

HUMAN SPACEFLIGHT SYMPOSIUM (B3)  
Interactive Presentations (IP)

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ATOMIC CLOCKS ENSEMBLE IN SPACE OPERATIONS. THE ISS EXTERNAL SCIENTIFIC  
PAYLOAD LOOKING FOR EXPERIMENTAL CONFIRMATIONS ON THE GENERAL RELATIVITY  
THEORY

**Abstract**

ACES (Atomic Clock Ensemble in Space) is an ESA mission in fundamental physics based on a new generation of clocks operated in the microgravity environment of the International Space Station. ACES will be launched and installed on the international Station Columbus external platform facility in 2017.

ACES comprises two atomic clocks: PHARAO, a primary frequency standard developed by CNES and based on laser cooled caesium atoms, and SHM, an active hydrogen maser for space applications. The two clocks are compared and locked one to the other by means of the Frequency Comparison and Distribution Package (FCDP) in order to generate an on-board time scale combining the short-term stability of SHM and the long-term stability and accuracy of PHARAO. The on-board time and frequency reference is distributed via a dual-frequency Micro Wave Link (MWL) to ground sites situated all over the world.

The ground segment consists of a set of Micro Wave Link Ground Terminals installed at ground sites and linked to a local time reference generated by different types of atomic clocks. Seven terminals are located at universities or institutes: three in Europe, one in Japan, one in Australia and two in the United States. In addition, 2 mobile terminals are provided to allow fine calibration. The ground clocks can also be compared one to other using the common view technique, when two or more ground terminals are simultaneously in visibility of ISS, or, for distant terminals, using the non-common view technique thanks to the very high stability of the ACES on-board reference time.

Moreover, an optical laser link between the flight segment and the ground allows performing time and frequency comparisons between the on-board time reference and various Satellite Laser Ranging stations that are coordinated by the European Laser Timing Data Centre.

The planned mission duration is 18 months with the possibility to double it. During the first 6 months, the performances of the PHARAO and SHM clocks in space will be established. PHARAO target is  $7 \cdot 10^{-14} \cdot \tau^{-1/2}$  for frequency stability and  $10^{-16}$  for the frequency accuracy.

CADMOS, the ISS operational Control Centre USOC (User Support and Operations Centre) owned by CNES and located in Toulouse, France, is the ACES Mission Control Centre and carries out ACES operations under ESA contract.

This paper presents the detailed operational concept that introduces ACES into the ISS operational process and operates the ACES flight and ground segments.