GALILEO
A EUROPEAN SATELLITE NAVIGATION SYSTEM

POST 150
Post Note December 2000

On 20 December the European Union Transport Council will consider whether to develop a European, civilian satellite navigation system (Galileo). The two main current systems are run by the US and Russia, under military control, raising issues for Europe of sovereignty and security. This briefing describes satellite navigation, examines the case for Galileo and considers topics such as its funding and management.

WHAT IS SATELLITE NAVIGATION?

Satellite navigation establishes a user's position, movement and time, by measuring the distance to at least four satellites (see **Box 1** for details). Currently, the primary satellite navigation system is the US Department of Defense's Global Positioning System (GPS). A similar Russian system, Glonass, does not presently have a full working constellation of satellites and is used mainly in conjunction with GPS. **Box 2** describes these systems. Signals from both systems are available globally for civilian use, free of charge. The GPS civilian signal was initially degraded so that users could only receive a reduced accuracy. However, this intentional degradation ('selective availability') was removed on 1 May 2000 - at least partly in response to plans for Galileo.

Satellite navigation receivers range from hand-held sets, costing less than £100, to units used for precise surveying which cost more than £10,000. Positioning accuracy can range from 1mm to 100m, depending on factors such as receiver type, the user's environment and processing techniques. The value of international markets for satellite navigation information is expected to reach €50bn by 2005.

AUGMENTING GPS

GPS is generally reliable, but is not designed for 'safety of life' operations and has no performance guarantees. In particular, it does not transmit timely 'integrity' data, to enable users to identify a satellite which is malfunctioning. Thus, there is a perceived need for GPS/Glonass to be augmented, and international plans have been drawn up to create the Global Navigation Satellite System-1 (GNSS-1). Augmentation over Europe will be via the European Geostationary Navigation Overlay Service (EGNOS, see **Box 3**), Europe's contribution to GNSS-1. GNSS-1 will also include the US Wide Area Augmentation System (WAAS), developed for the Federal Aviation Authority, which started trial transmissions in August 2000, and a proposed Japanese system .

BOX 1 HOW THE GLOBAL POSITIONING SYSTEM WORKS

Each GPS satellite transmits a complex digital code. By comparing the signal detected from the satellite with the code generated by the receiver, the time for the signal to travel from the satellite to the receiver can be calculated. Multiplying this by the speed the signal travels (~the speed of light), gives the distance to the satellite. If distances to a minimum of four satellites are measured, the 3-D position of the receiver and its accurate time can be calculated.

The receiver must know both the distance to the satellite and the satellite's precise position in space. Each satellite is in a very accurate orbit. The US Department of Defense also tracks them and sends precise orbital information back up to the satellite, to be included in the broadcast signal. GPS gives a raw horizontal positional accuracy of at least ~20m (95% of the time), with height accuracy ~40m. However, there are two ways of improving this:

- By measuring the wave which carries the coded signal, rather than the signal itself, GPS can give millimetre accuracy. However, this method is more complex (and expensive) than 'normal' GPS, so is used only for high precision applications such as surveying.
- Nearly all the errors associated with satellite navigation can be removed by a technique known as differential GPS (dGPS). dGPS involves placing a stationary GPS receiver at a known position and measuring the supposed range to each satellite. Corrections are then calculated and used by receivers in the nearby area. dGPS can give sub-metre accuracy, but is limited by distance from the reference receiver. A free dGPS service is operated by the General Lighthouse Authorities, giving 10m accuracy up to 50 nautical miles around the coasts of the UK and Ireland.

Satellite navigation does not generally work inside buildings but is widely used in urban areas augmented by other information sources (such as digital maps, inertial sensors and terrestrial radio) that overcome shadowing by buildings.

GALILEO

Galileo is a joint initiative between the EU and the European Space Agency (ESA)[1] for a European, civilian, global navigation system to be part of GNSS-2[2]. In July 1999 the EU Transport Council asked the European Commission (EC) to begin the Galileo definition phase and report the results by the end of 2000. The Council will consider the issue at a meeting on 20 December 2000, when the EC would like a clear decision to proceed. However, it is probable that a decision will be subject to conditions, which may require further discussion at the Council meeting in autumn 2001.

The case for Galileo

Current satellite navigation systems are under US and Russian military control. The 'zero option' would involve relying on a US-run modernised GPS (the US is unwilling to share control of GPS), which would be the cheapest option in the short term for

[1] ESA has 15 member states: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Norway, the Netherlands, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Canada also takes part in some projects. Norway and Switzerland are members of ESA but not the EU.

[2] The successor to GNSS-1.

BOX 2 CURRENT SATELLITE NAVIGATION SYSTEMS

GLOBAL POSITIONING SYSTEM (GPS)

GPS was created by the US military for accurate position, movement and time measurement. The first GPS satellite was launched in 1978 and the system declared operational for civil users in 1995. It currently uses 24 satellites (plus 3 spares), in orbit 20,200km above the Earth. These continuously broadcast position and time data and are distributed so that a minimum of six satellites are generally in view anywhere in the world. On the ground, there is a master control station in Colorado and five monitor stations worldwide to track the satellites (three of the stations also send information to the constellation).

GPS broadcasts two types of signal:

- Standard Positioning Service (SPS), available for civilian use, broadcast at a single frequency.
- More accurate Precise Positioning Service (PPS) for military use, broadcast using two frequencies.

GPS Modernisation

The US has stated that it will continue to provide continuous GPS coverage worldwide, free of charge, to civilian users. It plans to broadcast a second civilian signal from satellites launched after 2003, and a third civil signal for services where lives are at risk will be added to satellites launched after 2005. These new signals will significantly improve accuracy, availability and reliability.

It also plans to modernise the military signal. The US NAVWAR programme aims to ensure that GPS civil signals can be selectively denied in an area of conflict, while US and allied military (and civilians outside the region of conflict) can continue to use GPS. New military codes are planned, with better encryption and more readily distinguished from civilian code. Current modernisation plans will take GPS up to 2010. A US Department of Defense study is considering requirements for the next generation of satellites beyond 2010, known as GPS III.

GLONASS

Glonass, the Russian satellite navigation system, nominally involves 24 satellites in orbits at 19,100km. It became fully operational in January 1998, but the satellites have been unreliable. Although 73 have been launched since 1982, only 11 satellites are currently available. There are two types of navigation signal – standard precision, for civilian users, and high precision for military use. The civilian signal has a horizontal accuracy of around 60m. Some receivers detect both GPS and Glonass signals, to maximise the number of visible satellites. Despite continued concerns over funding, three new satellites were launched in October 2000. Modernised Glonass-M satellites with a longer lifetime are planned for launch from 2001. There is also a possibility of Chinese participation in Glonass.

OTHER SYSTEMS

There are other satellite navigation systems available, either commercially or for specific applications. These include the Omnitracs/Euteltracs commercial system, with over 350,000 users, and the SARSAT/COSPAS search and rescue system.

BOX 3 EGNOS

EGNOS is a collaboration between the European Commission (EC), the European Space Agency (ESA) and Eurocontrol, the air navigation safety organisation. Costing ~€300m for design, development and validation (of which €200m is being provided by ESA), the UK has contributed €40m. It will consist of three geostationary satellites broadcasting GPS-like signals and a network of ground stations providing integrity data and wide area differential GPS (Box 1). EGNOS is due to start operation in 2003 and is already broadcasting test signals.

Europe. However, as satellite navigation is integrated into European transport, industry and services, reliance on GPS leaves Europe vulnerable to unilateral US decisions. Also, operating GPS and Galileo in parallel would increase availability and reliability of service, as more satellites could be seen. Other advantages for Europe seen by the EC include:

- Social - improved safety and efficiency of transport systems, better services for the citizen.
- Industrial competitiveness - stimulating competition, increasing market share (particularly for the space and receiver equipment industries).
- Economic - greater revenue for end-users and service providers, creation of ~ 20,000 jobs.

Proposed system

Galileo plans envisage 30 satellites in medium earth orbit (MEO) at ~23,000km. It would be a global system, with regional and local augmentation (for example, to provide better integrity data over Europe, or higher precision at an airport). Galileo is planned to be as accurate as modernised GPS, but would also provide a guarantee of continuous transmission, integrity data and liability for its quality of service. However, only a basic service may be free of service charges. Prototype Galileo satellites would be launched in 2004, with full operation by 2008 (although some analysts suggest this should be sooner, to take advantage of the rapidly developing market). The EC has identified three main services:

- General interest - open access and free of service charge, for the mass market. Higher precision than today's GPS but no service guarantee.
- Commercial service - a subscription service, with service guarantees and integrity monitoring.
- Public (state) services - restricted to authorised users, high integrity, with encryption, certified for safety of life applications. However, there is some debate as to whether an encrypted system is necessary. Safety of life applications might be able to use the commercial service.

A related communications service and a search and rescue service are being considered. The World Radiocommunications Conference 2000 allocated extra radio spectrum for satellite navigation, but the Galileo signal structure and its relation to GPS/ Glonass and other spectrum users are still to be determined.

Cost

Galileo is planned to be developed in phases. The definition phase runs to the end of 2000. This would be followed by a development and validation phase (2001-2005), then a deployment phase (2006/7). The total cost of Galileo to the end of the deployment phase is estimated by the EC as €3.25bn (not including the cost of market development or local augmentations of the system). Operational costs after 2008 are estimated at €222m per year.

It is planned to finance Galileo through a public private partnership (PPP - see Issues below). There is recognition that PPP funding is unlikely to be forthcoming in the validation and development phases as revenue streams are still far in the future, so €1.1bn would be provided from public funds (around half from ESA and half from the EU, with EU funding mainly from its Trans-European Networks programme). For the deployment phase, €1.5bn is anticipated from the private sector and €0.6bn from elsewhere. Contributions to the EU are currently in proportion to GDP. If this were true for all public sector contributions to Galileo, the UK would contribute about 18% of the total.

Definition phase

Galileo's definition phase has been split into four main projects:

- GALA - designing the overall system, worth €27m. Led by Alcatel Space Industries (France), including over 60 European companies.
- GalileoSat - worth €20m, defining the space segment and ground systems. Led by Alenia Aerospazio (Italy) and funded through ESA.
- Geminus - defining services. Led by Racal (UK).
- Integ - integrating EGNOS into Galileo. Led by Alcatel.

The definition phase has cost €80m, funded half each by ESA and the EU, with EU funding primarily from the 5th Framework R&D programme. Of this, the UK contributed €7m to ESA, plus an (automatic) 18% contribution to the EU budget as a whole.

GALILEO ISSUES

Revenue and PPP

Galileo must generate revenue if a PPP is to proceed. Satellite navigation applications are likely to be ubiquitous (**Box 3**) and Galileo's benefits to Europe up to 2020 have been estimated by the EC as €74bn. But it is unclear how much of this will be converted into revenue for those running the Galileo system. GPS and Glonass are currently free to users, so it is unlikely that a price sensitive mass market would be willing to pay service charges for Galileo. Hence, Galileo plans include a basic service free of charge at the point of use, as part of Europe's infrastructure. One proposal is a small levy on each of the estimated hundreds of millions of Galileo receivers.

BOX 4 SATELLITE NAVIGATION APPLICATIONS

Transport

Land

Satellite navigation systems are increasingly being built into cars for location and route finding. Traffic and travel information could also be provided for private cars and public transport. Satellite navigation can aid breakdown organisations and emergency services - for example, ambulances already use vehicle location information to identify the ambulance closest to an emergency and the optimum travel route. In future, satellite navigation could be used for automatic road tolling, speed management and perhaps even automatic vehicle control. On railways, satellite navigation information could aid track surveying and traffic management, to improve safety and minimise delays.

Sea

Mariners already make extensive use of GPS. Fishing fleets navigate to optimum fishing locations and track fish migrations. Hydrographic surveying, marine construction and rescue operations all use satellite location information. The International Maritime Organisation requires many ships to carry a GPS-based system which can send emergency distress signals including location and time data. A new Universal Automatic Identification System aims to prevent shipping collisions and depends on GPS for timing.

Air

Aviators use satellite navigation widely, although air transport is not permitted to use GPS as a primary navigation source as there is no integrity and availability guarantee. Together GPS and Galileo would provide a redundant system (with integrity) and hence the possibility of reducing terrestrial navigation aids, given regulatory acceptance. Satellite navigation could enhance safety, increase system capacity and allow landing in poor visibility conditions.

Personal

The next generation of mobile phones will allow relatively high speed data transfer. In April 2000, the UK Government auctioned the radio-communications spectrum for these third generation mobile services for £22bn. Adding location-based services could increase the appeal of these applications - for example, a mobile phone or digital organiser could direct the user to the nearest cinema. Mobile phone cells will be able to provide position information (particularly in urban areas), but for accuracy of a few metres, some combination of satellite navigation and cell identification may be the best solution, with the satellite navigation receiver built into the phone. These applications are likely to be accelerated by a US requirement that emergency services can locate mobile phone '911' calls by 2001.

High accuracy satellite navigation also introduces new possibilities for tracking individuals (although satellite navigation itself is passive, so a transmitter has to also be carried for tracking). The location of children, people with Alzheimer's disease or prisoners could be followed, and even their health monitored. However, this raises civil liberties issues.

Professional use

Professional applications which use satellite navigation include:

- *Land surveying* - accurate mapping and construction.
- *Environmental protection* - oil spill tracking and clean-up, mapping the habitats of endangered species, monitoring water levels.
- *Agriculture* - monitoring farm land and livestock.
- *Law enforcement* - tracking stolen vehicles, border surveillance
- *Timing* - synchronisation of digital telecommunications and power plant generators, timing of financial transactions and internet security protocols.

There are market areas where a service fee for improved features such as accuracy, integrity and liability cover might be viable - for example, oil exploration. Galileo could also be certified for safety-critical applications. The EC has suggested that regulation may be introduced to require its use in certain applications. Another possibility is a "shadow toll", where the private operator provides a public service and is then paid by the public sector.

Current plans require a minimum financial contribution of €1.5bn from the private sector during Galileo's deployment phase in 2006/7. There is currently no commitment of funds from potential PPP partners. Before this can happen a number of conditions will need to be met, including details of the business case and PPP structure. This will have to address the balance between freedom for the private sector to develop services and protection for public sector applications.

Management

One of the primary concerns expressed by industry has been over the management of the programme (**Box 5**). It is generally recognised that the current joint ESA/EC management structure is far too complex but precise details of the future management are not yet clear. While uncertainty remains over future management structures, potential PPP partners are unlikely to commit funds.

International co-operation

It is essential for Galileo's success that it is interoperable with GPS, so receivers can easily detect both sets of satellites. Negotiations are underway between the US and Europe but there are difficulties. The US would prefer Galileo be run as a publicly financed service, offering free access. Progress in negotiations is likely to be helped by a clear political decision to proceed with Galileo.

Discussions with Russia are focussing on independent but complementary constellations, with shared development and deployment costs and industrial co-operation. Other countries, such as Canada, have also expressed interest, although the exact nature of their involvement is yet to be determined.

Security

Although Galileo is civilian-led, satellite navigation is of interest to the military in two respects. First, European and allied forces will make use of the system. It has been suggested that the proposed public (state) service, with encryption, could be used for military purposes. Encryption adds costs to the satellite and ground segment hardware, so its precise benefits will need to be detailed. If it is intended for military use, there is concern that this may undermine the civilian, independent nature of the system. Second, hostile forces may use the signal or attempt to jam or distort it. Galileo may thus consider means to deny service in regions of conflict.

BOX 5 GALILEO ORGANISATION AND MANAGEMENT

Currently, the EC is responsible for the political management of the programme, system architecture and international dimensions. ESA is focussing on design of the space segment and application development. Strategic management is run by a Steering Committee with members from EU states and observers from ESA, Norway and Switzerland (who are members of ESA but not of the EU) and Iceland. There is also a joint EC/ESA Programme Management Board, a joint Galileo Programme Office, and both ESA and the EC have Galileo project offices, which report to separate Committees.

It is recognised that this structure is too complex. Therefore it is proposed that from 2001, an coordinated management framework should be created, involving the Commission and ESA. This would oversee a technical management office in ESA. Later, technical development (and operation) of the system would be transferred to a commercial 'vehicle' company consisting of the PPP partners, to finalise satellite specifications and procure the system.

In the operational phase, the vehicle company would work with a public agency, with an investment budget combining all the funds for the project (EC, ESA and private sector). In addition, a regulatory body would oversee the field (no general civil regulations currently exist for satellite navigation).

Role of the UK

Government policy on Galileo is led by the Department of the Environment, Transport and the Regions, who liaise with other parts of Government such as the British National Space Centre (BNSC, a partnership of UK Government Departments). In its inquiry into UK Space Policy, the House of Commons Trade and Industry Select Committee recommended "*a sustained effort [...] to ensure joined-up thinking across Government*" on the Galileo programme.[3] It also heard evidence from industry that Government's reluctance to commit funds early to EGNOS, because they hoped to find matching private sector funding, led to lower level roles in the consortium for UK companies.

The UK Government is broadly supportive of Galileo in principle and has argued strongly during the definition phase for a PPP. It recognises that Galileo could bring benefits to British business and individuals and allow the UK to build on its high-tech expertise. However, the Government considers that Europe must be sure that the project offers the UK and EU taxpayer good value for money. To help meet this objective the Government has specified a number of conditions, covering financial and management aspects of the project and PPP, which it considers should form part of any decision by the Council to proceed.

[3] House of Commons Trade and Industry Committee, UK Space Policy, Tenth Report of the 1999-2000 Session, 4 July 2000