CREDIT: ESA-D. DUCROS

IN-ORBIT OEM GNSS SOLUTIONS

UNLOCKING PRECISION BEHIND ESA'S ACES MISSION

Customer Story

- The Atomic Clock Ensemble in Space (ACES) is a European Space Agency mission that places two ultra-precise atomic clocks aboard the International Space Station (ISS). A core requirement of ACES is the precise determination and prediction of the ISS trajectory, which must be known continuously and accurately to meet distinct operational needs. The use of three JAVAD OEM GNSS receivers in a redundant architecture was foundational to mission function and integrity.

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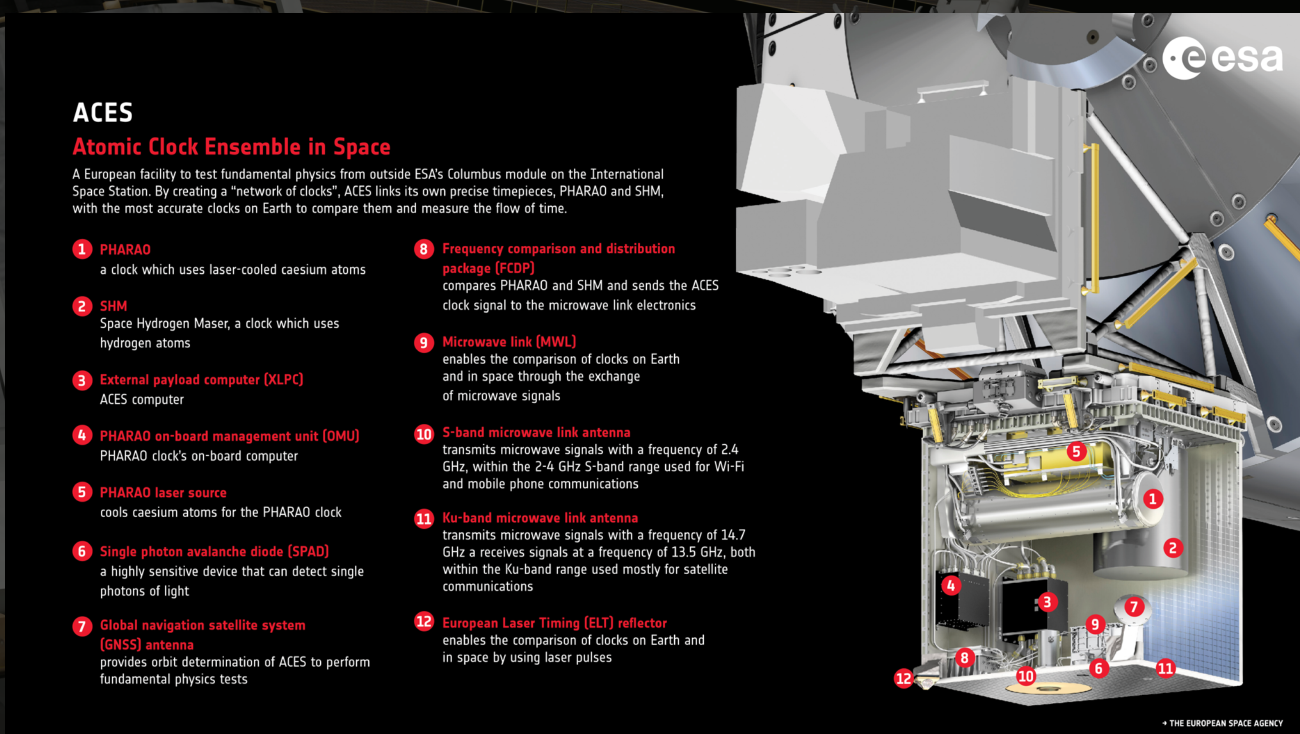
May 2026

THE CHALLENGE

The Atomic Clock Ensemble in Space (ACES) is a European Space Agency mission that places two ultra-precise atomic clocks aboard the International Space Station: 1) **CNES-developed PHARAO caesium cold-atom clock and 2) Swiss-built Space Hydrogen Maser.** Together accurate to roughly one second over 300 million years, they create a highly stable orbital timescale for comparison with ground-based atomic clocks, supporting tests of gravitational time dilation, searches for variations in fundamental physical constants, and chronometric geodesy — inferring the shape of Earth's geoid by measuring gravitational potential differences across continents through clock comparisons.

A core requirement of ACES is the precise, continuous determination and prediction of the ISS trajectory to meet two distinct needs: mission support, where ground-based satellite laser ranging stations and microwave link terminals must point accurately at the ISS as it passes overhead; and data processing, where relativistic clock corrections, dependent on the station's altitude and orbital velocity, must be computed to interpret the scientific data. Without a reliable GNSS solution, any uncertainty or gaps in trajectory knowledge would compromise both the pointing of ground terminals and the accuracy of those corrections, ultimately undermining the sub-picosecond clock comparisons at the heart of the mission.



CREDIT: ESA–K. Lochtenberg

The Outcome

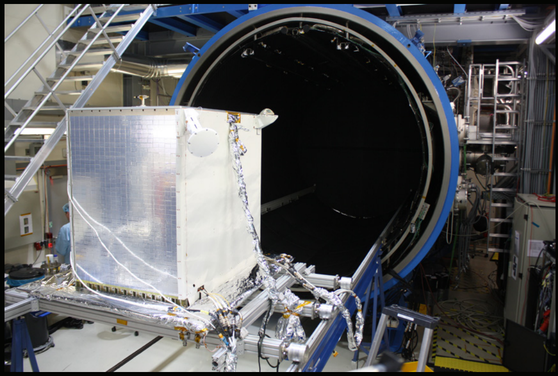
The solution to this challenge was provided by the integration of three JAVAD TRE-G3TH GNSS receivers into the ACES payload. The receiver supports tracking of GPS, GLONASS, and Galileo signals in the L1/E1, L2, and L5/E5a frequency bands, offering access to a much larger number of signals and measurements than legacy space receivers. This multi-constellation, multi-frequency capability made it possible to continuously determine the ISS position and velocity with high precision, even in low Earth orbit (LEO).

The use of three receivers in a redundant architecture directly addressed both operational needs. For mission support, the continuously computed trajectory enables ground-based microwave link terminals and satellite laser ranging stations to point accurately at the ISS during contact windows, with trajectory predictions generated far enough in advance for the terminals to acquire and track the station. For data processing, the high-precision position and velocity outputs feed directly into the computation of relativistic clock corrections.

Takeaways

With a reliable trajectory solution provided by the JAVAD TRE-G3TH receivers, the ACES ensemble is capable of producing a set of calculable, high-precision scientific outcomes. The most direct is the measurement of gravitational redshift — the fractional frequency difference between onboard and ground-based clocks — resolvable at around 2 parts in 10^{16}, an order of magnitude improvement over prior experiments. The same data supports new constraints on time variations of fundamental physical constants, such as the fine structure constant, by identifying drifts in frequency ratios between different atomic species. Precise trajectory knowledge further enables geopotential differences between continental clock sites to be computed at the centimeter level. Underpinning all of this is the three-receiver architecture, ensuring uninterrupted trajectory determination even in the event of a single-unit failure — keeping relativistic corrections consistent across the mission and ensuring the dataset remains coherent, reproducible, and defensible.

ACES in space *CREDIT: ESA/NASA*

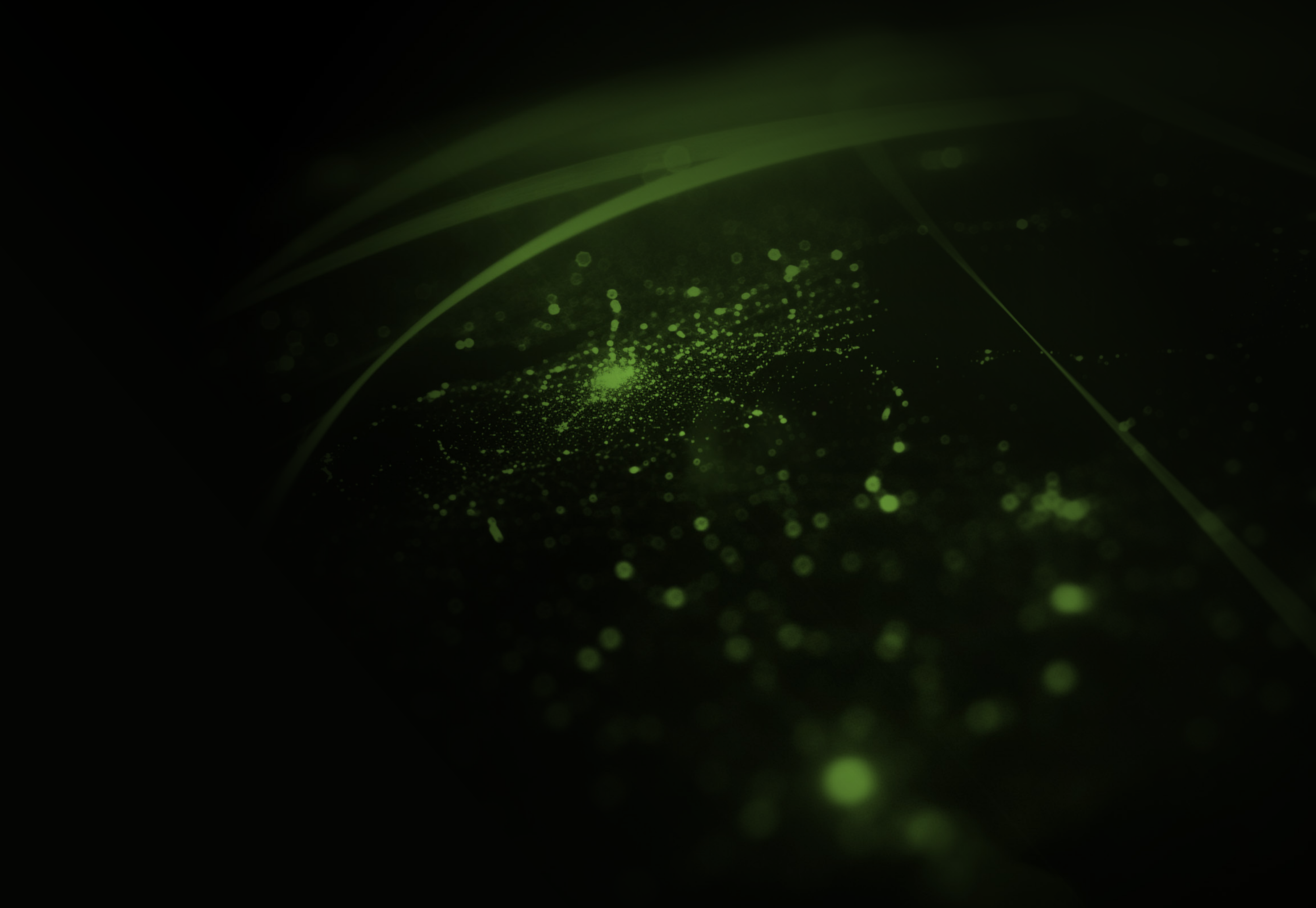


ACES vacuum testing *CREDIT: ESA/Airbus*

Differentiators

JAVAD plays a critical role in ACES. The mission needed geodetic-grade GNSS data for precise orbit determination, and getting that data from the ISS is not straightforward. Limited antenna visibility, multipath interference, signal interruptions, and the drag-modeling complexity of the station itself all work to create adverse conditions.

The JAVAD receiver handled it. Multi-constellation, multi-frequency, and capable enough to produce orbit solutions at roughly the one-meter level or better, confirmed by SLR validation. For a platform as challenging as the ISS, that is a result worth noting.



Contact Us

Phone: 408-770-1770
sales@javad.com

Headquarters
900 Rock Ave
San Jose, CA, USA 95131

EU Sales & Support
Seskines sodu str. 12-53, LT-08343
Vilnius, Lithuania