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## Analogue lunar research for commercial exploitation of in-situ resources and planetary exploration - Applications in the PRO-ACT project

**Luís Lopes**<sup>1</sup>, Shashank Govindaraj<sup>2</sup>, Wiebke Brinkmann<sup>3</sup>, Simon Lacroix<sup>4</sup>, Jakub Stelmachowski<sup>5</sup>, Fran Colmenero<sup>6</sup>, Joseph Purnell<sup>7</sup>, Kevin Picton<sup>8</sup>, and Nabil Aouf<sup>9</sup>

<sup>1</sup>La Palma Research Centre SL, Garafia, Canary Islands

<sup>2</sup>Space Applications Services, Brussels, Belgium

<sup>3</sup>DFKI Robotics Innovation Center, Bremen, Germany

<sup>4</sup>Centre National de la Recherche Scientifique, Toulouse, France

<sup>5</sup>PIAP Space, Warsaw, Poland

<sup>6</sup>GMV Aerospace and Defence, Madrid, Spain

<sup>7</sup>Thales Alenia Space UK, Bristol, UK

<sup>8</sup>Added Value Solutions, Sevilla, Spain

<sup>9</sup>School of Mathematics, Computer Science and Engineering, University of London, London, UK

The PRO-ACT project studies, designs and develops the establishment of a lunar base with the support of a multi-robotic platform, entailing different features, tasks and capabilities. The activities are inline with the preparation of the commercial exploitation of in-situ resources and planetary exploration research by assembling an ISRU (In-Situ Resource Utilisation) system tested in a lunar analogue setting. The vision of PRO-ACT is based on the extraction of oxygen from lunar regolith which serves as oxidizer for fuel and artificial atmosphere generation for habitats and 3D printing of relevant structures using regolith for construction purposes.

The main goal of PRO-ACT is to implement and demonstrate the cooperative capabilities of the multi-robot system in a Moon-like environment. PRO-ACT uses three robots: Veles - a six-wheeled rover; Mantis - a six-legged walking system; and a mobile gantry. The final demonstration tests are set for early 2021.

Work implementation for the final deployment on the lunar analogue comprises: 1) during simulations, the planned mission scenarios and functional tests of the sub-components are carried out, to gain results of the real systems as well as to check the function of the developed software on the involved robotic systems; 2) remote testing of the robotic elements are implemented with the goal to integrate the software developed in the project and develop the first functional tests of the robot systems with the implemented software, 3) onsite demonstration of the project in Bremen, Germany, in a lunar analogue setting. For this indoor lunar analogue environment it was decided to create and set up a testbed with regolith simulant for testing purposes. It will be possible to replicate realistic simulation conditions (eg. navigation, mobility,

autonomy) as found in the moon, which are adequate to certify the project's goals.

The final demonstration will be conducted in the Space Exploration Hall at DFKI in Bremen. During the project, it was decided to build a large test field (with an area of 48m<sup>2</sup>) in front of the crater in the Hall, which will be filled with granulate/simulant (fill level 20-30 cm) in order to carry out moonlike mission scenarios with the involved robotic systems. The challenge was to find the appropriate granulate: the choice fell on using sand from the Baltic sea with grain size of 0.1-1.0mm, with the majority in the larger fraction. This simulant presents both relevant geomorphological and space exploration lunar conditions that are necessary for the certification of PRO-ACT's activities, while complying with necessary health regulations. Other considered options included EAC-1A, the European Astronaut Centre lunar regolith simulant 1, which is a special mixture of 0.2-1.0mm (65% 0.2-0.5mm and 35% 0.5-1.0mm), but this is very dusty and hazardous to health in enclosed rooms, such as the Space Exploration Hall. It was, therefore, disregarded due to health and safety conditions.

To keep lunar fidelity up to a maximum, the final demonstration setup will include, besides the referred simulant, boulders (~2m), slopes of different angles, the Hall's crater, light/darkness conditions controlled by a light system and environmental dryness.