EMERGING APPLICATIONS OF GLOBAL NAVIGATION SATELLITE SYSTEMS

R. Rashad & M. Fekry

Abstract

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 “info mobility”- where users receive information tailored to their needs, and pertaining to their precise location.

Converging factors have favored 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 maximizes the use of satellite navigation services to increase safety and efficiency of all types of transport modes.

مستخلص

تزايدت في السنوات الاخيرة استخدامات تكنولوجيا الملاحة بالأقمار الصناعية في معظم القطاعات والأنشطة اليومية لما لها من دقة ومعايير قياسية عالية بما يجعلها أداة أساسية في مجالات وتطبيقات متعددة تجارية ومهنية وعلمية. فقد أصبحت الأن جزءا من مفهوم أعم واشمل فبعد ثورة تكنولوجيا المعلومات أصبح من الممكن لاي مستخدم من الحصول علي معلومات مصممة خصيصا لاحتيجاتهم و ترتبط بموقعهم الدقيق.

ولقد أدي انخفاض سعر أجهزة الاستقبال وصغر حجمها و انتشار شبكات الاتصالات ونظم المعلومات الجغرافية الي زيادة عدد المستخدمين في شتي المجالات والتطبيقات حيث يلعب القطاع العام دورا رئيسيا من خلال التحسين المستمر لنظم الملاحة بالأقمار الصناعية وأنشاء إطار تنظيمي لها الأمر الذي سيزيد من استخدام خدمات الملاحة بالأقمار الصناعية لزيادة سلامة ورفع كفاءة جميع أنواع وسائط النقل.

1 Introduction

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 applications that have emerged recently. It analyses the factors that are driving the hundreds of applications in various domains such as aviation, maritime, communications, leisure, timing, science, agriculture.

The main outcome of this paper is that the demand on the GNSS applications is on the brink of an even wider expansion of applications, representing a huge economic gain in terms of industrial products and services provision.

In this context, the Global contributions to satellite navigation infrastructures, namely the American GPS, the Russian GLONASS, the Chinese COMPASS, the Japanese QUESI, the Indian GAGAN and the European 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. In this paper, some GNSS 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 are explained. Four important transport domains, i.e. Road assistant navigation, Aviation and air transportation, Maritime Transportation and Railways are also presented. 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, and timing.

2 Location Based Services

The **Location Based Services** (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 optimization.
- 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 is enormous, as it is correlated to the expansion of the mobile phone market. This market is still growing. Market forecasts indicate that 2.7 billion mobile phones will be in use worldwide in 2020.

Adding the facility to compute the location of a mobile subscriber will enable telecom operators to focus on a very large market. 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. Mobile phone service, among the various services offered, the user can be located on a map, ask for personalized information regarding a point of interest.

By combining satellite navigation tracking and wireless communications, the telemetric systems offer automatic post collision notification integrated into the 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 centers.

3 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.

There are more than 670 million cars, 33 million buses and trucks and 200 million light commercial vehicles worldwide. In 2020, there will be over 450 million cars with GNSS-based navigation systems onboard. A number of interesting developments in this market will also favors 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 are diversifying their businesses and are providing, or plan to provide, telematics services to their customers. In some cases, they are forming strategic partnerships to develop and operate such information provision.

Satellite navigation will help regulate road use and minimise traffic jams. If all vehicles are fitted with a navigation satellite receiver and a data transmitter, their position can be relayed automatically every few seconds to a central station. This information can then be used in a number of ways to control road usage. It could, for example, be used to charge motorists for using a stretch of road, to restrict access to congested roads, or to inform drivers of congestion and suggest alternative, quieter routes.

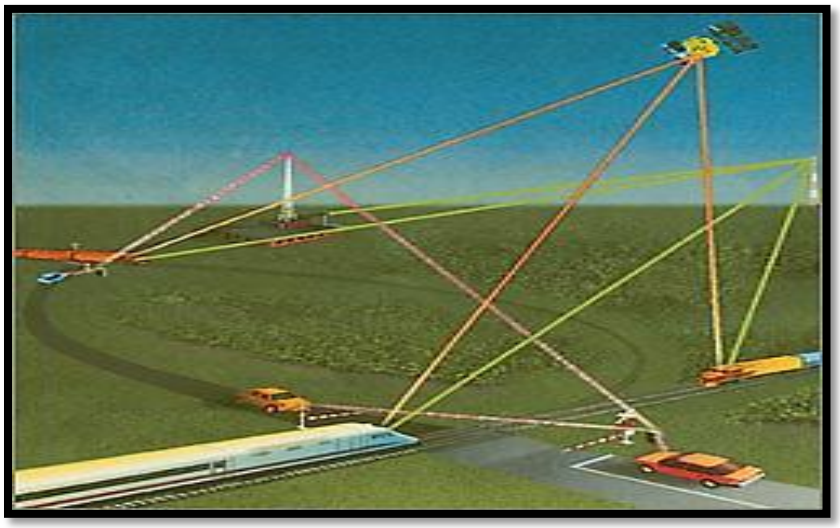

Figure (1), Tracking and Traffic Management

4 Aviation Applications

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 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.

GNSS assists 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. GNSS, with the aid of Space Base Augmentation Systems SBAS, 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, lack the appropriate ground infrastructure, including secondary radar and communication links. GNSS 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 lead to severe accidents. Satellite navigation improves operations safety.

5 Maritime Applications

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 efficiency, safety and optimization 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 also benefit from the availability of GNSS services.

Increased accuracy and integrity, certified services and high availability brought by GNSS 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 harbor maneuvers, under all weather conditions.

Marine navigation is regulated by the International Maritime Organization IMO. GNSS is an additional means of implementing the regulations on Automatic Identification Systems (AIS), Electronic Chart Display and Information system (ECDIS) and Vessel Traffic Management Systems (VTMS) 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 optimized. Even the location of shipping containers can be facilitated, and satellite navigation could be used for automatic piloting of barges. Within harbors, a system for information services tailored to each ship's location is being considered.

Handling of containers is crucial for efficient commercial harbor operations. Many systems were developed to equip containers with standardized positioning devices allowing better logistics operations. Satellite navigation guidance systems can steer giant port cranes past stationary containers. The cranes' actions are controlled to centimeter level accuracy. In inland waterways, accuracy and integrity of navigation data are essential to automate accurate maneuvers in narrow rivers and canals.

The satellite positing systems also contributed to the international search and rescue service, enhancing the worldwide performance of the current COSPAS-SARSAT system. The time to alert is reduced and the position of the distress beacon is determined to within a few meters.

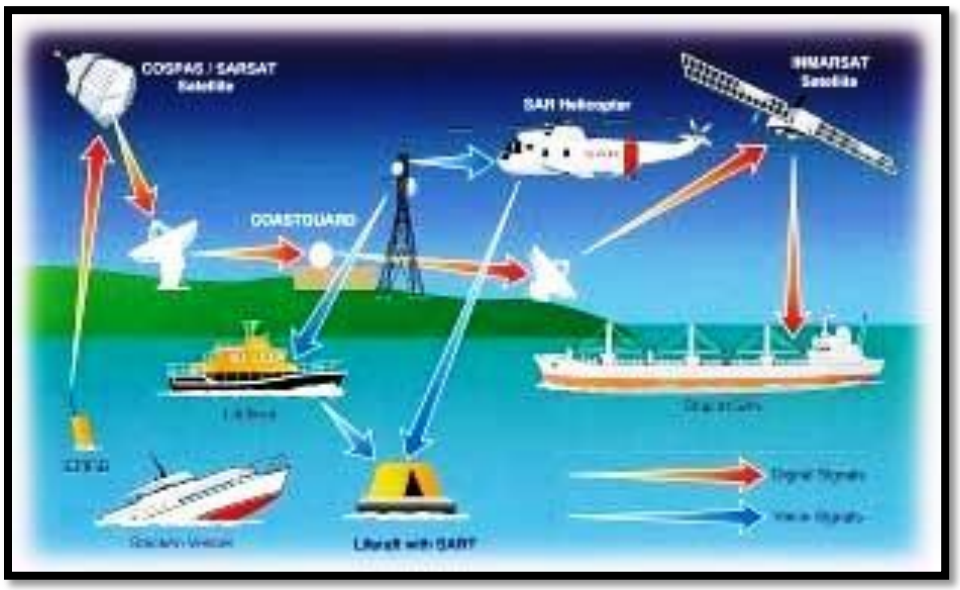

Figure (2), Distress, Search and Rescue Application

6 Railways Applications

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. 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 the performance.

Applications concerned with multi-modal transport and remote asset tracking deal with the possibility of managing fleets or keep track of dangerous goods in many different domains (aviation, road, maritime, rail…). The key advantage of the Fleet Management Solution is that the end user reduces costs and improves customers' service.

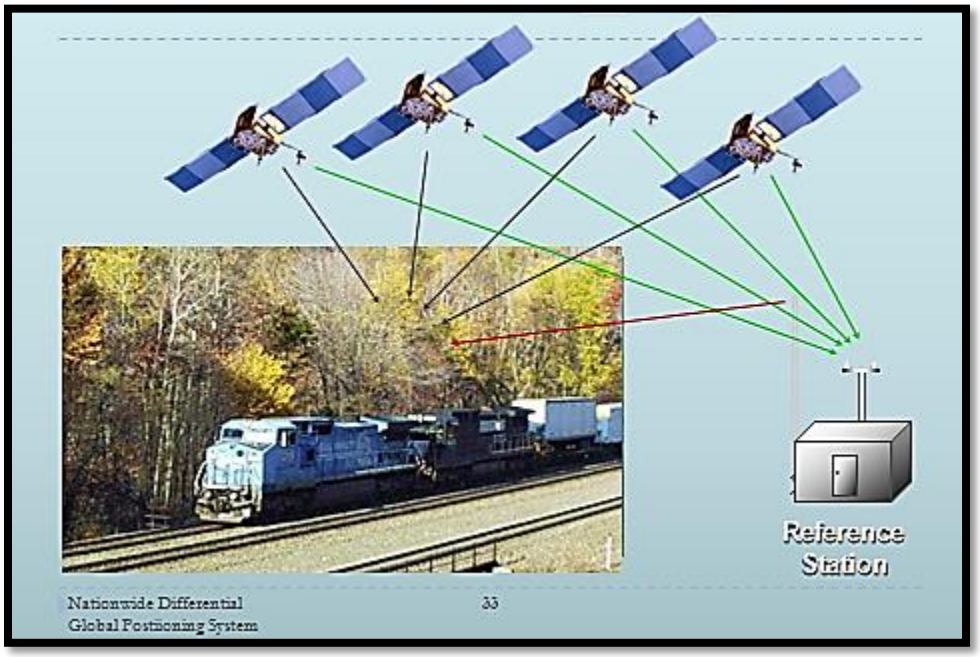

Figure (3), Train tracking and Rail control

7 Oil and Gas Applications

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.

Figure (4), Positioning of Huge Offshore Platform

8 Agriculture Applications

Precision Agriculture applications include the measurement of crop yield during harvesting, management of soil sampling and weeds, variable rate fertilizer spreading, auditing of fertilizer, 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. Hybrid station with satellite imagery has already demonstrated large benefits. Authorities responsible for animals and livestock have invested in satellite navigation equipment to improve identification operations in emergency cases.

Figure (5), Precision of Agriculture

GNSS provides precision soil sampling, data collection, and data analysis; enable localized variation of chemical applications and planting density to suit specific areas of the field. It also provides ability to work through low visibility field conditions such as rain, dust, and fog and darkness increases productivity.

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

9 Fisheries Applications

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

10 Survey and Marine Engineering Applications

Satellite navigation has revolutionized hydrographic surveying. Most marine engineering activities benefit from satellite navigation, like dredging and maintenance of harbors and waterways, mapping underwater obstacles during hydrographic surveys, pipe and cable lying, 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.

11 Science Applications

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.

Animal movements are studied in many research centers: 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. Using the precise position information provided by satellites, scientists can study how strain builds up slowly over time in an attempt to characterize and possibly anticipate earthquakes in the future.

12 Electricity Applications

For their synchronization, 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 systems operators can determine the exact location and nature of the problem.

13 Social Applications

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. 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.

Whereby commercialize a personal locator system for children which are 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. GPS tracks are proposing both the human and animal tracking devices.

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.

14 Customs, Justice and Home Affairs Applications

In the field of justice, customs, police, etc. various applications are already being implemented. Vehicle theft represents an annual cost of some G8 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 government cheap alternatives to incarceration and allows offenders an opportunity to continue working and living at home. There are electronic tracking systems that allows tracking of suspects and criminals around their neighborhoods and comparing the information with recent crimes

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.

15 Leisure Applications

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.

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

16 Indoor Navigation Applications

GNSS has become an emerging and important positioning source for a wide range of applications, many of which going much beyond the traditional transport sector, i.e. personal mobility including dense urban, indoor, and outdoor applications. Practically all of the current applications rely on the GPS signals, sometimes also exploiting regional or local augmentations to increase accuracy. As applications also move into safety-critical areas where service reliability is of concern, users and services providers alike are becoming aware of the importance of service qualities and ultimately service guarantees.

17 Conclusion

Widening the use of Satellite Navigation System and an offering of high-accuracy location and the availability of inexpensive receivers to become in all areas of daily life will help significantly in solving many problems such as the solution to the problem of traffic congestion, especially in developing countries.

On the level of use in the railway, Satellite Navigation Systems will contribute to the reduction of accidents and to provide more convenient service for users of trains.

In the field of aviation new generations of satellites provide service integrity performance of the system in addition to SBAS allowing the use of satellites in all phases of flight

In the maritime domain there are new applications depends entirely on Satellite Navigation Systems such as Automatic Identification System (AIS) and Electronic Chart Display and Information System (ECDIS), which becomes useless without a system for accurate positioning

Given the dependence on satellite navigation in all areas of daily life and a lot of critical applications, Governments should test the system and make sure there are no local systems operating in the frequency band of satellite Navigation Systems, after the emergence of a problem LightSquared/GPS Interference in the United States and the countries of Europe. The international community must adopt an alternative system to be relied upon by the GNSS such as E Loran System.

References

1. A. Norris (2010). ECDIS and Positioning Vol. 2 Integrated Bridge Systems, The Nautical Institute, London.
2. European commission (2010). Action Plan on Global Navigation Satellite System (GNSS) Applications, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, Brussels.
3. J. Marais (2011) Satellite propagation analysis in a masking environment for GNSS applications, INRETS-LEOST.

4. Spirent Communications (2011). Testing GNSS for Railway Applications DAN011 Issue 1-00. Available online http://www.spirent.com/positioning-and-navigation.aspx.
5. http://ec.europa.eu/enterprise/policies/satnav/galileo/applications/index_en.htm cited on 2/2012.
6. http://ec.europa.eu/transport/strategies/2011_white_paper_en.htm cited on 2/2012
7. http://www.directionsmag.com/articles/location-based-services-technology-platforms-applications/123741 cited on 2/2012
8. http://www.gps.gov/applications/aviation/ cited on 2/2012