→ GALILEO: THE FUTURE BECOMES REALITY

→ WHAT IS GALILEO?

The Galileo navigation system will provide high-quality positioning, navigation and timing services to users across the whole world, as a civil-controlled service offering guaranteed continuity of coverage. Galileo is the outcome of a partnership between ESA and the European Commission.

→ TAKING SHAPE

An initial constellation of four 'In-Orbit Validation' (IOV) Galileo satellites – the minimum number to guarantee the provision of exact positioning and timing at test locations – was launched in 2011 and 2012. These created the foundations of Galileo, validating the overall Galileo system while also forming the operational nucleus of the full satellite constellation to come.

With four satellites in orbit, Galileo was able to perform its historic first position fixes in March 2013. This opened the way to establishing the full Galileo system, with additional satellites and ground stations across Earth.

→ GALILEO DEPLOYMENT

The remainder of the Galileo constellation is being progressively deployed in batches, some launched in pairs (using the Soyuz) and some in fours (using the Ariane 5).

With sufficient satellites in orbit and ground stations in place, the Galileo system can begin delivering initial navigation services to users worldwide.

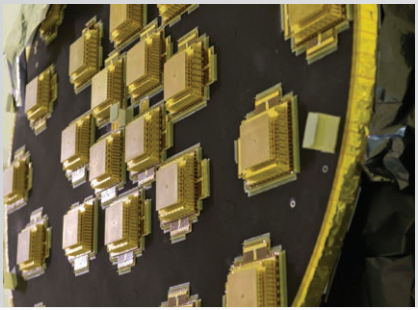
The constellation will reach its Full Operational Capability (FOC) – 24 operational satellites plus spares – which will then enable the full range of Galileo services by the decade's end.

→ STEPS SO FAR

Two test satellites, GIOVE-A and –B, were launched in 2005 and 2008, respectively, securing the frequencies reserved for Galileo, demonstrating its atomic clocks in orbit and gathering orbit environmental data.

The next step was the four pioneer Galileo In-Orbit Validation satellites, launched in pairs in 2010 and 2011, sufficient to achieve navigation fixes and validate the system design.

Then the remainder of the Galileo system began to be built up, with FOC satellites being launched from 2014 onwards. The goal is to reach a point where at least four Galileo satellites are visible from any point on Earth, so the system can be used anytime, anywhere.



→ GALILEO SERVICES

Satellite navigation has swiftly become a crucial part of everyday life and work. Using signals broadcast by satellites in orbit, anyone with a receiver can fix their 3D location, spurring a host of novel applications. The signals' time stamps also serve to synchronise global electronic transactions, such as inter-bank exchanges, telecommunications and energy networks.

Once Galileo becomes operational, a portfolio of navigation services will be offered, based on varying user needs:

Open Service The navigation signal will be accessible by the general public free of charge, providing improved global positioning.

Safety-of-Life Service Available in Europe since 2011, this service is available through the European Geostationary Navigation Overlay Service, EGNOS. By improving GPS signals, it offers guaranteed increased performance for critical transport applications such as aviation and precision maritime navigation. It includes a key 'integrity' function to warn users promptly if the system becomes less reliable. EGNOS will be extended to augment Galileo as well.

Public Regulated Service Two encrypted signals with controlled access for specific users such as governmental bodies.

Search and Rescue Service Galileo will contribute to the international Cospas–Sarsat system for search and rescue. A distress signal will be relayed to the Rescue Coordination Centre, and Galileo will inform users that their situation has been detected.

Commercial Service Galileo will provide a signal for high data throughput and highly accurate authenticated data, particularly interesting for professional users.

→ GROUND SEGMENT

The satellites in space are only the tip of the Galileo iceberg. A worldwide ground network – one of the most complicated developments ever undertaken by ESA – is essential to oversee the satellites and ensure the continued reliability of the time and positioning information embedded within the navigation signals from orbit. This requires both a Ground Control Segment and a Ground Mission Segment.

The Ground Control Segment, which monitors and controls the satellite platforms, is based in the Galileo Control Centre in Oberpfaffenhofen near Munich in Germany, and linked to telemetry, tracking and telecommand stations in Kiruna, Sweden, and Kourou, French Guiana.

Satellite navigation relies on the receiver calculating the distance to the orbiting satellites with 'nanosecond' accuracy – to a billionth of a second. For this the receiver must know with high precision the point in time at which the signal was transmitted by the satellite, and its position in orbit.

The Ground Mission Segment, located in the other Galileo Control Centre, in Fucino, central Italy, ensures cutting-edge navigation performance from Galileo by continuously checking on each

LEGEND

- GCC: Ground Control Centre
- GSS: Ground Sensor Station
- ULS: Uplink Station
- TTCF: Telemetry, Tracking and Command Facility
- SAR MEOLUT: Search and Rescue – Medium Altitude Earth Orbit Local User Terminal
- GSMC: Galileo Security Monitoring Centre
- TGVF: Timing and Geodetic Validation Facility
- IOT: In-Orbit Test Centre
- LEOPCC: Launch and Early Operations Phase Control Centre

satellite and producing a correction message to compensate for any slight timing or orbital drift. This correction message is uplinked to the satellite for rebroadcast to users embedded in the navigation signal every 100 minutes or less.

In the future, Oberpfaffenhofen and Fucino will host equivalent facilities, working together as 'hot backups' with realtime data synchronisation to increase the system's overall robustness.

→ FINDING YOUR PLACE

Your satnav receiver needs a minimum of four satellites in the sky, their onboard clocks synchronised and orbital positions monitored by global ground segments. It picks up signals from each satellite, which incorporate a precise time stamp.

By calculating the length of time it takes for each signal to reach your receiver, the receiver builds up a three-dimensional picture of your position – longitude, latitude and altitude – relative to the satellites. Future receivers will be able to track Galileo satellites in addition to US and Russian navigation satellites, providing metre-scale positioning accuracy almost anywhere on or even off Earth: satnav is also heavily used by satellites.

→ A EUROPEAN PARTNERSHIP

The definition, development and IOV phases of the Galileo programme were carried out by ESA and co-funded with the European Commission. The subsequent FOC phase is managed and funded by the Commission. The Commission has delegated the role of design and procurement agent to ESA for the FOC phase. At the same time as the satellites are being assembled on a production-line basis, ground stations are also being established on far-flung European territories around the globe.

→ INDUSTRIAL PARTNERS

Building Europe's satellite navigation system is a complex, multifaceted effort, involving many partners across the European continent:

- **Thales Alenia Space Italy** is supporting ESA in the overall design of the combined space- and ground-based Galileo system
- **Airbus Defence & Space** (formerly Astrium in the UK) contributes the satellite control facilities, known as the Ground Control Segment
- **OHB** in Germany and **SSTL** in the UK are building the 22 FOC satellites; OHB is producing the satellite platforms, while SSTL is providing the navigation payloads
- **Airbus Defence & Space** (formerly Astrium in Germany) led construction of the first four IOV satellites, with Thales Alenia Space Italy responsible for satellite integration and Airbus D&S in the UK providing navigation payloads
- **Thales Alenia Space France** oversees the navigation service facilities, called the Ground Mission Segment
- **Arianespace** is contracted to launch the Galileo satellites, using both Soyuz and Ariane 5
- **Spaceopal** operates the Galileo system. This company is a joint undertaking between Italian company Telespazio and German firm Gesellschaft für Raumfahrtanwendungen (GfR) mbH, part of the DLR German Aerospace Center

FACTS AND FIGURES

Satellites 1–4	
Launch mass	700 kg
Size	2.74 x 14.5 x 1.59 m (solar wings deployed)
Available power	1420 W
Satellites 5–26	
Launch mass	732.8 kg
Size	2.5 x 14.67 x 1.1 m (solar wings deployed)
Available power	1900 W
Launch vehicles	Soyuz ST-B (two-satellite configuration) or Ariane 5 (four-satellite configuration)
Launch site	Europe's Spaceport near Kourou, French Guiana
Navigation payload	Passive hydrogen maser atomic clocks (two) Rubidium atomic clocks (two) Clock monitoring and control unit Navigation signal generator unit L-band antenna for navigation signal transmission C-band antenna for uplink signal detection Two S-band antennas for telemetry and telecommands Search and rescue antenna
Orbit	23 222 km, 56°
Operational lifetime	more than 12 years
Satellite control centre	Oberpfaffenhofen Galileo Control Centre in Germany with CNES in Toulouse, France with the support of ESOC in Darmstadt, Germany for launch and early operations, while Redu in Belgium performs the in-orbit test campaign
Navigation control centre	Fucino Galileo Control Centre in Italy
	www.esa.int/Our_Activities/Navigation ec.europa.eu/galileo

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