PRO+ACT

Planetary Robots Deployed for Assembly and Construction of Future Lunar ISRU and Supporting Infrastructures

EGU2020: Sharing Geoscience Online
Discussion block/Live chat: May 4th 2020, 16:15-18:00 CEST

Luís Lopes and PRO-ACT consortium

LPRC LA PALMA RESEARCH CENTRE

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PRO-ACT Overall details

- Funding: Horizon 2020, Grant agreement ID: 821903
- Programmes:
  - H2020-EU.2.1.6.1. - Enabling European competitiveness, non-dependence and innovation of the European space sector
  - H2020-EU.2.1.6.2. - Enabling advances in space technology
- Start date: February 2019
- Duration: 24 months
- Consortium: 9 organizations, 6 EU countries
- Website: https://www.h2020-pro-act.eu/

Consortium

Space Applications Services, Belgium

DFKI, Germany

PIAP Space, Poland

AVS, Spain

GMV, Spain

University of Cranfield, UK

Thales Alenia Space UK

LAAS CNRS, France

La Palma Research Centre, Spain

PRO-ACT Abbreviations

- ISRU – In Situ Resource Utilisation
- RWAs – Robot Working Agents
- OGs – Operational Grants
- CREW – Cooperative Robotics for Enhanced Workforce
- TRL –Technology Readiness Level
- ICD – Interface Control Document
- ICU – Instrument control unit
- EST – Environment simulation tool
- IMU – Inertial Measurement Unit
- ESA – European Space Agency
- ICU – Instrument Control Unit
- DEM – Digital Elevation Model
- CSLAM – Cooperative Simultaneous Localization and Mapping
- VSLAM - Visual Simultaneous Localization and Mapping
- F/T – Force/Torque
- COTS – Commercial Off-The Shelf
- VO – Visual Odometry
- FMS – Fluid Management System

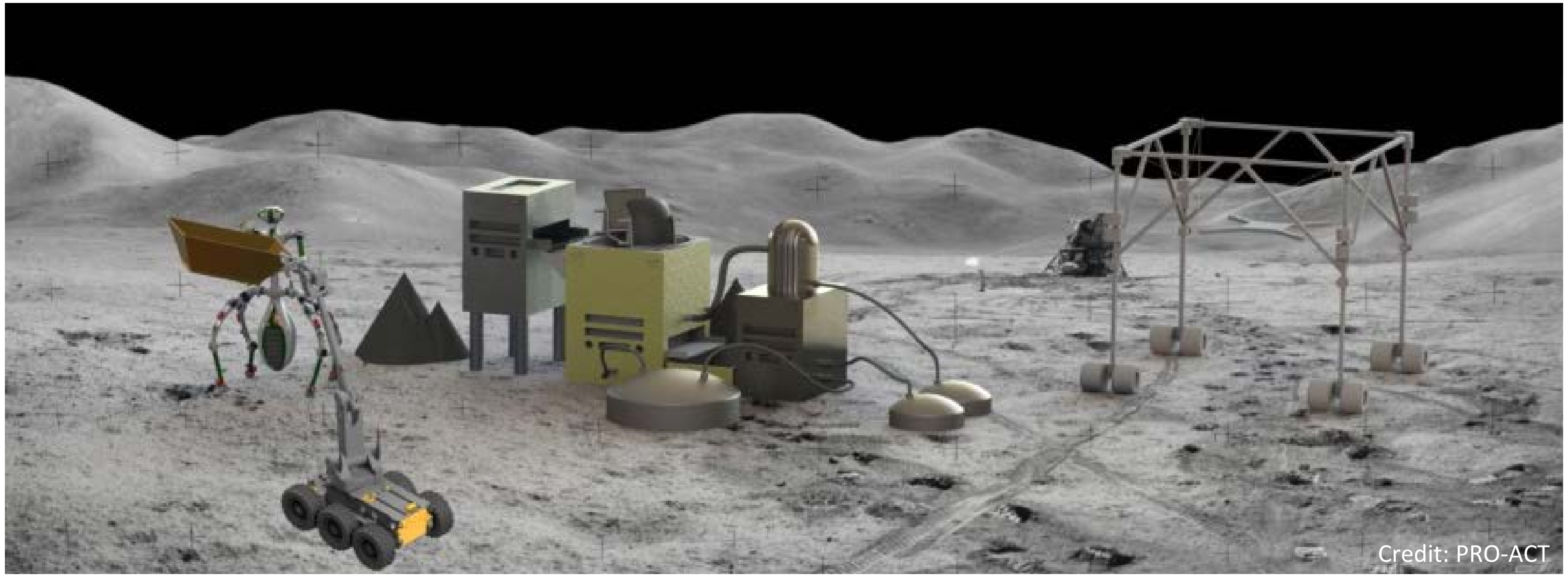
Concept and approach

The Moon is considered the next step in space exploration

In-Situ Resource Utilisation with lunar resources will enable developments

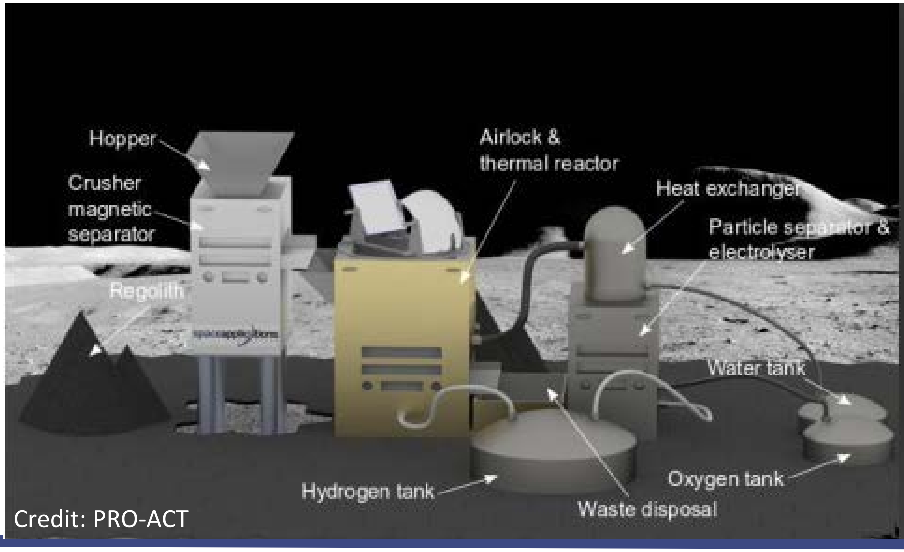
ESA wants to demonstrate the feasibility of ISRU in the next decade

PRO-ACT deploys robots for collaborative approach as a precursor lunar base with essential capabilities in preparation of commercial exploitation of in-situ resources by assembling an ISRU plant and a mobile gantry for 3D printing building elements for future human habitation

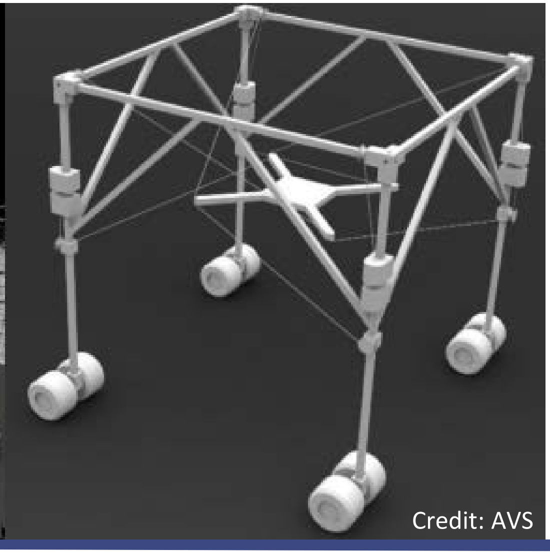


Concept and approach

- Cooperative scenarios will be based on:
  - 1) Fine scale surveying of areas prior to construction work
  - 2) Site clearing by grading stones and debris
  - 3) Unloading equipment/construction elements and transportation to assembly sites
  - 4) Assembly of specific modular components of an ISRU plant
  - 5) Assisting partial assembly and mobility of a gantry
  - 6) 3D printing of modular building elements from pseudo-regolith simulant
  - 7) Sample assembly of printed elements to construct sections of storage, habitation spaces or dust mitigation surfaces



Credit: PRO-ACT


Credit: AVS

Main objectives

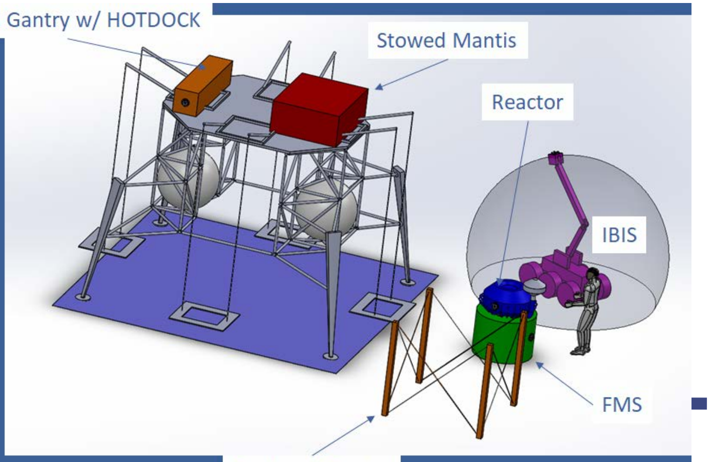
- Implement and demonstrate the cooperative capabilities of the multi-robot system in a Moon alike environment, replicated at two analogue sites
- Review, extend and integrate previous OGs – Operational Grants - outcomes as part of a comprehensive multi-robot system
- Develop robust cooperation capabilities allowing joint interventions (navigation in close vicinity and joint manipulation actions) in mixed structured/unstructured environments
- Make the capabilities available within a CREW module
- Customize existing mobile robotic platforms and prepare facilities to perform tests and demonstrations in a selection of relevant scenarios of Moon construction activities

Impact

- PRO-ACT provides tools in preparation of the commercial exploitation of in-situ resources by assembling an ISRU system, essential for a future human settlement on the Moon
- PRO-ACT's vision of ISRU focuses on the extraction of oxygen from lunar regolith to serve as the oxidizer for fuel and artificial atmosphere generation within habitats and 3D printing of relevant structures using regolith for construction purposes (tiles for roads and elements for shelters). The mineral ilmenite, found in lunar rocks, is the perfect target for the ISRU platform as it contains oxygen, iron and titanium as construction materials
- Technology will reach a TRL 4/5 (depending on scenarios subparts), supporting exploration of the Moon in the next decade

The scenario

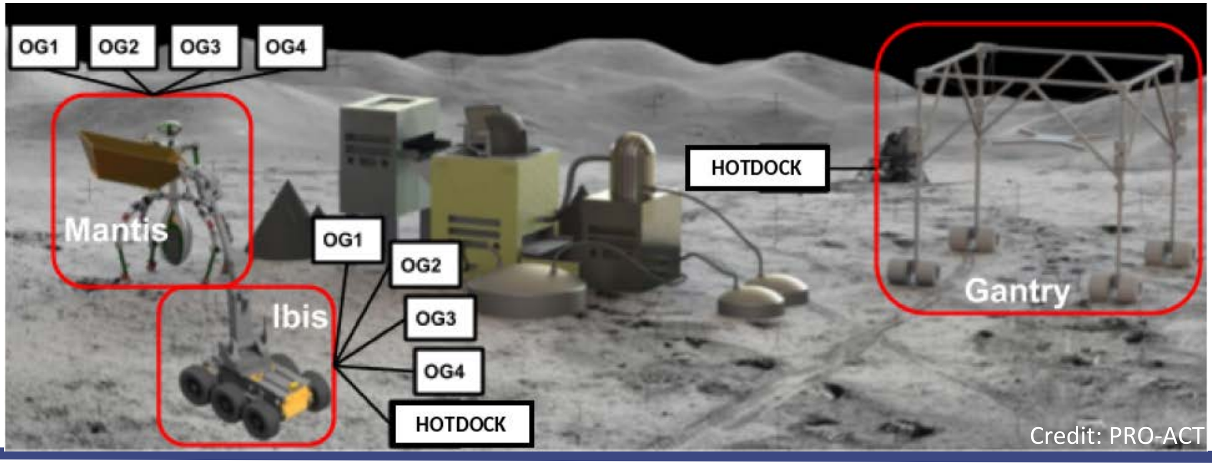
1. Site selection for an ISRU Plant
2. Approach the lander spacecraft and identification of the components to be unloaded
3. Unloading modules from the lander – ISRU plant components and 3D printer
4. Transporting mobile gantry trusses, beam connectors and ISRU plant components to assembly site
5. Assembly of the mobile gantry structure
6. Positioning the mobile gantry at a required location
7. 3D printing construction elements by the gantry
8. Preparation of dust mitigation surface around ISRU plant by laying 3D printed tiles or bricks
9. Drilling anchor points for pillars of the base of the ISRU plant
10. Assembly of the ISRU plant with all 3 RWAs
11. Loading regolith into the ISRU plant for extraction of resources



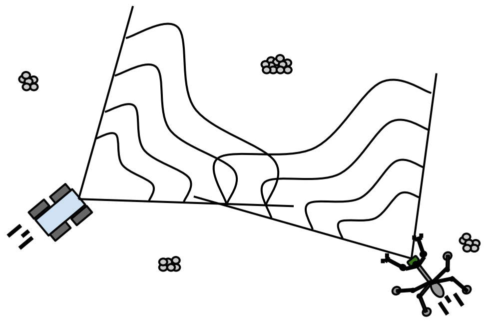
Credit: PRO-ACT

The scenario

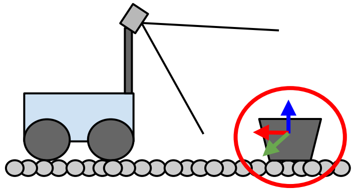
- **The mission scenario links high priority scientific goals with the intention to utilize lunar resources, and human exploration scenarios, providing an excellent basis to demonstrate the technology**
- **Following the described scenario, the key robotic elements, namely the mobile rover Veles, the six-legged walking robot Mantis and a mobile gantry are outlined according to the corresponding mission architecture. The ISRU plant is sized to be representative of a future lunar mission, with grasping points to assist robotic manipulation capabilities and considering the effects of reduced lunar gravity**
- **The project aims to demonstrate the integration of common building blocks for robots that are composed to create functional and intelligent robotic agents**



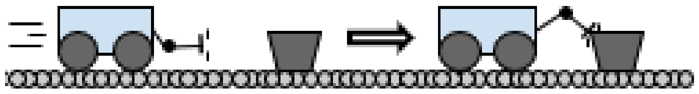
The scenario - tests



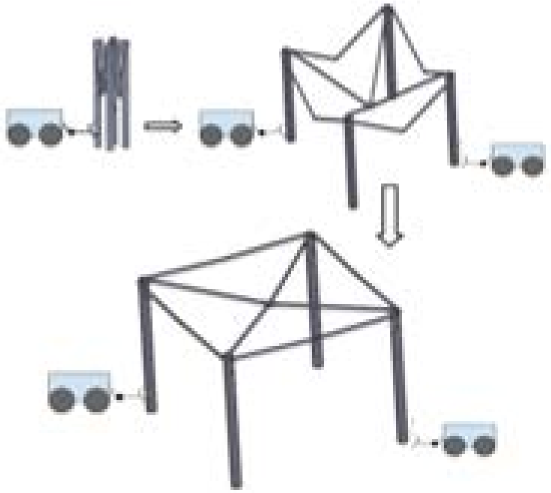
Cooperative area mapping



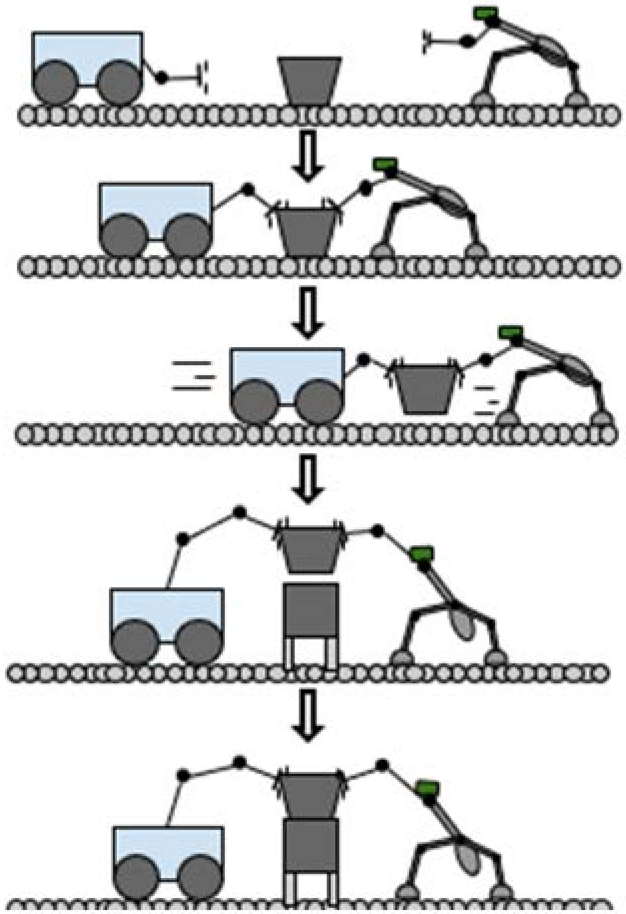
Detection and tracking of assets



Rendezvous and grasping



Gantry deployment



Cooperative manipulation (assembly) and transportation

The robots

Veles

Characteristics

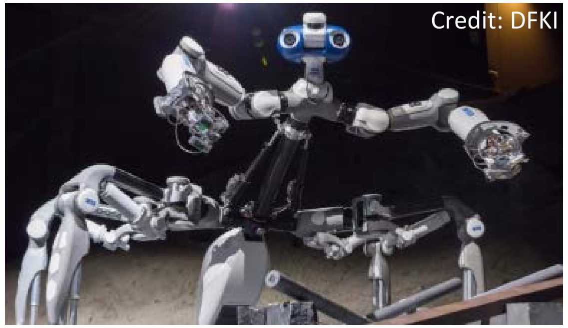
- Dimensions: 135 x 88 x 125 cm (LxWxH)
- Total mass: 300 kg
- Manipulator's maximum lift: up to 50 kg
- Manipulator's maximum range: 3,3 m
- Max radio transmission range: 600m
- No. of robot's cameras: 4
- Gripper
- Selection two COTS end-effectors: adapted drill and shovel
- Selection of COTS bucket for regolith transport

Credit: PIAP Space

Mantis

Characteristics

- Multi-legged robot with six extremities
- Flexible
- Total mass: 110 kg
- Locomotion mode – movement in difficult terrain
- Manipulation mode - dual-arm manipulation while being firmly grounded
- 3D laser scanner
- IMU

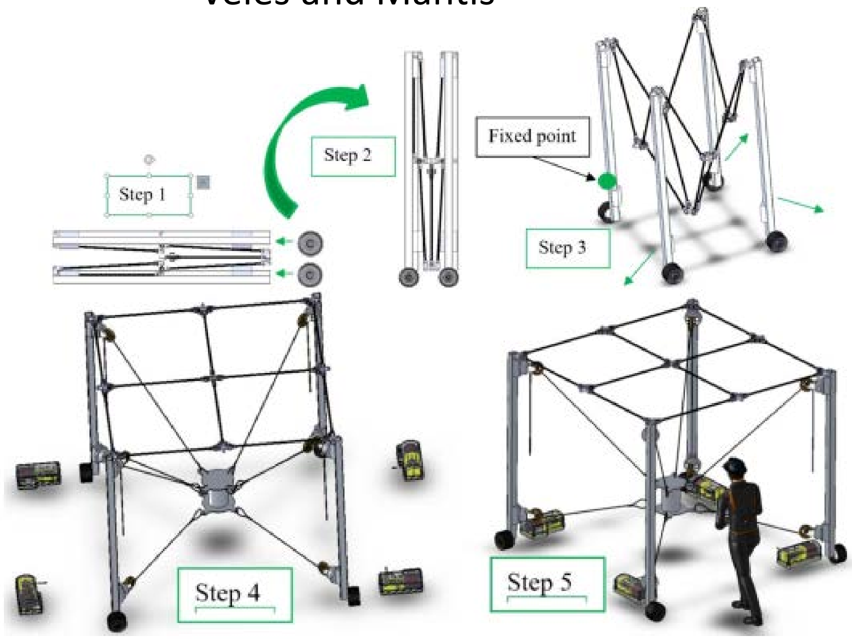


Credit: DFKI

Mobile Gantry

Characteristics

- Modular mobile gantry solution for lifting, positioning and 3D printing
- Will be mounted with the help of Veles and Mantis



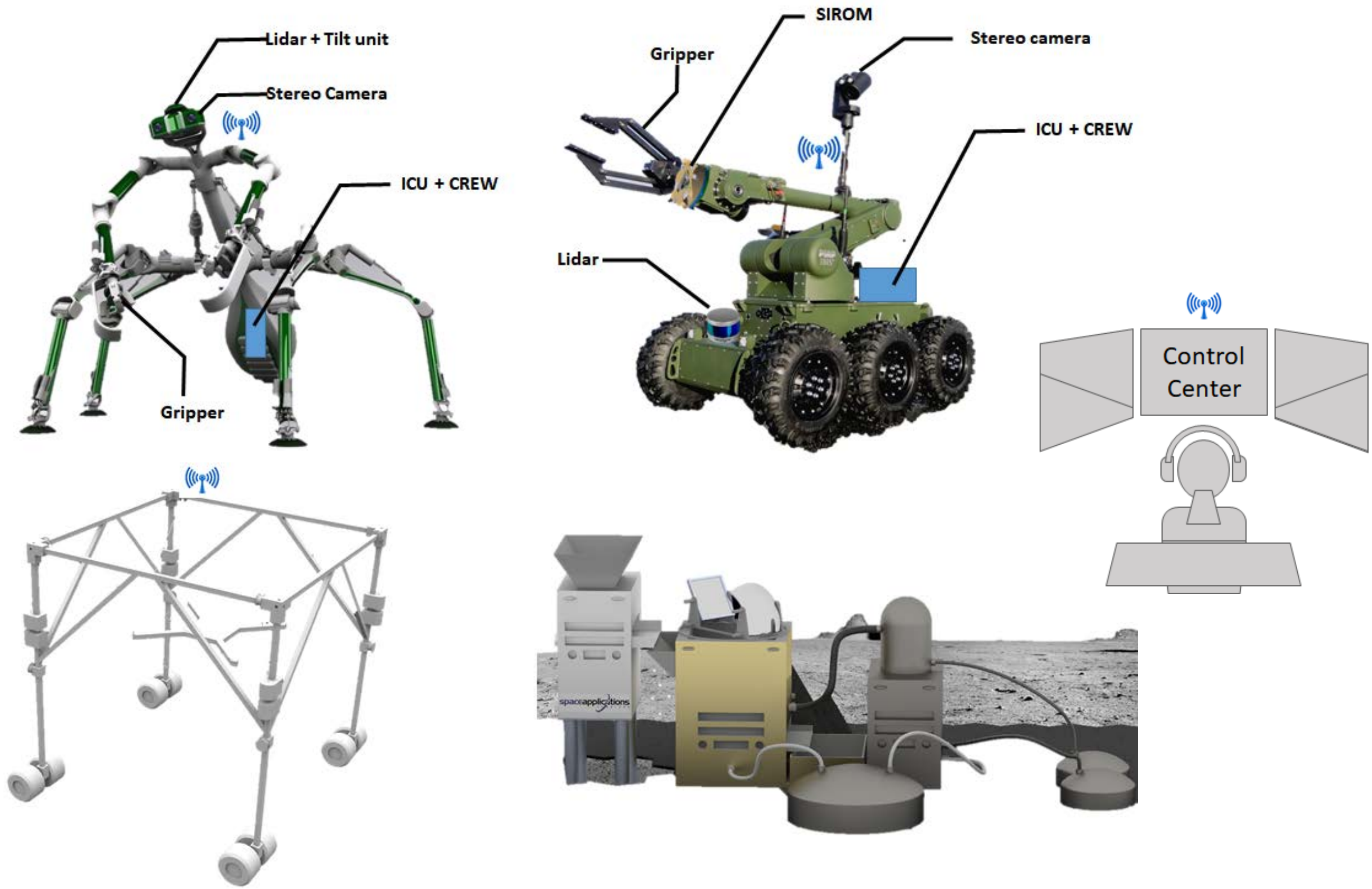
Credit: AVS

The demonstrations – lunar analogues

- Demonstrations of the technology at two lunar analogues – outdoor and indoor
  - Outdoor – A basalt quarry in Poland
  - Indoor – The facilities of DFKI in Germany, member of the consortium
- Analogues will replicate lunar terrain conditions
  - Presence of large quantities of loose material with mechanical fidelity
  - Large particles, rocks and boulders
  - Boulders of approximately 2m
  - Slopes
  - Craters
- Machinery and tools will be used to setup the terrain at the demonstration sites

Outdoor lunar analogue – mid 2020

- **Necessary equipment**
  - **Mantis + ICU + Stereocamera + Lidar + IMU**
  - **Veles + ICU + Stereocamera + Lidar**
  - **Mantis support equipment**
  - **Veles support equipment**
  - **ISRU mockup modules FMS and/or Reactor**
  - **Ultrasound localisation**
  - **Rocks for representative lunar terrain**



PRO-ACT unmanned agents (Veles, Mantis, Gantry) and supporting infrastructure (Control center, ISRU plant) that are part of the operation and demonstration scenarios

Outdoor lunar analogue – mid 2020

- Location – A basalt quarry in Poland
- Geomorphological fidelity
  - Loose material with mechanical fidelity – basalt fragments of different sizes
  - Geological composition of the terrain
  - Rocks and boulders of different sizes – organized in clusters
  - Slopes and craters – mimicking the lunar ones
- Exploration conditions fidelity
  - Light/Darkness – day/night cycle
  - Dryness – Tests performed during summer period

The test location, used for another project's tests.

Outdoor lunar analogue – mid 2020

- Tests to be performed – single agent
  - DEM generation in the same trajectory
  - Visual Odometry and VSLAM and VSLAM (map-based implementation) in the same trajectory
  - Detection and continuous estimation of the ISRU lander mockup pose while the robots are in motion
- Tests to be performed – multi agent
  - CSLAM/VO implementation in similar and distinct conditions
  - Comparison of CSLAM implementation in the flat surfaces vs non-flat surfaces where there are some shared areas between the robots
  - Mapping the environment using the output of task allocation for cooperative mapping

Indoor lunar analogue – early 2021

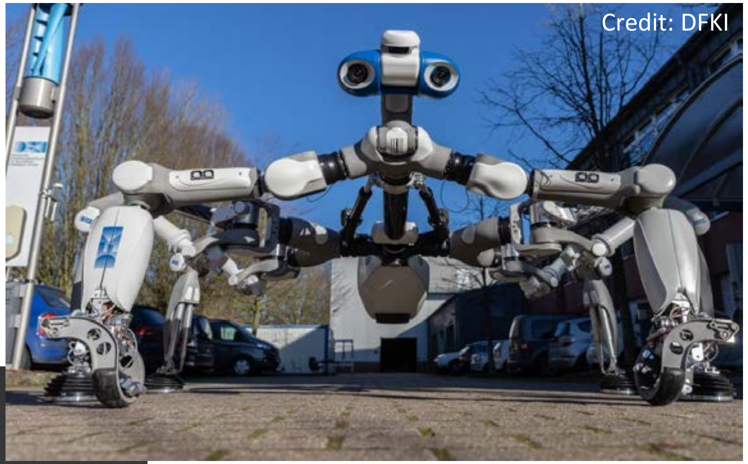
- Location – DFKI's facility in Bremen
- Geomorphological fidelity
  - Loose material with mechanical fidelity – simulant will be purchased
  - Geological composition of the terrain - The fragment sizes will follow approximately the size distribution seen in lunar regolith
  - Rocks and boulders of different sizes – present at location
  - Slopes and craters – mimicking the lunar ones – Mechanical structures at site

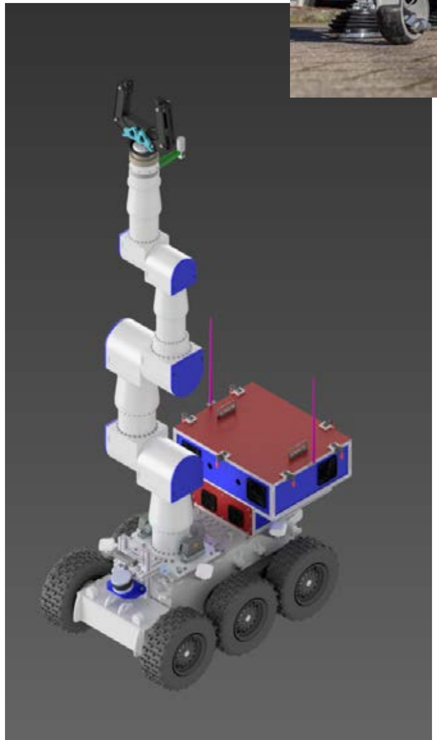
Space Exploration Hall at DFKI Bremen, Germany (source: DFKI)

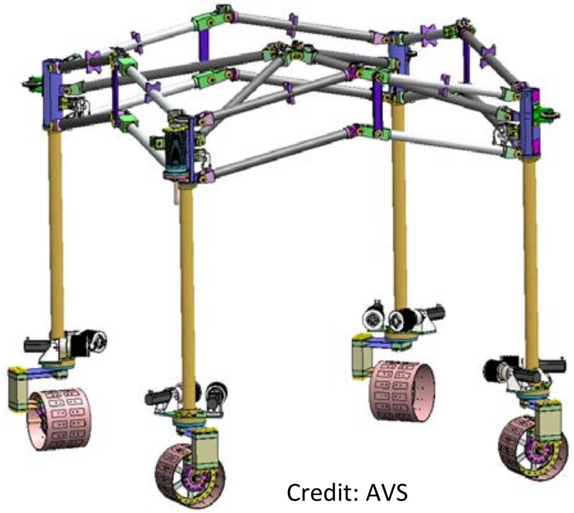
- Exploration conditions fidelity
  - Light/Darkness – Lighting system in place; With the ability to influence the light cone in its form, defined areas of light and shadow can be created. For similar light conditions as the Moon's, the inner walls are furnished with a black non-reflective coating.
  - Dryness – Will be guaranteed since the demonstration is indoors

Indoor lunar analogue – early 2021

- Necessary equipment
  - Mantis + ICU + Stereocamera + Lidar + IMU + F/T sensor at wrist
  - Veles + ICU + Stereocamera + Lidar + drill end-effector + shovel end-effector + grading blade
  - Mantis support equipment
  - Veles support equipment
  - ISRU mockup modules FMS and/or Reactor
  - Ultra sound localisation
  - Vicon Tracking system
  - Gantry + Control Unit
  - Regolith sandbox
  - Rocks for representative lunar terrain


Credit: DFKI


Credit: PIAP Space


Credit: AVS

Indoor lunar analogue – early 2021

- Tests to be performed
  - Elevation Map generation of Lunar Hall
  - Cooperative area mapping
  - Surface grading and drilling using Veles
  - Unloading ISRU modules from Lunar Lander
  - Cooperative transport of ISRU modules from Lunar Lander
  - Collaborative assembly of ISRU plant
  - Collaborative deployment of Gantry

Thank you!

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Project website

https://www.h2020-pro-act.eu/

More information

https://cordis.europa.eu/project/id/821903