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Press release

CNES delivered PHARAO ultra-precise atomic clock to the European Space Agency

PHARAO was delivered this week to the European Space Agency (ESA) for integration with ACES (Atomic Clock Ensemble in Space), to be flown to the International Space Station (ISS) in 2016. This ultra-precise atomic clock, designed to vary by no more than 1 second in 300 million years, will be used to test the fundamentals of Einstein's theory of general relativity with unparalleled precision.

Delivery of the flight model of PHARAO and its associated software to ESA marks a major milestone for the ACES project. On delivery, the PHARAO atomic clock will already be mated with the main structure of the ACES payload. The other elements of the experiment will be added as they become available, some of them as soon as this summer. ACES is to be launched in May 2016 and attached outside Europe's Columbus module on the International Space Station, in orbit around Earth at an altitude of about 400 kilometres.

At the start of the 20th century, Albert Einstein revolutionized the way we understand space and time, which he showed to be interwoven. He also showed that this space-time continuum 'warps' due to the effect of gravitation. The passage of time is therefore dependent on gravity and in turn on altitude. In other words, time passes more quickly at the top of the Eiffel Tower than at the bottom! Current clocks have been used to detect this 'Einstein effect' by measuring the frequency shift of two clocks at different altitudes. The effect is also recorded and corrected by the GPS and Galileo positioning systems, which use space clocks.

The PHARAO atomic clock will measure time with a much greater degree of accuracy and stability, thanks to laser cooling and manipulation of cesium atoms, and will only vary by the equivalent of 1 second in 300 million years. The ACES experiment will use microwave or optical links to compare PHARAO with ground-based atomic clocks using different types of atoms and at locations around the globe. ACES will perform a range of tests to push the theory of general relativity to its limits, including measuring the Einstein effect with an accuracy of 10^{-6} (almost 100 times better than previously) and searching for possible anisotropies in the speed of light around the threshold of 2 x 10^{-10} as well as possible variations in the fine-structure constant, which is one of the fundamental constants of physics, characterizing the strength of electromagnetic interaction. The discovery of any of these effects would be a major event and another step towards the era of new physics beyond the 'standard model' and reconciliation of the two major theories of the 20th century: general relativity and quantum mechanics.

"*Delivery of the flight model is the culmination of the years of effort our partners have put into building the clock's subsystems, notably the cesium tube and laser source at SODERN, the microwave source at Thales Alenia Space and the processor at EREMS, as well as the particularly complex and flexible flight software at CS,*" says Didier Massonnet, PHARAO project leader at CNES. "*In that time, the CNES teams have closely monitored construction progress and tested the PHARAO engineering model. Over the last year, they have assembled and tested the flight model of the clock. A lot of work went into measuring its ultimate performance and we are all proud of the result.*"

The PHARAO project team will now provide support for integration and testing of ACES, chiefly at Airbus Defence & Space's facility in Friedrichshafen, Germany.

CNES is also involved in the ACES experiment through its CADMOS centre for the development of microgravity applications and space operations. Once the experiment, dedicated to testing the theory of general relativity, has been attached outside the ISS, it will be operated by CADMOS engineers in Toulouse.

The PHARAO atomic clock project was proposed by the Kastler-Brossel laboratory (École Normale Supérieure / CNRS / Université Pierre et Marie Curie) and the Syrte laboratory (Observatoire de Paris / CNRS / Université Pierre et Marie Curie / LNE) and developed by CNES.

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