigation will reduce cost, allowing cheap train signalling and traffic management systems whilst simultaneously increasing line capacity and efficiency.

In the non safety-of-life application sector, many national train fleets use satellite navigation for fleet management, including certain United Kingdom fleets (mainly freight), SNCF in France and DB in Germany.





These systems, along with proper communications infrastructure, allow tracking and monitoring of rolling stocks, especially of locomotives, enabling operators to efficiently track the position of their resources.

With a view to half a million transport wagons and some 100,000 vehicles (including locomotives and passenger transport vehicles) in use today, GALILEO performances offer opportunities to enter a large professional European market with specific needs.

FGC (Ferrocarriles Generalitat Catalunya) in Spain is already implementing the SITCAS system for Traffic monitoring of its network, allowing control centres to receive real time information on train location and speed.

Kaiser-Threde in Germany commercialises the Railtrac-Kt system to supervise and locate mobile objects (e.g. containers, wagons, construction machines). Routes, timetables, operating condition, loads and temperatures of 13,000 wagons are monitored using existing satellite navigation infrastructures. Unplanned stops or faults are reported via GSM or satellite communication links. It is planned to use the system for the transport of dangerous goods in Russia.

In the rail sector, other applications are also designed for proximity alarms, triggering reports when two trains on the same track are too close and velocity limit alarms to report that a train is surpassing the allowed speed for that section of the track.

For track survey purposes, satellite navigation services are not only used for construction work where very precise

differential techniques are used but also for video recorded track survey techniques, as done, for instance, in the UK.

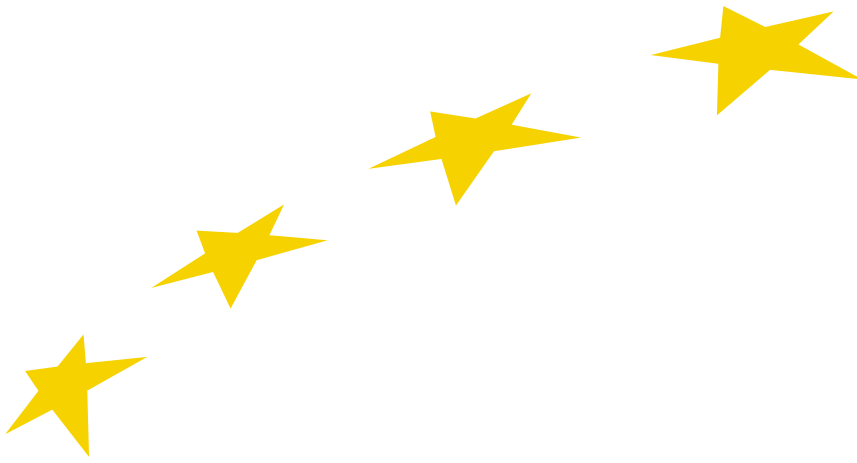
More sophisticated applications are being designed. It is known that train tilting in curves improves passenger comfort. Up to now the detection of curves is performed through a combination of accelerometers and other sensors. The use of satellite navigation services, along with track information (curve radius, location, etc.) is being studied and tested to improve performance of such systems.

5.6 Oil and Gas

The oil and gas industry is largely using satellite navigation for onshore and offshore operations, both in exploration and exploitation activities. Accuracy levels between 0.5 and 1.0 m up to 1,000 km offshore are commonly expected. The promise of GALILEO is of great interest to this sector since it provides a second independent system for activities where high costs associated with exploration and exploitation do not tolerate any errors and delays.

Whether geophysical exploitation, geotechnical evaluation, rig and platform services, underwater inspection, underwater construction support services, pipe laying and pipeline surveys etc., most, if not all, of these operations rely heavily on the positioning accuracy.

In the global market, a few companies like Fugro, Thales GeoSolutions operate satellite navigation differential services, which allow for "decimetre" accuracy. NavCom Technology Inc. distributes time satellite position and clock via the Internet.



Development of systems using satellite navigation to monitor and prevent accident for the security of gas transport (pipelines) and storage infrastructures in the Russian Federation and the Newly Independent States are under way.

5.7 Precision Agriculture

Precision Agriculture applications include the measurement of crop yield during harvesting, management of soil sampling and weeds, variable rate fertiliser spreading, auditing of fertiliser, insecticide and herbicides, autonomous farm machinery or tracking of animal movements through the addition of short range tagging technology. Corn and soybeans producers have tested systems to improve management of soil acidity and lime application (reduction of lime need by 60%) based on the use of satellite navigation. Hybridisation with satellite imagery has already demonstrated large benefits.

Federal authorities responsible for animals and livestock in Arkansas have invested in satellite navigation equipment to improve identification operations in emergency cases like foot-and-mouth disease or poultry disease.

Agriculture is of major economic significance and farmers and related industry are seeking ways in which to differentiate their new products in order to boost their sales through improved efficiency.

Trimble recently started to commercialise its AgGPS Autopilot system, based on differential satellite navigation. The system guides agriculture vehicle in consistent rows for tilling, spraying and applying fertilisers.

5.8 Fisheries

As sea resources decrease, specific measures are being taken to monitor and control the activities of the fishing sector. The current reform of the EU fishery policy will make the technology indispensable.

Simultaneously, fishermen are investing in satellite technology in order to direct their boats to good fishing waters, saving fuel and time.

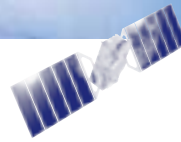
The fishery department in the U.K. has called on Precise positioning Products Inc. and Applied Satellite Technology Ltd. to equip some 1,500 fishing vessels with the AEGIS system for monitoring of fishing activities and comprehensive intelligence on the state of all fishing areas monitored.

Escotel and BPL Mobile, two large mobile phone operators in India, estimate that 10% of their customer are fishermen (the country counts some 1 million active fishermen).

5.9 Survey and marine engineering

Satellite navigation has revolutionised hydrographic surveying. Most marine engineering activities benefit from satellite navigation, like dredging and maintenance of harbours and waterways, mapping underwater obstacles during hydrographic surveys, pipe and cable laying, and mineral and aggregate extraction.

Ice-breaking ships in the arctic start to use satellite navigation to adjust their paths in the shipping lines according to ice thickness.



5.10 Science

Satellite navigation technologies are providing tools for science and environmental studies like the observation of tides and currents. The deployment of moving buoys reporting their positions helps scientists to study the oceans and seas, generating information to merge with data from different sources (e.g. Earth observation and remote sensing) in a comprehensive and integrated approach to the study of the environment.

The Nebraska Parks Commission has recently completed, with the help of satellite navigation technology, new topographic maps of 13 lakes and reservoirs to help managing water resources and assist aquatic habitat projects.

Animal movements are studied in many research centres: for example, grizzly bears movements, habitats and migration paths of sharks, movements of birds around the world, all help us understand mobility patterns of wildlife, hence mastering essential data for the preservation of our ecosystem.

Earthquake warning systems based on satellite navigation are being developed primarily in seismic areas and close to volcanoes.

Taiwan has implemented such an alert system and California has built a network of 250 satellite navigation stations to monitor earth movements. Newcastle University in U.K. gauges movements in the earth's crust.

5.11 Electricity networks

For their synchronisation, power distribution networks use the very accurate timing functions of satellite navigation.

Electronic mapping systems are also used to reduce power outage time by as much as 20%.

In Alabama, 30,000 transformers, 60,000 utility poles and a large set of customers have been mapped with positioning systems. When customer's power goes out, systems operators can determine the exact location and nature of the problem.

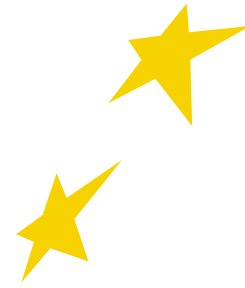
The electricity network company Vector has introduced a mobile and computer system for field crews which is believed to save half a million € a year.

5.12 Social

People with disabilities will soon benefit from the latest satellite navigation technology. Various research institutes have invested into wearable computer systems to create navigational aids to blind people.

The Sendero group allocated some €2 million grant in 2001 to researchers for the development of satellite navigation-based systems to guide blind people wherever they go.

The Geodetics Laboratory of the Swiss Federal Institute of Technology (EPFL) with Leica Vectronix have developed a pedestrian navigation module weighing less than 150 grams at the size of a portable phone. This ergonomic system supplies positioning data for blind navigation to bring people to their destinations.



Keeping track of people can be of great value. Lightweight devices are already available on the market. While privacy concerns have been raised, it is expected that some well-defined applications will emerge rapidly.

Wherify commercialise a personal locator system for children which is worn as a watch and can determine a child's location in minutes. Applied Digital Solution produces the "Digital Angel" product, a combination of watch and clip-on tracking device. GPSTracks is proposing both the human and animal tracking devices. These products are sold for some €400, with monthly fees in the range of €30.

The insurance industry has shown real interest into the possibilities offered by the advent of mature satellite navigation technologies. Using such techniques can improve safety and permit to retrieve lost goods in a faster way.

Norwich Union Insurance is researching direct payment for motor vehicle insurance based on the active use of the vehicle. The trial involves 7,000 volunteer customers and, if positive, will result into commercial insurance products of a new type.

In Canada, Grey Island Systems has equipped the snowploughs of the city of Vaughan with receivers. Citizens can see live digital maps through internet displaying information on where those vehicles are working with respect to their own location.

5.13 Customs, Justice and home affairs

In the field of justice, customs, police, etc. various applications are already being implemented. Vehicle theft represents an annual cost of some €8 billion in the U.S.

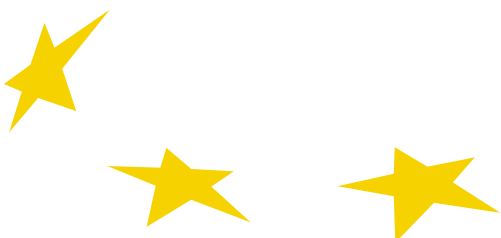
Specific policies to combat vehicle crime are being proposed in the EU, in terms of standard for tracking and tracing systems of vehicles and development of after-alarm procedures for private security branches and police.

Satellite navigation monitoring gives governments cheap alternatives to incarceration and allows offenders an opportunity to continue working and living at home.

Veridian is selling Veritracks, an electronic tracking systems that allows tracking of suspects and criminals around their neighbourhoods and comparing the information with recent crimes. It is estimated that the savings are in the order of €50 a day per offender with respect to jail.

Coastguards also make use of satellite navigation to help maritime borders control activities, whether for smugglers or other illegal activities surveillance.

Customs administration are investigating the possibilities to deploy systems allowing to interrogate trucks transporting various goods to check whether they are still on the most direct route to their final destination. When unexpected movements or operations occur (e.g. the backdoor of a truck opens open before it has reached its final destination) alarms are sent to the closest customs office with the positioning and identification of the truck.





5.14 Leisure

This sector is the one where the most unexpected and sometimes the most exotic applications are developing.

Huge market can be found by fitting satellite navigation receivers on cameras and video cameras to record the place where photos or video sequences were taken, on "intelligent suitcases" that can be recovered in theft cases.

Suunto, a Finnish company, has started to sell a wristwatch-like personal golf computer using satellite navigation. The product, called G9, sold for some €700, allows golfers to measure distance from tee to hole and the length of each shot. It advises on the best clubs based on a golfer's history, average length of shot and distance to the green.

Treasure hunting and geocaching are become favorite sports in many U.S. states and European countries. Dedicated associations have formed in the last two years.

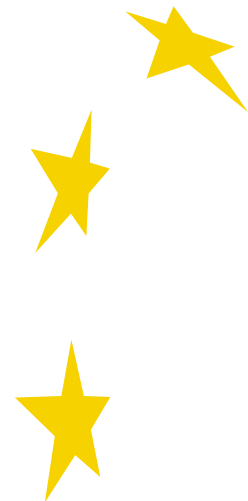
In 2002 there were at least 20,000 "caches" spread over 120 countries. With a few thousands people registered in the "geocaching" association, close to 100,000 people had already tried geocaching.

One location-based tag game is available in parts of Scandinavia and in Ireland. The game, developed by a Swedish company in cooperation with SignalSoft, called "It's Alive," has people chasing each other through the streets, virtually gunning down complete strangers who are playing the same game.

In the tourism sector, special visits to towns, museums or castles based on the use of satellite navigation receivers are proposed in various countries.

Assessment of market drivers

6



6.1 Identification of market drivers

The trend as illustrated in Figure 8 in established markets for satellite navigation is more than likely to continue in the future, as economic activity drives demand for commercially-oriented services in all the transport modes, together with professional surveying, timing and scientific applications.

As already stated, in the very near future new developments will overlay on this existing trend as mass consumer markets become established for both hand-held and in-vehicle devices. This results in a step-change in the market for navigation products, with an acceleration of the market growth in the next 2-3 years.

There are a number of important drivers that cause this evolution, though this development will come about differently in different regions of the world. These factors can be divided into four groups as depicted on Figure 12.

Technological trends:

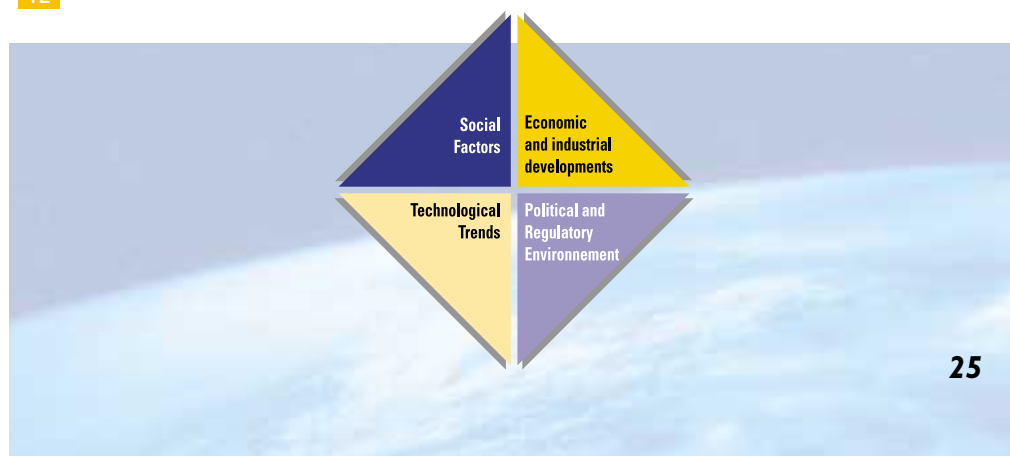
- Miniaturisation and receiver advances improve price versus performance and favour its use in portable devices. Advances in geographical information systems and digital mapping provide the necessary data to support new Location Based Services.
- Mobile communication technologies push the markets for positioning and timing services.
- The European Geo-stationary Navigation Overlay Service (EGNOS) in a first stage and GALILEO in a second stage provide for quantum leaps in satellite navigation performances, hence stimulating demand and supply industries.

Political and regulatory environment:

- Development and specification of new, more efficient and safer transport networks (road, rail, maritime, aviation).
- New directives in fishery policies, in environment monitoring, in agriculture, etc.
- New measures to enhancing public and consumer protection (customs, justice and home affairs, external relations, etc.).
- Measures in support of people with disabilities, for regional development or for humanitarian aid in poor countries, etc..

Driving factors for satellite navigation development

12





Social factors:

- Increased demand for consumer electronics.
- Changing work patterns and increased mobility heighten demand for efficient travel in both personal and public modes.
- Concerns about transport and personal safety drive better safety performance and monitoring needs.

Economic and industrial developments:

- Overall economic activity and production patterns drive demand for corporate transport.
- Pressures within consumer electronics industry require maintaining high product replacement rates.

6.2 Technological trends

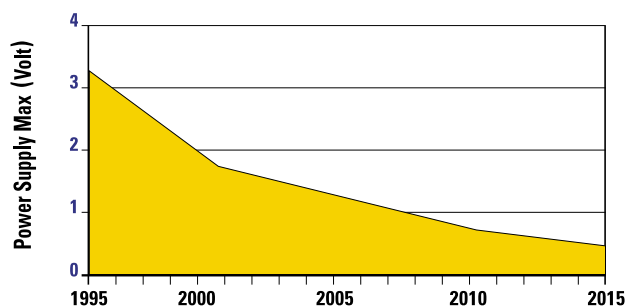
6.2.1 Receivers technology

The main trend in receivers is the miniaturisation of the satellite navigation hardware. The progress made in silicon technology allows for size reduction, power consumption reduction, and integration of additional functionalities, encompassing communication and computation. At the same time the software content is steadily increasing.

The decrease in power consumption and size of electronics hardware is a major condition for receivers to be used in conjunction with mobile handset. In particular, the reduction of power consumption in electronic devices determines user autonomy. Figure 13 shows the decrease in receivers internal voltage needs. As power is proportional to the

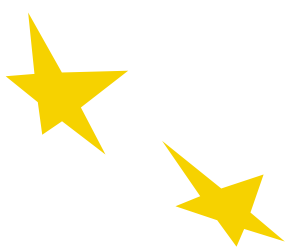
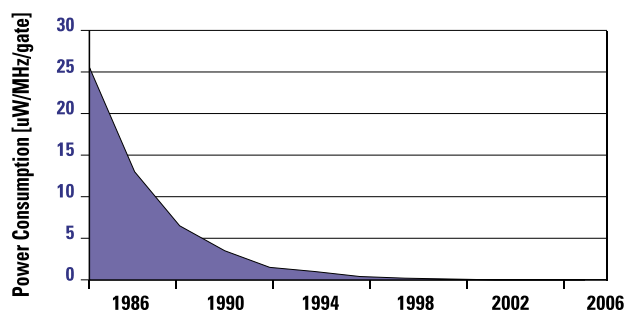
Decrease in receivers voltage need

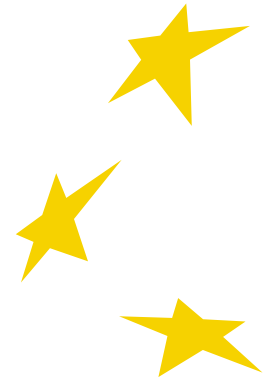
13



Power consumption reduction trend

14





square of the voltage, the diagrams demonstrate the very significant decrease in power needs (Figure 14), which in turns translate to much larger receiver autonomy (i.e. leading to much smaller battery size and an increased number of hours without the need for re-charging). These factors impact most applications, where no connection to fixed power supplies is available.

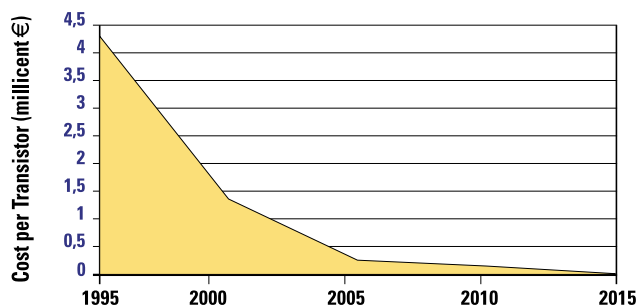
The integration of satellite navigation modules within mobile communication handsets is, no doubt, one of the biggest evolutions over the next decade for the mass-market user. This will allow the development of smaller terminals, which will support Location Based Services, gathering position and commercial information. It is worth noting that emergent techniques like "software" radio (i.e. using appropriate software on to the same hardware components for both navigation and

communication functions), might also promote dual use of the terminal. The actual ability to reduce the cost per function by an average of 25-30% each year represents one of the unique features of the semiconductor industry and has a direct consequence on the ability to double functionalities on chipsets every 1.5 years in an environment of constant prices. Figure 15 shows identified trends in Micro Controller Unit prices, taking an integrated transistor as a reference. The cost reduction is observed for development costs, when the product is introduced within the market (year one), and without taking into account further cost reductions that could result from mass production.

The cost reduction of elementary integrated functions as depicted above impacts directly on receivers unit cost, which is falling at a rate of nearly 30% per year as shown on Figure 16.

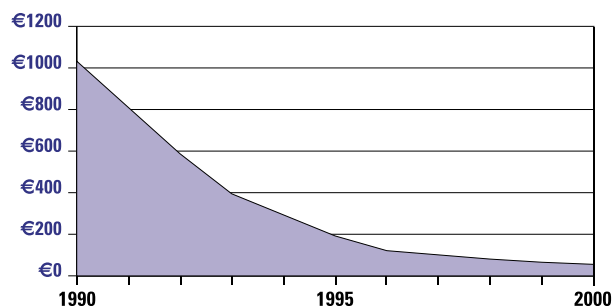
Trend in cost reduction

15



Receivers average cost

16





6.2.2 Geographic Information System

A Geographic Information System (GIS) is defined as a computer system capable of storing and managing data identified according to their locations (geographical referenced information).

Over the past decade, companies such as ESRI, Intergraph, Laser Scan and SICAD were formed, transforming GIS into a multi-billion Euro industry. In parallel, the advent of satellite navigation provided a valuable tool for surveyors, hydrographers, geodesists, geophysicists and other environmental scientists in general.

GIS systems are nowadays largely used not only in the science domain, but also in commercial and public service activities. Managers of both fixed and mobile assets and business analysts throughout the world routinely use geographical information systems. Fixed physical assets such as street furniture, power and telecom infrastructure are just some of the assets whose efficient management is facilitated by modern PC-based GIS. Digital map displays are routinely used in fleet management systems for vehicles of all types, relying heavily on GIS technology. Digital maps are fundamental components for in-car navigation systems.

The combination of geographical information systems with satellite navigation is at the root of most of the new applications already on the market.

6.2.3 Synergies with mobile telecommunication

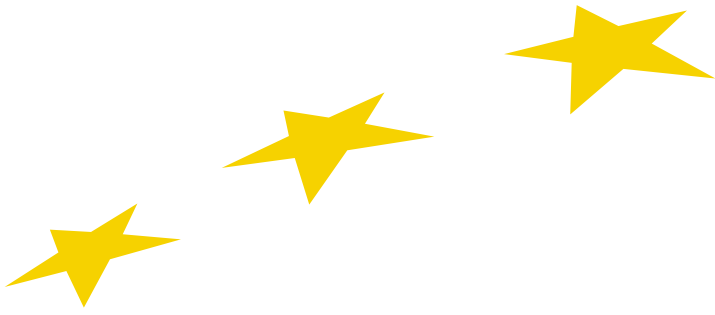
The above-mentioned convergence is further enhanced by the development of mobile communications networks (GSM, UMTS etc.) that enable real time data to move between system components. Location Based Services (LBS) are predicted to be amongst the most promising services of future wide-band mobile networks, alongside with voice and multimedia services.

LBS services are now rapidly growing in the regions where cellular networks are already widely deployed like in Europe, North America or the Asia. With the advent of enhanced technologies and third generation mobile networks, offering multi-media services, LBS applications will be further encouraged.

Furthermore, by using ranging signals from satellites in conjunction with additional data provided by mobile networks, it is possible to reduce the typical satellite navigation computation time, thus increasing positioning performances (i.e. parameters such as availability, continuity, time to first fix, etc.). Reference stations can also transmit additional navigation data, e.g. satellite ephemeris, synchronisation time, differential corrections, etc.. As part of the data is not retrieved directly from satellite signals through classical algorithms, mobile handsets can use far weaker navigation signals than with conventional receiver.

In summary, hybridisation of communication and satellite navigation signals will enhance indoor positioning capabilities, which is a benefit of paramount importance for users.





6.2.4 EGNOS and GALILEO differentiators and benefits

Satellite navigation applications are currently based on GPS performances, and great technological effort is spent to integrate satellite-derived information with a number of other techniques, in order to reach better positioning precision with improved reliability.

This scenario will significantly change in the short-term future. EGNOS, the European regional augmentation of GPS, will as from 2004 start to provide its services. Four years later, the global satellite navigation infrastructure will double with the advent of GALILEO. The availability of two or more constellations, more than doubling the total number of available satellites in the sky, will enhance the quality of the services, increasing the number of potential users and applications.

GALILEO specific characteristics will bring themselves significant enhancements. Firstly, for urban areas or indoor applications, the design of the GALILEO signals will improve the availability of service (broadcast of dataless ranging channels, in addition to the classical pseudo random ranging codes). Secondly, the high-end professional market will also benefit from GALILEO signals characteristics. Three carriers phase measurements will be essential for the development of specific "TCAR" algorithms, leading to centimetre accuracy over large regions.

Figures 17, 18 and 19 (page 30) show a comparison in terms of mean horizontal accuracy achieved through the GPS constellation alone in the first case, through GPS and EGNOS together in the second case and finally through the overall GPS, EGNOS and GALILEO altogether.

Simulations demonstrate that availability of positioning services in urban areas where "canyons" occur (satellite visibility obstruction by high buildings and skyscrapers) is increased typically, from 50% to above 95% using GPS and GALILEO.

GALILEO, which is under civil control, is operated in a transparent way, allowing for full service certification.

The need for service guarantee for safety-of-life and commercial applications has been taken into account in the design of the systems. Legal implications of service level commitment are driving the GALILEO system implementation. Accountability requirements regarding service provision has led to clear traceability requirements on detailed system performance history (already implemented in EGNOS). This approach significantly improves navigation system safety, facilitates detection and investigation of any malfunctioning and allows recording of service level performance in case of claims. In this context, the integrity information function plays an important role.

Law enforcement in the road and maritime domains, road charging and tolling, safety-of-life navigation in all modes of transport will soon rely on dedicated infrastructures with reliability and guarantee characteristics that are simply not available with current systems.

17

18

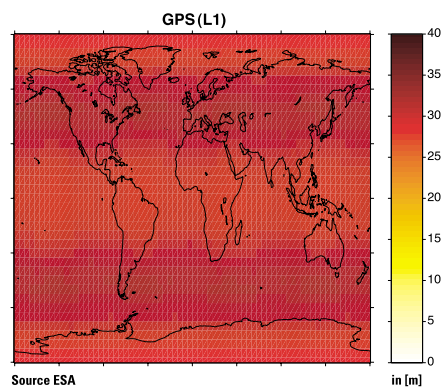
19





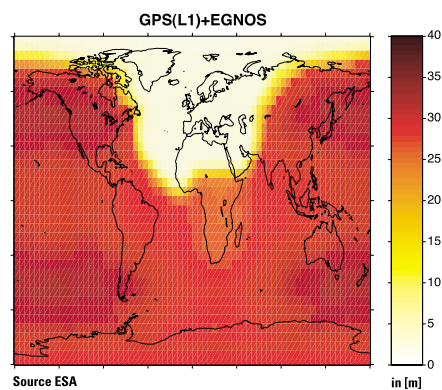
Mean horizontal positioning accuracy (95%) achieved through the GPS constellation alone ¹

17



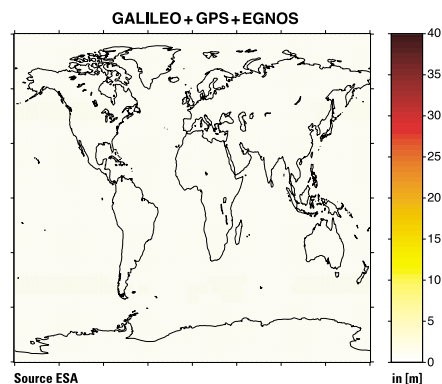
Mean horizontal positioning accuracy (95%) achieved through the GPS constellation augmented by EGNOS ¹

18

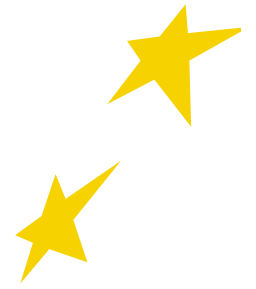


Mean horizontal positioning accuracy (95%) achieved through the use of GPS, EGNOS and GALILEO ²

19



- (1) Simulated GPS performance is based on empiric performance parameters reported in "GPS Standard Positioning Service Performance Standard", Oct. 2001. Results include atmospheric and local effects.
- (2) For this simulation the ranging performance of modernized GPS was assumed to be equal to Galileo. Results include atmospheric and local effects.



6.3 Regulation and policy

Regulation at a number of levels, international, EU-wide and national, will indirectly steer the use of satellite navigation systems, hence also of GALILEO.

In general, regulation either mandates performance or mandates technology or authorises certain technology.

Mandate of performance

Such regulations require provision of service with a set of performance criteria, and are technologically neutral. A typical example is the U.S. regulation mandating localisation of calls to emergency services from mobile phones, known as “911 numbering”.

E-911: To comply with FCC regulations mandating the localisation of calls to emergency services, several US carriers have adopted GNSS-based solutions. Whereas AT&T and Cingular Wireless chose network-based solutions, Cingular, Nextel, Sprint PCS, and Verizon Wireless opted for Assisted-GPS solutions. The latter companies are to provide 95% of all subscriber handsets in service nationwide with an A-GPS-capability by 31 December 2005. Given that Nextel, Sprint PCS, and Verizon Wireless have more than 50 Million wireless users together, E-911 regulation will considerably improve the market uptake of satellite navigation.

Mandate of technologies

In this case, regulations require a particular technology to be used for provision of services. This obviously boosts the mandated technologies. The existence of such regulations give GNSS (and therefore GALILEO) a certain and well-defined market boost over other technologies.

An example of this is the British government policy to equip all ambulances with satellite navigation units for resource management. Another example is the German toll system for truck journeys on motorways, collected through satellite navigation-based systems. It is estimated that 1.2 to 1.4 million trucks will be subject to this toll, and hence they will all be fitted with satellite navigation receivers.

Technology authorisation

There are cases where the use of satellite navigation is not obligatory but recommended as a standard navigational aid.

This is the case of the Standard And Recommended Practices (SARPs) in Annex 10 of the aviation Chicago Convention. Many countries (in particular in South America and Africa) normally transpose these SARPs into national legislation without major modifications, leading to direct positive impact on receiver sales. International bodies like ICAO (International Civil Aviation Organisation) and IMO (International Maritime Organisation) are elaborating future policies based on the use of satellite navigation.

In Europe, regulation is either being implemented or under discussion in various domains, whether for road tolls, agriculture, fisheries, road (eSafety), customs, justice and home affairs, environment, telecommunication (E112), etc.. These new policies and standards will drive the demand for accurate and reliable navigation systems. Satellite navigation infrastructures, boosted by the advent of GALILEO, will offer readily available solution.

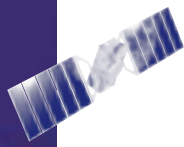


Conclusion 7

Satellite navigation technology is rapidly evolving. The downstream sector spans across all sectors of modern economies. Expected turnovers are huge as confirmed by the current trend. The advent of improved systems like EGNOS and as from 2008 GALILEO facilitates the development of new applications, hence opening new markets.

It is time to prepare for this new commodity: ubiquitous provision of reliable and accurate positioning and timing services has already started to transform our societies.





Further information



GALILEO Joint Undertaking

B-1000 Brussels
Email: JU@galileo-pgm.org



European Commission

Directorate General for Energy and Transport
Unit E.4 Satellite Navigation System (Galileo), Intelligent Transport
DM28 1/64
B-1049 Brussels
Belgium
Phone: +32 2 295 6040
Fax: +32 2 296 5372
Email: tren-galileo@cec.eu.int
Web: http://europa.eu.int/comm/dgs/energy_transport/galileo



European Space Agency

Applications Directorate
Navigation Department
8-10 rue Mario Nikis
F-75738 Paris CEDEX 15
France
Phone: +33 1 5369 7247
Fax: +33 1 5369 7445
Web: <http://www.esa.int/navigation/>

Part of the information contained in this document has been obtained from public domain sources. It is intended to provide actual examples and may contain omissions. This document does not engage the European Commission, the European Space Agency or the Galileo Joint Undertaking in any way.

Text completed on March 5, 2003.

Photo Credits: Thales Group, Thales Navigation, Airbus, Lufthansa (cover), Omnistar, European Space Agency, European Commission Audio Visual Library.



