

ACES: First Results from Space

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On 21 April 2025, the Atomic Clock Ensemble in Space (ACES) payload was launched to the International Space Station (ISS) and installed at the external payload facility of the Columbus module (see Fig. 1).

Since then, the PHARAO clock, which uses laser cooled cesium atoms to generate a signal with a predicted stability and accuracy of $1\text{-}2 \times 10^{-16}$, is compared to atomic clocks on ground by means of two time and frequency transfer systems: a link in the microwave domain (MWL) and a pulsed optical link (ELT). The ACES microwave link is expected to deliver comparisons of

clocks to a few parts in 10^{17} , opening unique opportunities to test general relativity, constrain dark matter models, and develop applications in relativistic geodesy, time & frequency metrology, and timescales distribution.

ACES is currently completing its in-orbit commissioning. During this phase, the PHARAO clock is optimized in terms of frequency stability, the on-board links are characterized, and the accuracy evaluation of PHARAO is initiated using MWL comparisons with ground-based atomic clocks. Connected to the ground terminals of the ACES MWL, the atomic clocks operated by LNE in France, PTB and Wettzell in Germany, NPL in the United Kingdom, JPL and NIST in the United States, and NICT in Japan are contributing to the ACES clock network. The ACES ground segment is then completed by satellite laser ranging stations connecting their clocks to ACES via the ELT optical link. The commissioning activities are expected to be concluded before the end 2025, thus releasing ACES to start the routine science phase.

In this paper, we will present the first space-based results of the ACES mission, including the PHARAO characterization measurements, the ACES links performance evaluation, and the first comparisons of the PHARAO clock with atomic clocks on ground.



Fig. 1: ACES installed on the ISS, at the external payload facility of the Columbus module (Credits: ESA-NASA).