INFRASTRUCTURE STATUS AND DEVELOPMENTS

Global Navigation Satellite Systems

The concept of GNSS was first introduced by the European Space Agency (ESA), the European Commission (EC) and Eurocontrol in the early nineties. They defined requirements for a European GPS augmentation system, GNSS-1, and a full European satellite navigation system, GNSS-2, later together renamed EGNOS (European Geostationary Navigation Overlay System) and Galileo. Satellite navigation infrastructure status and developments are described here.

Nowadays the term GNSS is used for the system of systems comprising GPS and GLONASS, with the later addition of Galileo. Satellite-based and ground-based augmentation systems (SBAS and GBAS) were introduced to augment GPS and GLONASS. Hydrographers were early users of GPS, even long before the system was declared Fully Operational Capable (FOC) on 17th July 1995. Satellite positioning is now widely used in the great majority of hydrographic applications. However, over the coming decade the advent of Galileo, modernisation of GPS and the restoration of GLONASS will dramatically improve the performance of satellite positioning for both standalone and differential use, especially when using the combined systems.

GPS Background

The first GPS satellite was launched on 22nd February 1978 and the system has evolved successfully since then. GPS is currently the only fully operational global satellite navigation system. Although 24 satellites would be sufficient for full operation, the number of satellites is now 29 (sixteen Block II/IIA, twelve Block II-R and one IIR-M), including two of insufficient performance. The GPS modernisation programme will upgrade both ground infrastructure and perform-ance of new satellites. The network of ground-monitor stations has been gradually extended: five new stations have been added to the network, six will follow in the course of this year. The accuracy for standalone oper-ations has hereby improved by about 15%. Over a longer period, the URE (User Range Error for constellation only) has been reduced from 4.6m in 1990 to 1.2m in 2005. A GPS Operational Support Center has been installed to provide information to customers worldwide on the status and performance of the system. Civil and military activities related to the GPS system are co-ordinated by a US National Space-based Position Navigation and Timing (PNT) Co-ordination Office.

Selective Denial

On 25th September 2005 the first GPS-2R-M satellite was launched with the new civil L2C signal and additional M-code signals on L1 and L2 for military use; the satellite was declared operational on 16th December 2005. There are five IIR-Ms in stock for launching, the next being scheduled for 14th September. Military signals are completely separated from civil signals, providing jamming capabilities for civil signals in areas of US military operations whilst continuous civil GPS service is maintained outside this area. This is called selective denial (SD), and replaces the selective availability (SA) which was turned off on 1st May 2000. Civil receivers for L1/L2C are able to compute the ionospheric delay in standalone mode, hereby giving accuracies better than 3m. Full constellation with dual-frequency capability will be reached around 2015.

The next generation will be the GPS IIF satellite, transmitting the additional L5 signal in the aeronautical band, allowing aviation users to position in dual-frequency mode. The first launch was initially planned for May 2007; however, the Joint Program Office has announced that the first launch will be delayed until at least March 2008.

Interoperability

There will be an aggressive transition from ground-based aeronautical navigation support to space-based systems after full availability of L5, while back-up ground infrastructure will be retained. Additional modernisation will include increased power; spot beam for M-signal, flex power for the different signals (allowing more power to selected signals), survivability of the system (inter-satellite ranging to maintain orbit accuracy in case of ground infrastructure failure) and increased ground infrastructure performance. The first GPS III satellite with the Galileo-like L1C signal - a linear combination of BOC(1,1) and BOC(6,1) - is expected to be launched in 2013 with data and data-less channel, other data format and two codes; inclusion of integrity messages is under consideration. Full GPS III constellation is expected in 2030. It is reported, however, that due to delays in the II-F programme and other reasons, the GPS III contract process will be pushed back by at least one year. In December 2005 came publication of the policy report The Future of the Global Positioning System led by Dr

James Schlesinger and Dr Robert Hermann, see http://www.acq.osd.mil/dsb/reports/2005-10-GPS_Report_Final.pdf. In this report it is proposed that the constellation of GPS in the GPS III era be changed to three orbits of ten satellites. On 28th June 2004 an EU-US agreement was signed on interoperability between GPS and Galileo.

GLONASS

The first GLONASS satellite was launched on 12th October 1982. With three satellites in one launch-er, the system was quickly built up; however, the satellitesÃ¢â‚¬â„¢ lifetime of three years slowed down progress. In 1995 the GLONASS constellation was complete, with 26 satellites. Due to the economic situation in Russia, no new satellites were deployed for quite some time. An important step towards the modernised GLONASS was set by a presidential decree of 1999, followed by government approval and funding of the GLONASS programme from 2002 to 2012, with FOC expected by 2011. There are now sixteen satellites in space, including four new M-satellites (two in test phase) with an eight-year lifetime and civil L2 signal, see www.glonass-center.ru.

Russia's president Putin decreed on 18th January 2006 to speed up the GLONASS programme and made available additional budgets. FOC with 24 satellites should be reached now by the end of 2009. By 2010 performance has to be comparable with GPS and Galileo. The next launch of three GLONASS-M satellites will take place in December 2006. In 2008 will come introduction of the GLONASS-K satellites with L3, integrity information and a SAR function onboard and ten years lifetime. A new generation of GLONASS KM satellites will be introduced after 2015. The nation-wide differential network transmits GPS and GLONASS corrections, among other means, via TV stations. A co-operation agreement with India has been signed; India will carry out a number of launches for M satellites. An agreement with the US on interoperability was signed in December 2004 and a similar agreement with the EU will be consolidated soon.

Galileo

Galileo will be Europe's own global navigation satellite system, providing a highly accurate, guaranteed global positioning service under civilian control. It will be interoperable with GPS and GLONASS. The constellation will consist of thirty satellites in three orbits with the following services:

- Open Service (OS) results from a combination of open signals, free of user charge
- Safety of Life Service (SoL) provides integrity information and signal authentication in addition to the OS; it is envisaged that a service guarantee will be provided for this service
- Commercial Service (CS) with two additional signals to allow for higher data rate throughput and enable users to improve accuracy. It is envisaged that a service guar-antee will be provided for this service, which will also provide a limited broadcasting capacity for messages from service centres to users (in the order of 500 bits per second)
- Public Regulated Service (PRS) provides position and timing to specific governmental users requiring a high continuity of service, with controlled access. Available will be two PRS navigation signals with encrypted ranging codes and data
- Search and Rescue Service (SAR) broadcasts globally the alert messages received from distress-emitting beacons. It will contribute to enhancing the performances of the international COSPAS-SARSAT Search and Rescue system.

PPP Programme

The Galileo project is a public-private partnership (PPP) programme. ESA and the EC (1.2BÃ¢â€šÂ¬) will finance Phase 1, the in-orbit-validation (IOV) phase, and it will be carried out under the responsibility of a joint ESA/EC office: the Galileo Joint Undertaking (GJU). In December 2005 the Galileo GIOVE-A test satellite was successfully launched, and performs well in space. Notification of frequency filing at ITU took place on 8th and 9th March 2006. On 23rd May 2006, the Galileo Joint Undertaking released the newest Interface Control Document (ICD) for the OS signal in space for receiver manufacturers, see www.galileoju.com. On 19th January 2006 a 1BÃ¢â€šÂ¬ contract was signed between ESA and Galileo Industries GmbH on the IOV phase, guaranteeing four working satellites in orbit by 2008. More than a thousand highly skilled experts in more than a hundred companies are now at work in Europe to fulfil contractual obligations.

The next phase is deployment, wherein the system will be completed to number thirty satellites, and ground infrastructure will also be completed. The cost of this phase is estimated to be 2.4BÃ¢â€šÂ¬, a third of which to be carried by EC/ESA and two thirds by a private concession-aire. Negotiations between the EC/ESA and the earmarked concession-aire have been struggling on since 2004; finalisation is not expected before the end of 2006. The GJU will then end its work and hand over the public responsibilities to the Galileo Supervisory Authority (GSA). This authority will act as the legal public owner of Galileo, responsible for its development, maintenance and certification, and acting as licensing authority to ensure that the Concessionaire meets its contractual obligations. Details of the concession contract are now further worked out, notably on risk sharing between public and private and between the private partners. Maintenance and replenishment of the infrastructure (220 MÃ¢â€šÂ¬/y) is part of the contract, as its lifetime is twenty years. Running GJU contracts have to be handed over to the GSA and/or Concession-aire. The content of Galileo services as described above could be modified by negotiations between GJU and the earmarked Concessionaire. It is agreed between Concessionaire partners that the locations will be:

- Concession Headquarters in France
- Operating Company in the UK
- One Control Centre in Germany

- one Control Centre in Italy
- Safety-of-Life centre in Spain.

Two consortia were initially bidding for the concession. However, the GJU has accepted a merger between them "because the separate bids were complementary and the EU taxpayer would benefit from this merger". Israel is participating, investing 18MÃ¢â€šÂ¬ in the Galileo project through the MATIMOP Center. China is also participating, with 200MÃ¢â€šÂ¬ in the GJU and signed contracts for a number of development projects. Australia has submitted a proposal to ESA for installation of a Galileo Sensor Station. Co-operation contracts have been signed with India, Morocco, Ukraine and South Korea; negotiations and talks are ongoing with several other countries in South America and Asia.

SBAS Systems

The US Wide Area Augmentation System (WAAS) is basically designed for aeronautical use, although other users have free access. Via geostationary (GEO) satellites the system provides additional GPS ranging, differential corrections and integrity information (6 seconds time to alarm), computed from information collected from 25 reference stations in the US; the system is therefore only usable in the US coverage area. It can be extended to other areas within GEO coverage when reference stations are installed in that area. In the three years of operation, approaches with vertical WAAS guidance have not suffered from vertical errors in GPS/WAAS of more than 11 metres and no hazardous misleading information (HMI) has been reported. WAAS will undergo a considerable upgrade over coming years. From 2015 onwards L5 corrections will be included.

Interoperable with the US WAAS system, Europe has developed the EGNOS system and Japan the MSAS system. By extending reference stations in these areas both systems can be extended to adjacent areas. In July 2005 Initial Operations of EGNOS began on the part of the contractor ESSP in Brussels, a company formed by ESA and a number of European Air Traffic Service providers. SoL services are planned to be operational by mid-2007. Measured horizontal accuracies within the EGNOS coverage area are in the order of 1m. EGNOS information is also distributed over the internet through SISNET. Later in the Galileo development phase the EGNOS system will be integrated with Galileo and operated by the Concessionaire.

India is developing its own SBAS named GAGAN; China is developing a similar system called BEIDOU. The Quasi Zenith Satellite System (QZSS) is a Japanese PPP project that will supplement GPS with three satellites in highly elliptical orbits in order to have at least one satellite near zenith in Japan at all times and so improve availability and accuracy of GPS in urban canyons etc. The first satellite is planned for 2008; it will carry Hydrogen Maser clocks. The URE is expected to be around 30cm.

The FUGRO Starfix and SeaSTAR are commercial SBAS systems for offshore survey work; the FUGRO OmniSTAR-HP (High Performance) solution is a commercial dual-frequency SBAS that provides GPS augmentation of decimetre level accuracy.

GBAS

Hundreds of IALA maritime DGPS stations are operational worldwide. The system works in the former 300kHz maritime radio beacon band. The accuracy is in the order of 5m, often better. Many networks are extended for inland operations, notably in the US, where the NDGPS will have nation-wide coverage by the end of 2006. The intention is that double coverage will soon follow. For hydrographic operations, several RTK networks are operational providing corrections on GPS carrier-phase measurements. The accuracy of these augmentation systems is in the order of cm or better.