

Journées Luxembourgeoises de Géodynamique;

A European project: the GALILEO project

François Barlier

Since the early 's1960, it was clear that navigation and positioning could be performed using radio signals transmitted from space vehicles. For the US Navy and the US Air force in the beginning, the purpose was to demonstrate the feasibility of a Defense Navigation Satellite System. So, the US Navy sponsored a program, TRANSIT, which was operational for about 35 years. In Europe several global positioning systems were proposed very early as GEOLE (1968) by CNES, or POPSAT (1978) by DGFI but they were not adopted for economic possibilities. At the Schloss ELMAU meeting in Germany in 1978, during the SONG European meeting dedicated to space geosciences applications, a general positioning system was proposed to be operational in 1990 but unfortunately this program was not realized. However, it proved the scientific community was very keen very early on the importance of a global and very precise positioning system. On the other hand, in Europe radio tracking satellite systems were developed like PRARE in Germany or DORIS system in France. In USA the Global Positioning System, the GPS system, was proposed in the 70's. The purpose was to develop a new positioning and navigation system revolving at very altitudes (20000 km) when compared to previous projects (a few thousand km) but it was not dedicated to scientific purposes because it was thought the precision would not be sufficient to open new possibilities in scientific uses. It was wrong. This original idea of the system was pertinent and it was a success for operational and military operations and also for scientific uses. Indeed and fortunately, the system was based on very precise atomic clock on board the satellites and by this way, scientific applications were developed in using the phase differences between satellites and receiving stations. As a result, GPS was a great success concerning navigation and precise positioning and including also the dissemination and the diffusion of a very precise time at a planetary scale. To some extent, many people are now very much GPS dependent around the world but they ignore this fact as we are for example electric energy or telephone dependent!

At this stage, the role of GPS was more and more important every day and the question rose, if it was reasonable to rely so many strategic and important applications upon a unique system developed in the beginning only for military objectives and always under the military control. It was the reason why in USSR, a similar system was developed but not at the same level of success for economic reasons. It was the Global Navigation Satellite System or GLONASS System, which continues also to be used. Moreover in any case, a unique system cannot bring integrity and security what is absolutely required for example for air traffic and many other applications.

In this context, in Europe, a project called GALILEO was proposed in 1994. This name is not an acronym and its origin is sometimes discussed but in any case, it makes reference to a very famous Italian scientist the role of which was important to develop the determination of longitudes thanks to the observations of Galilean satellites. We would like to briefly describe this project.

GALILEO is a European Program for Global Navigation Services, supported by the European Space agency and the European Commission. It is specifically designed for civil purposes. The main characteristics are:

- A free public service with performances better or the at the same level than the future GPS service in 2008;
- A service, which is commercial or governmental;

- A financial support which is a public and private partnership;
- A system, which must be compatible and interoperable with GPS.

The management is based on a novel company structure: GALILEO Joint Undertaking founded by ESA and the European Union.

From a very general point of view, GPS and GALILEO are similar concerning the techniques and the concept but with some differences.

GALILEO includes 30 satellites at 23600km of altitudes with an inclination with respect to the equator of 56° for the 3 fundamental orbital planes versus 27 satellites at 20200 km of altitude with an inclination of 55° for the 6 fundamental orbital planes. Galileo satellites will be regularly positioned in the 3 orbital planes. Efforts have to be made to have a better homogeneous accuracy thanks to the satellite constellation and the ground system, a better reliability at high latitudes and in big cities thanks to more satellites at higher altitudes, a service guarantee. The interoperability of GPS and GALILEO will be also a decisive factor to improve globally the present status of good and very accessibility

The satellites will have an Earth-pointing axis, a mass of 700 kg, a power of 1500 w, and a revolution period of 14 hours. Three frequency bands will be used: 1164-1215 MHz; 1260-1300 MHz; 1550-1563 and 1587-1591 MHz. The signals will deliver ranging codes and data messages. The system must use the EGNOS complementary system based on geostationary satellites. The European Geostationary Navigation Overlay service (EGNOS) results from a tripartite agreement between the European Commission, the Euro control service, and ESA. Its objective is to disseminate on the GPS-L1 integrity signals on the health of the GPS/GLONASS constellation. It disseminates also corrections of ephemerides to get a precision of about 5 m and now between 1 and 2 meters in October 2002. EGNOS infrastructure will be integrated into GALILEO. Operation centers are located in Madrid and Toulouse. It is of interest to note the existence of several differential GPS services, so the SKYFIX DGPS system and JPL differential GPS system. The SKYFIX DGPS system has been developed by the Racal Survey Group to deliver a very good precision and constitutes now a very large commercial DGPS network in the world. The JPL's Global Differential GPS system wants to offer a decimeter real time positioning, anywhere, anytime. The 'Organisation Maritime Internationale' supports also a dedicated DGPS service for the maritime navigation along the coasts.

The GALILEO system must include a control segment with 2 centers, 5 sites of telemetry and telecommand and 12 orbitography and synchronization stations, then an integrity segment with a satellite observation station network, data processing and links between satellites and stations, finally a communication network.

The purpose is to have with respect to the present situation with GPS and GLONASS,

- A better homogeneous accuracy thanks to the new satellite constellation and the ground segment;
- A better reliability thanks to satellites at high latitudes and better performance in big cities;
- A service guarantee, what is required for navigation by air, road, and sea;
- A better security and a better integrity.

The management will be performed by a novel company structure: the GALILEO Joint Undertaking founded by ESA and the European Union.

First launchings of Galileo satellites will 2005 and 2006 and the start of an operational system should be in 2008. The whole system, which includes GPS, GLONASS, GALILEO and the

complementary components as EGNOS, is called Global Navigation Satellite System (GNSS-2 or GNSS).

For Europe, the critical points are: the technology of atomic clocks, the reality of financial support over a long term by a private public partnership, the set-up of a new type of organization in Europe.

The scientific applications are as with GPS and in a very complementary and very positive interaction: the plate tectonic motion, the crustal deformation, the Earth rotation parameter determination, the geocenter location determination, the precise orbit determination of low satellites like CHAMP or GRACE or JASON, the attitude restitution of satellites, the tropospheric and stratospheric sciences, the diffusion of time and frequency. This list is not exhaustive; all these objectives are comparatively well known in the Luxembourg group. We would like to emphasize the crucial role of international services, International Earth Rotation Service (IERS), IGS (International GPS Service, the central bureau of which is located at JPL in California) processing with a great success the GPS and GLONASS data to determine very precise orbits allowing their scientific uses. GALILEO data will have to be integrated in this service.

We can be optimistic on GALILEO and the new concept of GLOBAL NAVIGATION SATELLITE SYSTEM or GNSS. Many applications are enthusiastic.