ESA sets clock by distant spinning stars

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Pulsar encased in supernova bubble. Credit: ESA/XMM-Newton/ L. Oskinova/M. Guerrero; CTIO/R. Gruendl/Y.H. Chu

ESA's technical centre in the Netherlands has begun running a pulsar-based clock. The "PulChron' system measures the passing of time using millisecond-frequency radio pulses from multiple fast-spinning neutron stars.

Operating since the end of November, this pulsar-based timing system is hosted in the Galileo Timing and Geodetic Validation Facility of ESA's ESTEC establishment, at Noordwijk in the Netherlands, and relies on ongoing observations by a five-strong array of radio telescopes across Europe.

Neutron stars are the densest form of observable matter in the cosmos, formed out of the collapsed core of exploding stars. Tiny in cosmic terms, on the order of a dozen kilometres in diameter, they still have a higher mass than Earth's Sun.

A pulsar is a type of rapidly rotating neutron star with a magnetic field that emits a beam of radiation from its pole. Because of their spin – kept steady by their extreme density – pulsars as seen from Earth appear to emit highly regular radio bursts – so much so that in 1967 their discoverer, UK astronomer Jocelyn Bell Burnell, initially considered they might be evidence of 'little green men."

"PulChron aims to demonstrate the effectiveness of a pulsar-based timescale for the generation and monitoring of satellite navigation timing in general, and Galileo System Time in particular," explains navigation engineer Stefano Binda, overseeing the PulChron project.

Atomic clocks at ESTEC's Navigation Laboratory: the container on the far right of the image houses an active hydrogen maser atomic clock - an order of magnitude more accurate than the passive hydrogen masers aboard each Galileo satellite, themselves accurate to one second in three million years. The rack to its left houses additional caesium clocks, with a clock comparison system to its left and a clock distribution system to send data to users visible on the left hand side of the image. Credit: ESA - Anneke Le Floc'h

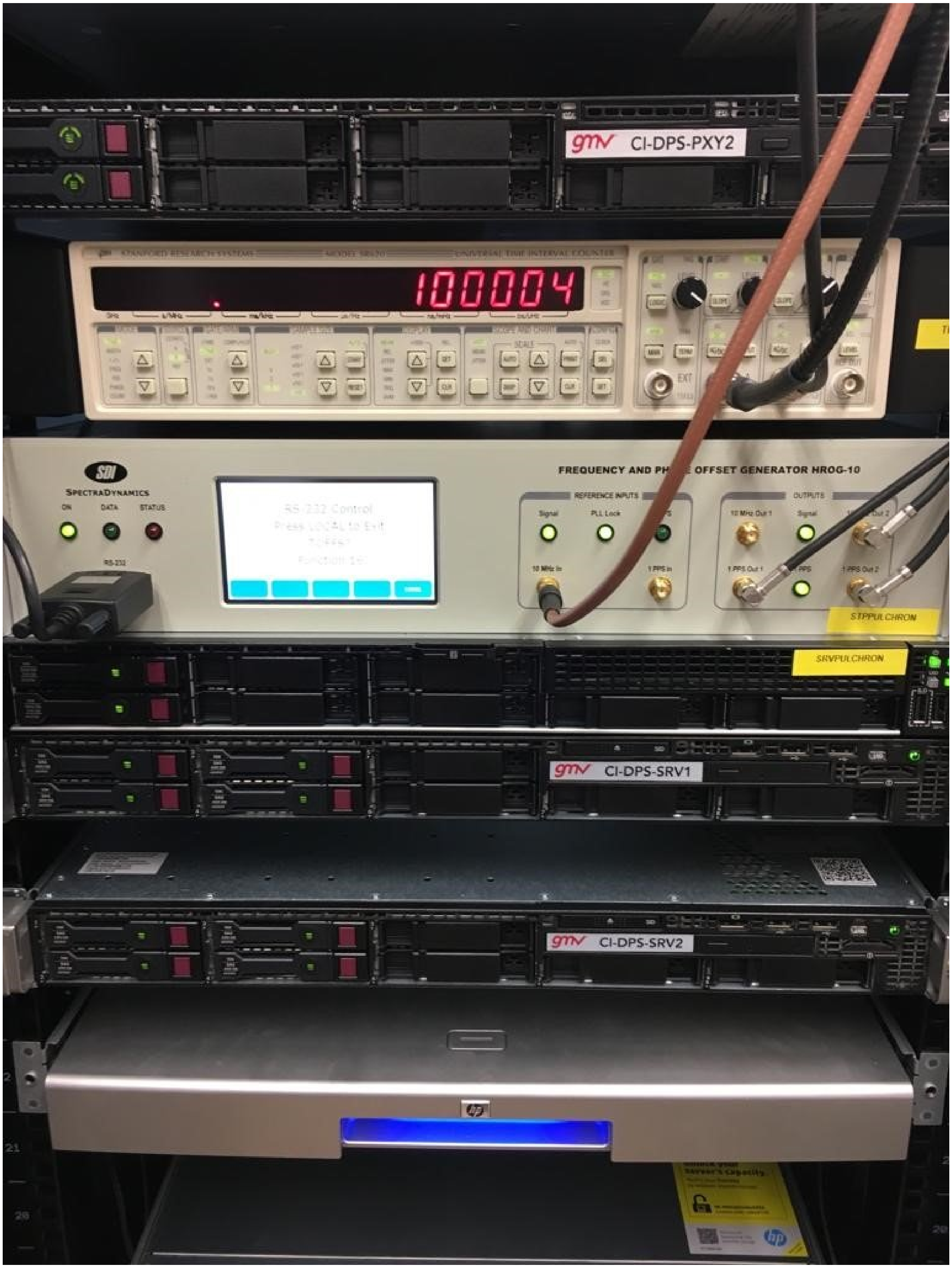
"A timescale based on pulsar measurements is typically less stable than one using atomic or optical clocks in the short term but it could be competitive in the very long term, over several decades or more, beyond the working life of any individual atomic clock.

"In addition, this pulsar time scale works quite independently of whatever atomic clock technology is employed – it doesn't rely on switches between atomic energy states but the rotation of neutron stars."

PulChron sources batches of pulsar measurements from the five 100-m class radio telescopes comprising the European Pulsar Timing Array – the Westerbork Synthesis Radio Telescope in the Netherlands, Germany's Effelsberg Radio Telescope, the Lovell Telescope in the UK, France's Nancay Radio Telescope and the Sardinia Radio Telescope in Italy.

This multinational effort monitors 18 highly precise pulsars in the European sky to search out any timing anomalies, potential evidence of gravitational waves – fluctuations in the fabric of spacetime caused by powerful cosmic events.

For PulChron, these radio telescope measurements are used to steer the output of an active hydrogen maser atomic clock with equipment based in the Galileo Timing and Geodetic Validation Facility – combining its extreme short- and medium-term stability with the longer-term reliability of the pulsars. A 'paper clock' record is also generated out of the measurements, for subsequent post-processing checks.



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Setup of the PulChron system, setting an atomic clock using millisecond-scale pulses from fast-spinning pulsars. Radio telescope measurements are used to steer the output of an active hydrogen maser atomic clock with equipment based in ESA's Galileo Timing and Geodetic Validation Facility – combining its extreme short- and medium-term stability with the longer-term reliability of the pulsars. A ‘paper clock’ record is also generated out of the measurements, for later, post-processing checks. Credit: European Space Agency

ESA established the Timing and Geodetic Validation Facility in the early days of the Galileo programme, first to prepare for ESA's two GIOVE test satellites and then in support of the world-spanning Galileo system, based on "Galileo System Time' which needs to remain accurate to a few billionths of a second. The Facility continues to serve as an independent yardstick of Galileo performance, linked to monitoring stations across the globe, as well as a tool for anomaly investigation.

Stefano adds: "The TGVF provided a perfect opportunity to host the PulChron because it is capable of integrating such new elements with little effort, and has a long tradition in time applications, having been used even to synchronise time and frequency offset of the Galileo satellites themselves."

PulChron's accuracy is being monitored down to a few billionths of a second using ESA's adjacent UTC Laboratory, which harnesses three such atomic hydrogen maser clocks plus a trio of caesium clocks to produce a highly-stable timing signal, contributing to the setting of Coordinated Universal Time, UTC – the world's time.

The gradual diversion of pulsar time from ESTEC's UTC time can therefore be tracked – anticipated at a rate of around 200 trillionths of a second daily.

Provided by European Space Agency