Galileo – keeping time with atomic clocks

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Update, 20 October, 10.55 CEST: Launch is delayed. Latest news at Arianespace or ESA.

An equation with four unknowns – at least, that is how satellite navigation is summarised by Walter Päffgen, Managing Director of the German Aerospace Center's (Deutsches Zentrum für Luft- und Raumfahrt - DLR) Space Applications Company (Gesellschaft für Raumfahrtanwendungen; GfR) and Head of the Galileo Control Centre located at the DLR facility in Oberpfaffenhofen, near Munich. Three coordinates for spatial position and one for time. Taken together, these will give the position of a vehicle on Earth's surface in the new Galileo satellite navigation system. But for this equation to yield the correct result anywhere on Earth, a total of 30 satellites carrying highly accurate atomic clocks will be placed in orbit by 2018. The first two are due to be launched from Europe's Spaceport in French Guiana on 20 October 2011.

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"In order to achieve the desired accuracy, we need to measure the transit time of the signals with nanosecond precision, then use this to determine the distance between the satellite and the location on the ground," explains Päffgen. The Galileo signals travel to Earth at nearly the speed of light, or about 300,000 kilometres per second. If the measurements were only a microsecond out, there would be a 300-metre difference between the actual and the calculated position on the ground. Anyone wanting to consult their navigation device at a crossroad to check which way to turn would have some difficulties. "It is for this reason that we have the latest generation of atomic clocks on board the satellites," continues Päffgen. Every signal that the satellites send to Earth includes the very precise time of transmission, so that the transit time of the signal can be accurately calculated. To ensure that the clocks in all the satellites are keeping time correctly, the ground stations specify the time – the control centres supply the reference time that the Galileo satellites in space are synchronised with.

30 satellites to control

In total, ensuring a flawless function of the European navigation system requires 30 satellites at an altitude of 23,222 kilometres, 30 to 40 antenna stations on the ground across the world and control centres in Toulouse, France, Darmstadt and Oberpfaffenhofen in Germany and Fucino in Italy. The satellite launches and initial operations phases will be monitored alternately in Toulouse and Darmstadt; Oberpfaffenhofen will then take over operation of the satellites and Fucino will be responsible for processing the navigation data. According to Päffgen, this makes Galileo more accurate than the US GPS satellite navigation system. "Many applications will only be possible with this improved accuracy. Container trains are a good example of this," he says. When trains are running on adjacent tracks in a station, you cannot use just a fairly accurate positional calculation to allocate the correct track to a freight train. Even differences of a few metres make it impossible for the user of the navigation system to track their container during its journey.

Shortly after the launch of the first two satellites, there will be a lot of work for DLR GfR. As the operator of the Galileo Control Centre under contract to the European Space Agency (ESA), DLR GfR will monitor the status of the satellites and the systems on board, as well as their orbits. Each satellite transmits some 20,000 pieces of data about its status back to Earth. In the future, when the 30 Galileo satellites are in orbit, a massive amount of data will be collected for analysis and assessment by engineers. In the case of an emergency – if a satellite is not functioning as it should – the engineers in Oberpfaffenhofen will need to intervene and correct the problem. "In the initial few months, we will be checking out the first two satellites very thoroughly," explains Päffgen. Systems must be prepared for power-up and every part of the satellites' payloads will undergo an extensive programme of tests.

Fit for space

ESA has already demonstrated that the new atomic clocks and the navigation signal generator will work in space with two test satellites, GIOVE A and B, launched in 2005 and 2008. In addition, eight transmitting stations in the Alps have been used to simulate satellite signals coming from space for receivers in the Berchtesgaden region since February 2011. This has enabled developers to test their applications under 'real' conditions in the Galileo Test and Development Environment (Galileo Test- und Entwicklungsumgebung; GATE). The first opportunity for calculating a location based purely on Galileo satellite navigation data from space will come in August 2012, when two additional satellites will be sent into orbit. The first quartet will then be complete; position calculations are only possible with a minimum of four satellites.

With 30 Galileo satellites and 24 GPS satellites – the two systems will be interoperable in the future – there will be an increased ability for users to receive signals from more than four satellites and thus be able to determine their position with greater accuracy. "Then, it will even be possible to receive an adequate satellite signal in narrow urban canyons, for example," says Päffgen. But one thing is essential to ensure that nobody using a mobile phone or a car will get lost in the city – the clocks in space must be accurately synchronised with the time provided by the control centres.

Live broadcast

DLR and ESA will be broadcasting the launch of the first two operational satellites, planned for 20 October 2011, live from the Galileo Control Centre at the DLR site at Oberpfaffenhofen.

- www.DLR.de/live

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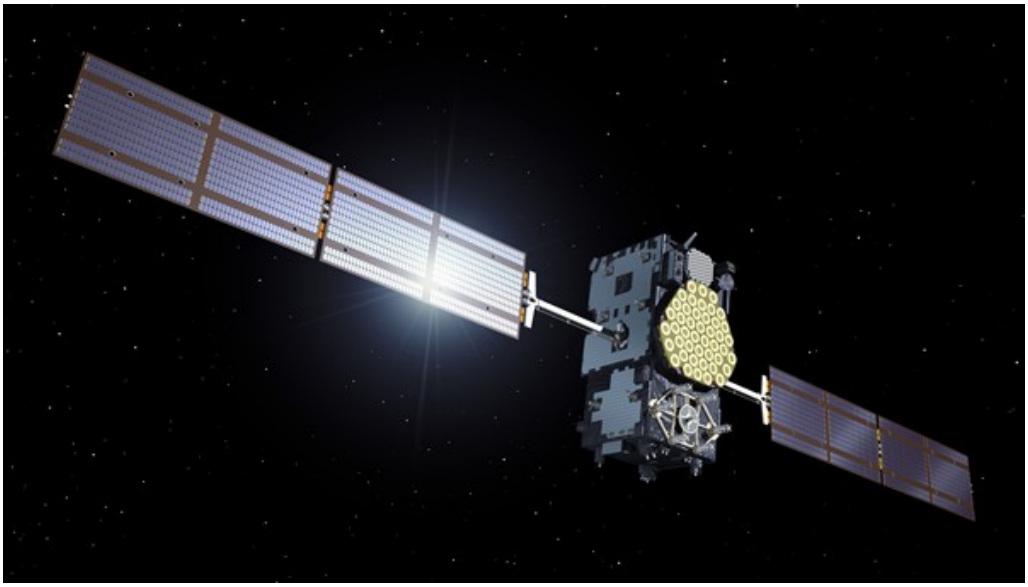
Galileo In-Orbit Validation satellite



Artist's impression of a Galileo In-Orbit Validation (IOV) satellite.

Credit: ESA.

Testing the Galileo satellite

The Galileo satellite during testing at Thales Alenia Space in Rome during May 2011.

Credit: ESA - S. Corvaja, 2011.

Galileo Control Centre at the DLR Oberpfaffenhofen site

The Galileo Control Centre at the DLR site in Oberpfaffenhofen, near Munich.

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