Galileo satellites set for year-long Einstein experiment

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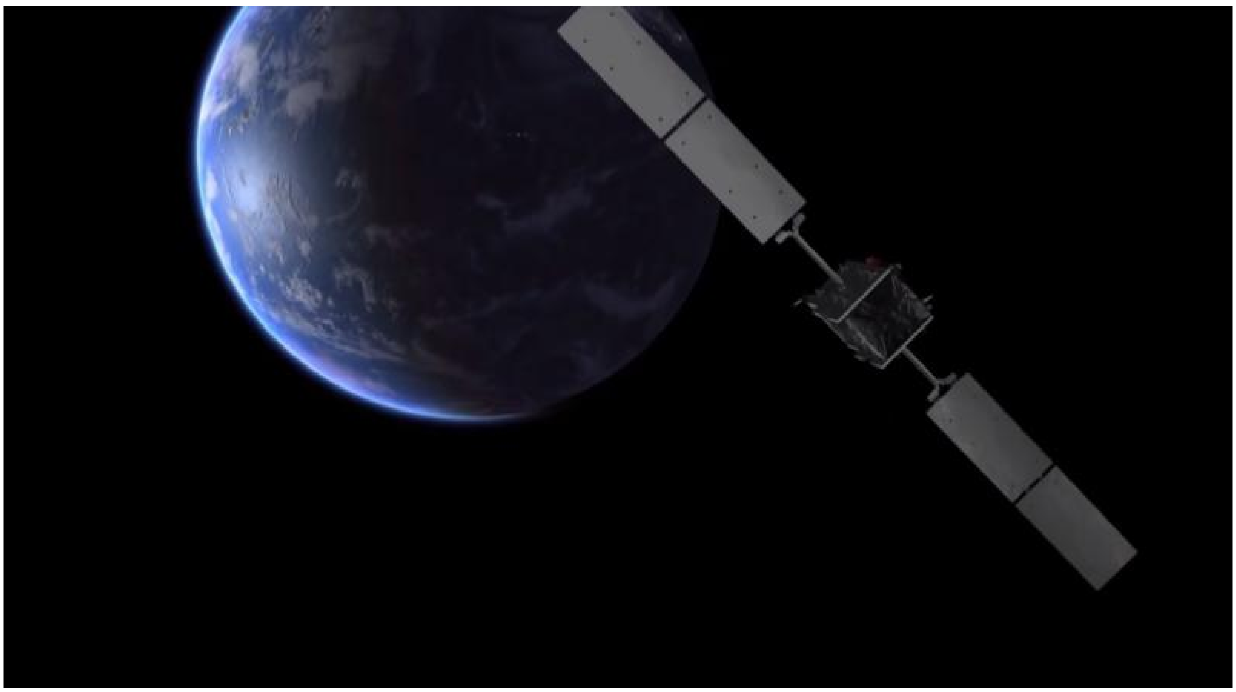

Galileos 5 and 6 were launched together by a Soyuz rocket on 22 August 2014, but the faulty upper stage stranded them in elongated orbits that blocked their use for navigation. Orbital modifications followed to make them usable, and their future operational use in the Galileo constellation is now under study. In the meantime, the satellites have accidentally become extremely useful scientifically, as tools to test Einstein's General Theory of Relativity by measuring more accurately than ever before the way that gravity affects the passing of time. Although the satellites' orbits have been adjusted, they remain elliptical, with each satellite climbing and falling some 8500 km twice per day. It is those regular shifts in height, and therefore gravity levels, that are valuable to researchers. The year-long experiment will follow a similar methodology to the

1976 Gravity Probe A experiment, with a continuous two-way microwave link between a spaceborne hydrogen maser atomic clock and reference hydrogen masers back on the ground to pinpoint frequency modulation due to the 'gravitational redshift' – changing time duration due to shifting gravity levels as the satellite periodically moves further away from Earth and then back again. The long duration of the test – known as the Fundamental Physics with Galileo: GNSS General RElATivity experiment, or GREAT – opens up the prospect of gradually identifying errors in the signal from factors such as satellite temperature changes and orbital model inaccuracies, potentially to quadruple the accuracy of the Gravity Probe A results, which remain the best available. Credit: GSA

Europe's fifth and sixth Galileo satellites – subject to complex salvage manoeuvres following their launch last year into incorrect orbits – will help to perform an ambitious year-long test of Einstein's most famous theory.

Galileos 5 and 6 were launched together by a Soyuz rocket on 22 August 2014. But the faulty upper stage stranded them in elongated orbits that blocked their use for navigation.

ESA's specialists moved into action and oversaw a demanding set of manoeuvres to raise the low points of their orbits and make them more circular.

"The satellites can now reliably operate their navigation payloads continuously, and the European Commission, with the support of ESA, is assessing their eventual operational use," explains ESA's senior satnav advisor Javier Ventura-Traveset.

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Relativity by measuring more accurately than ever before the way that gravity affects the passing of time."

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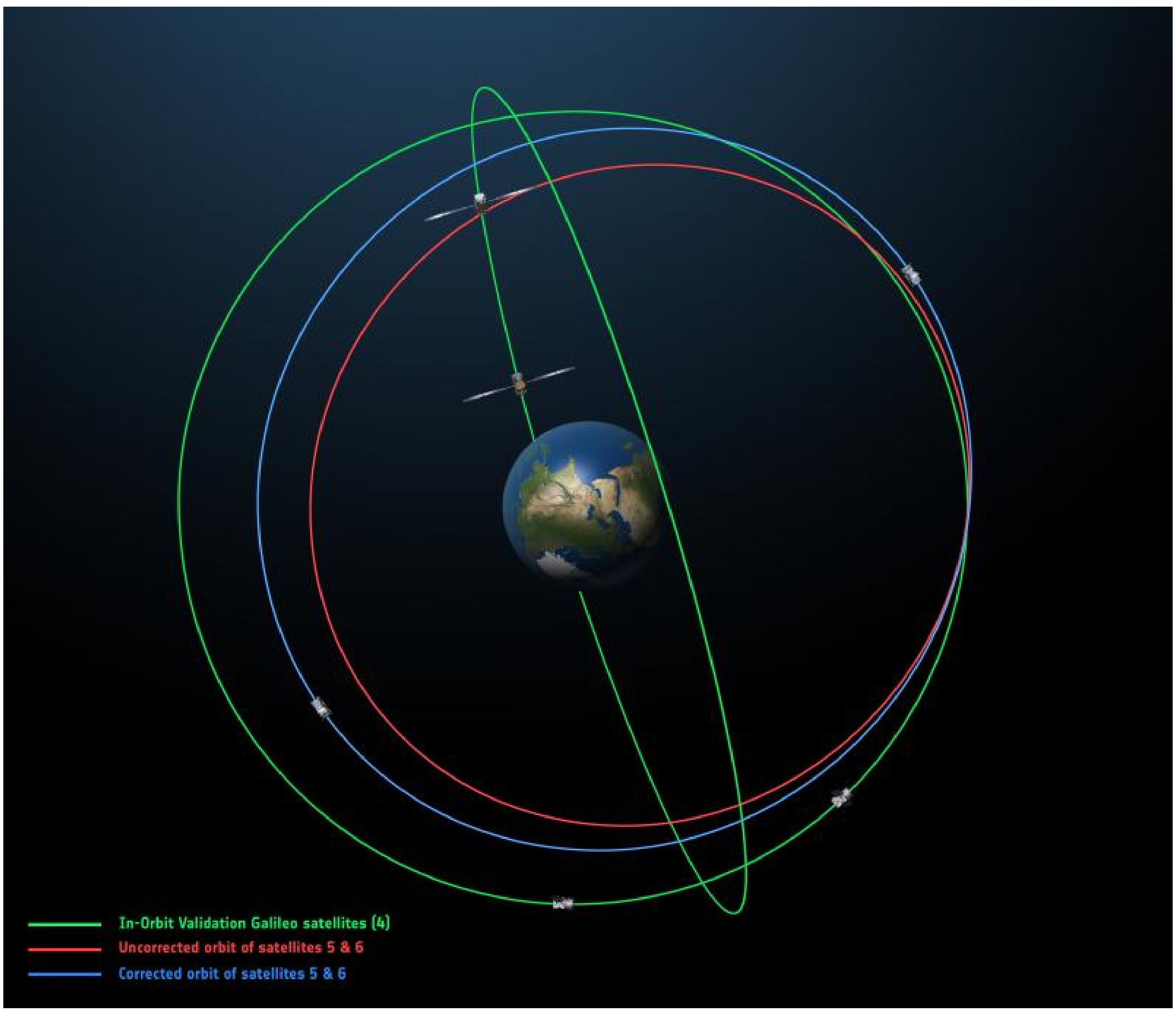

The original (in red) and corrected (in blue) orbits of the fifth and sixth Galileo satellites, along with that of the first four satellites (green). The first four, launched in pairs in 2011 and 2012, were released into circular 23 222 km-altitude orbits in two planes. The fifth and sixth, launched by Soyuz–Fregat on 22 August 2014, ended up in an incorrect orbit because of a problem with the upper stage. This elongated orbit took them up to 25 900 km above Earth and back down to 13 713 km, too low for their navigation payloads to operate throughout. So, during November 2014 and January–February 2015, the satellites respectively underwent a series of manoeuvres to raise the low point of their orbits by 3500 km while also making their orbits more circular. So now their navigation payloads are operable, and undergoing testing, while the European Commission – the Galileo system owner – prepares to decide whether the salvaged satellites will be incorporated into the constellation. Credit: ESA

Albert Einstein predicted a century ago that time would pass more slowly close to a massive object. It has been verified experimentally, most significantly in 1976 when a hydrogen maser atomic clock on Gravity Probe A was launched 10 000 km into space, confirming the prediction to within 140 parts in a million.

Atomic clocks on navigation satellites have to take into account they run faster in orbit than on the ground – a few tenths of a microsecond per day, which would give us navigation errors of around 10 km per day.

"Now, for the first time since Gravity Probe A, we have the opportunity to improve the precision and confirm Einstein's theory to a higher degree," comments Javier.

"This increased precision is of great interest because it will test several alternative theories of gravity."

This new effort takes advantage of the passive hydrogen maser atomic clock aboard each Galileo, the elongated orbits creating varying time dilation, and the continuous monitoring thanks to the global network of ground stations.

"Moreover, while the Gravity Probe A experiment involved a single orbit of Earth, we will be able to monitor hundreds of orbits over the course of a year," explains Javier.

The Gravity Probe A payload of 1976, flown in a highly elliptic single orbit to measure the 'gravitational redshift' of Einstein's Theory of General Relativity more accurately than ever before, seen with its designers Robert Vessot and Martin Levine of the Smithsonian Astrophysical Observatory. The experiment compared a hydrogen maser clock on Earth with its replica in space as it ascended to about 10 000 km, and confirmed theoretical expectations to an accuracy of 0.02%. Credit: https://einstein.stanford.edu

"This opens up the prospect of gradually refining our measurements by identifying and removing errors. Eliminating those errors is actually one of the big challenges.

"For that we count on the support of Europe's best experts in Europe plus precise tracking from the International Global Navigation Satellite System Service, along with tracking to centimetre accuracy by laser."

The results are expected in about one year, projected to quadruple the accuracy on the Gravity Probe A results.

The two teams devising the experiments are Germany's ZARM Center of Applied Space Technology and Microgravity, and France's Systèmes de Référence Temps-Espace, both specialists in fundamental physics research.

ESA's forthcoming Atomic Clock Ensemble in Space experiment, planned to fly on the International Space Station in 2017, will go on to test Einstein's theory down to 2–3 parts per million.

Provided by European Space Agency

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