



Caves as an analogue to space: five years of astronaut training, testing and operations in the ESA CAVES programme

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Since 2008 the European Space Agency has started investigating the use of scientific expeditions into caves as a novel platform for astronaut training, taking advantage of the natural analogies of the cave environment and associated technical operations with space missions. In 2011 a new ESA training programme named CAVES (Cooperative Adventure for Valuing and Exercising human behaviour and performance Skills) was launched, involving astronauts from Partner Space Agencies. During five editions of CAVES, from 2011 to 2016, 28 astronauts from space agencies around the world (ESA, NASA, JAXA, ROSCOSMOS, CSA, CNSA) have taken part to the training. CAVES has been recognised by all participant astronauts and, in particular, by experienced spacefarers, as a very realistic spaceflight analogue, providing unique multicultural operational team training opportunities, in one of the best space analogue environments available on Earth.

The real rather than simulated combination of challenging environment, scientific and technical exploration activities and objectives, and realistic International Space Station (ISS) astronaut crews provides a very credible platform and scenario for a training expedition. Despite important differences with space stations, that host current space missions (e.g. microgravity, enclosed quarters), caves are complex alien environments, where several of the same situations and associated spaceflight stressors and team processes are recreated, combined with science opportunities, making this training platform a valuable tool to experience and enforce positive team processes and expeditionary skills, as well as offering complex scientific and technological operations in an unusual and challenging, environment, where safety protocol are required and enforced. The space community has thoroughly recognized the value of the experience acquired by speleology in cave exploration for the preparation of space operations. This experience is valuable for current and planned orbital missions, and will become invaluable for future surface and subsurface exploration and settlement on planetary bodies.