

Global Navigation Satellite Systems (GNSS)

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Introduction

Over the past three decades the Global Positioning System (GPS) has evolved from a system designed to provide metre-level positioning for military applications to one that is used for a diverse range of initially unforeseen, and mainly civilian, applications. This evolution has been both driven and underpinned by fundamental research, especially in the fields of error modelling, receiver design and sensor integration. However, GPS and its current augmentations still cannot satisfy the ever increasing demands for higher performance. For instance, there is insufficient coverage in many urban areas, it is not accurate enough for some engineering applications and receivers cannot reliably access signals indoors.

Evolution of Satellite Navigation Systems

However, things are changing rapidly. Over the next few years the current satellite navigation systems are scheduled to evolve into new and enhanced forms. Modernised GPS and GLONASS (Russia's equivalent to GPS) will bring new signals to complement those that we have been using from GPS for the last 30 years. The first eight GPS satellites transmitting the new, civil, L2C signal are now operational and we can expect there to be sufficient numbers of these satellites to reach operational capability by about 2015. In April 2009, the additional L5 signal was successfully transmitted by a GPS satellite for the first time. We have also recently seen the gradual re-population of the GLONASS constellation with GLONASS-M spacecraft, which are already transmitting a civil signal on G2, and future satellites (GLONASS-K and GLONASS-KM) propose a civil signal at (or close to) the GPS L5 frequency, and the potentially dramatic change of the current signal structure to one with the same characteristics as GPS and Galileo. We will also soon see the early deployment of four Galileo In-Orbit-Validation satellites closely followed by the full operational constellation with its new signals and facilities. Furthermore we will see the deployment of China's Compass system, initially providing only regional coverage over China (by 2012), but moving to global coverage by around 2020.

But it is perhaps at the GPS L1 frequency we are likely to see the most significant developments. GPS L1 is used by all GPS users, and is the only frequency used by the vast majority of civilian receivers. Through the landmark agreement signed in 2004, between the EU and the USA, it was agreed that a common signal would be used by both Galileo and GPS III. This was the first real step towards interoperability of the systems. However, it should be noted that although Galileo is scheduled to be operational during 2013 the first Block III GPS satellite is not expected to be launched until 2014 and the full constellation will not be deployed until perhaps 2021. The proposed switchover of GLONASS to a CDMA (Code Division Multiple Access – the GPS coding) signal structure, could perhaps also enable the adoption of the common GPS / Galileo signal at L1 by Glonass, but this is purely speculation at the moment.

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Position in 2015

So if we take a snap-shot at 2015 what can we expect to see in terms of GNSS signals? It is planned, and still expected that all the Galileo signals will be operational. We should have an operational constellations (24 satellites) of modernised GPS satellites, with all transmitting the new L2C signals (and the majority transmitting L5), and perhaps one or satellites transmitting the new L1C signal. They will of course all continue to transmit the legacy signals at L1 and L2. For Glonass all satellites will be transmitting the L1 and L2 civil signals, with just a few using the new CDMA signal structure.

To react to these new signals being transmitted, we expect to see new signal acquisition and tracking approaches within the next generations of receivers, with a flexible architecture that will facilitate the use of multiple GNSS systems. We will also see the growth in the use of deep integration of GNSS with other positioning sensors (e.g. inertial), which will also bring benefits to receiver signal acquisition and tracking performance. Not only will this lead to higher accuracy, with cm positioning being commonly achievable, but equally, if not more importantly, to increased availability and reliability.

These new signals have the potential to extend the applications of GNSS into those areas that GPS alone cannot presently satisfy. They will also enable the invention of new positioning concepts that will significantly increase the efficiency of positioning for many of today's applications and stimulate new ones, especially those that will develop in conjunction with the anticipated fourth generation communication networks to provide the location based services that will be essential for economic development across the whole world, including the open oceans.

GNSS Data Analysis

New algorithmic approaches to GNSS data analysis are also developing. Precise Point Positioning (PPP) aims to achieve centimetre level accuracy using a single GPS receiver, as opposed to the currently available Real Time Kinematic (RTK) systems which rely on relatively dense networks of reference stations. The advantages PPP offers are that it does not require complex supporting infrastructure and is therefore relatively inexpensive. It has the potential to revolutionize the applications of satellite positioning and unlock the significant economical potential associated with location based services. Research on PPP has been evolutionary, starting with static positioning using the International GNSS Service (IGS) products, and more lately leading to research aimed at realising real-time positioning at a similar level of accuracy, aided by near-real time products and error mitigation models provided by the Worldwide Differential GPS services and other agencies. Until recently, decimetre accuracy with an initial convergence time of about 10 minutes has been the limit achieved, but recent research (at the University of Nottingham) has shown centimetre accuracy is possible, in a kinematic environment, with

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only an initial sub-minute convergence being required. It can be confidently expected that within the next 5 years centimetre positioning in a mobile environment will be commonly achievable.

Impact on the Geospatial Industry

GNSS is one of the fastest growing leading-edge technologies and there is significant commercial potential identified for both industry producers and service providers in the short to medium term. The Galileo programme, and GNSS in general form, an integral part of the European Commission's Lisbon Agenda for Growth and Competitiveness to make Europe 'the most competitive knowledge based economy in the world, capable of sustaining economic growth with more and better jobs and greater social cohesion'.

The increased deployment of, and reliance upon, 'location based' services (increasingly embedded in mobile phones) as well as a wide range of other products and services, will ensure that GNSS technology will undoubtedly have a major impact on the everyday lives of the population in the near future. The development of new, high value-added services, products and applications will have a significant impact on global industry, such as: transport; security; medical; healthcare; fisheries and agriculture; oil prospecting; safety and security; civil protection; regulatory activities; building and public works; and natural disaster monitoring, early warning and subsequent handling. Multi-constellation GNSS will also provide additional stability to existing satellite networks (GPS, GLONASS) that suffer from signal interruption (e.g. in high-rise urban areas) and other reliability issues that have inhibited growth in the sector. The global growth, and public utilisation and acceptance, of in-car "SatNav" demonstrates that where availability and reliability are at acceptable levels personal convenience overcomes privacy and "Big brother" concerns.

Global revenues from GNSS product sales have risen rapidly by approximately 25% per year over the past five years - from around €14 billion in 2000 to €60 billion in 2005. Latest reports predict revenues will reach €400 billion by 2025. The market for products and services is growing at an annual rate of 25% and an estimated 3 billion receivers should be in operation by 2020 (EC Green Paper on Satellite Navigation Applications, Dec 2006). The revenues from GNSS services will match or even exceed those from products by 2020. It is also estimated that, between 2010 and 2020, Galileo alone will create between 8,000 to 24,000 job opportunities in the UK.

However, despite all this development GNSS alone will not enable indoor positioning to any reasonable degree of accuracy. Developments with other sensor systems (low-cost inertial, RFID, wi-fi, ultra wide-band etc) will need to be integrated with GNSS systems to provide seamless, all environment, positioning. Achieving this at equivalent centimetre accuracy will be a major challenge but is possibly achievable by 2015.

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Scenarios

- Formation vehicle control, (lane-keeping, separation etc) achievable in many transport environments.
- Real and virtual world integration in “Augmented Reality” scenarios (visualising buried infrastructure) with high precision image registration over long distances.
- High precision automated plant control in construction, mining and agricultural applications.
- Ubiquitous tracking capability for commodities and personnel

Summary of 5 main points

- Multi-constellation GNSS, providing around 100 satellites will be available for global positioning.
- New GNSS signals and constellations will provide better accuracy and reliability.
- Centimetre positioning will be commonly achievable in a mobile environment.
- Indoor positioning will still require augmentation with other sensor systems.
- High accuracy ubiquitous positioning will become an expectation amongst the majority of the population, at least in developed countries.

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