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TRAINING ASTRONAUTS FOR SCIENTIFIC EXPLORATION ON PLANETARY SURFACES

**Abstract**

Future human missions to the Moon and Mars will require astronauts to perform science-focused surface exploration in complex geological environments. However, much of the scientific expertise required for these activities has not been systematically trained into the astronaut corps. PANGAEA (Planetary ANalogue Geological and Astrobiological Exercise for Astronauts) is a geological and astrobiological field training course from the European Space Agency (ESA) that seeks to address some of these areas. While the course intends to impart core theoretical and practical knowledge of these disciplines, significant focus is given to skills in areas relevant to future missions, such as scientific decision-making, the ability to provide clear scientific descriptions of geological features and efficient documentation. For this reason, although portions of the course are taught in classrooms, developing independent field skills in analogue geological environments is a key part of the training. PANGAEA has been running since 2016, with participants including ESA and Roscosmos astronauts/cosmonauts, mission designers and engineers. The course forms part of the basic and pre-assignment training for European astronauts, and is open to trainees from other agencies. The primary field sites selected for the course are Permo-Triassic terrigenous sequences in the Italian Dolomites, impact lithologies in the Ries Crater, Germany, a comprehensive suite of volcanic deposits in Lanzarote, Spain, and anorthosite outcrops in Lofoten, Norway. Each is used as a base to deliver the main learning sessions, respectively; 1) Earth geology, rock recognition and sedimentology on Earth and Mars, 2) Lunar geology and impact cratering, and 3) volcanism on Earth, Moon and Mars, execution of geological traverses, and sampling techniques. This roster of analogues has been expanded to include a new field session in Lofoten, Norway, where anorthosites and other lunar highlands analogue rocks are present. Whilst PANGAEA's primary focus is training, where appropriate and complementary,

technologies being developed for future missions are used and tested by the trainees during geological traverses. This provides an opportunity to examine the performance of new equipment and software in analogue field environments, whilst also providing trainees with experience using technology that might support future missions. Additionally, the logistical framework established by the training course enabled the creation of PANGAEA-X (PANGAEA-eXtension), a campaign that focuses exclusively on testing technologies and operational concepts with applications to future Moon and Mars missions.