



## Announcement of Opportunity (AO)

Moonwalk Newsletter 1 - D 9.8



## Announcement of Opportunity (AO)

Subsea Marseilles / Rio Tinto



Project **MOONWALK**, is a 3-year cooperative Research & Development project funded by the European Commission under the “space activity” theme of the 7th Framework Programme and aims to compare the performance of different compositions of astronaut-robot teams over multiple tasks and operational scenarios, in two Analogue environments.

**MOONWALK** will conduct Earth-Analogue simulations to test new hardware and various EVA scenarios at the Subsea Marseilles Lunar Analogue site in France and Rio Tinto Mars Analogue site in Spain in preparation for future human and robotic mission to Moon and to Mars. The Marseilles site simulates the reduced gravity conditions of the Moon; the Rio Tinto site simulates Martian terrain conditions and facilitates astrobiological studies.

The objective of the present AO is to invite researchers / Principal Investigators (PIs) to submit experiment proposals in association with the simulation activities of MOONWALK. Proposed experiments should be focused on human and/or robotic exploration of the Moon and Mars. **The deadline for submissions is 31 October 2015. The announcement of the selected proposals will be released on 7 December 2015.**

For questions, please contact:

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<http://www.projectmoonwalk.net/>



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The **MOONWALK** consortium is comprised of 7 partners from six EU member states:

**DFKI** - Robotics Innovation Centre (Project Coordinator), Germany

**COMEX** (Technical Coordinator), France

**AIRBUS** Group, Great Britain

**LIQUIFER** Systems Group (LSG), Austria

**Space Application Services**, Belgium

**NTNU** - Centre for Interdisciplinary Research in Space, Norway

**INTA** - Instituto Nacional de Técnica Aeroespacial, Spain

**MOONWALK** started in September 2013 and will conclude in August of 2016.

### 1 Field mission aims of MOONWALK

**MOONWALK** will develop and test technologies and training procedures for efficient astronaut-robot cooperation for future missions to Moon and Mars.

The project develops a new planetary rover and an EVA astronaut training suit for future surface Extra-Vehicular Activities (EVA) on Moon or Mars involving geological soil sampling, field exploration, and astrobiology activities.

**MOONWALK** will conduct Earth-Analogue simulations to test this new hardware and various EVA scenarios at the Subsea Analogue Site in Marseilles, France and the Mars Analogue Site in Rio Tinto, Spain. The project aims to compare the performance of different compositions of astronaut-robot teams over multiple tasks and operational scenarios in Marseilles and Rio Tinto while collaborating with Mission Control Centre (storyboards see Annex 1). Conducting field research in analogue environments is an excellent tool for learning about the particularities of conditions similar to Moon or Mars. The analogue sites available through **MOONWALK** offer;

- an opportunity to study the behaviour of equipment, involving simultaneous usage of instruments by a human astronaut fitted with EVA suit
- a platform for testing various hardware, tools and techniques for scouting, imaging, monitoring, mapping, analysing and sampling the terrain
- the possibility to study iron-sulphate containing minerals (jarosite, hematite) and rocks as a model for their Martian counterparts
- the possibility to test EVA procedures and operations in reduced gravity conditions (neutral buoyancy)
- a platform for testing support teams in a remote location



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## 2 Components of the field mission of MOONWALK

### 2.1 EVA suit

The simulations in MOONWALK will be performed by either an astronaut-robot team or an astronaut-astronaut team. The EVA training suits that will be used simulate the movement constraints of a pressurized space suit (through its movement restricting exoskeleton – see figure below) and also the reduced gravity on the Moon (for the underwater trials in Marseilles only). Each suit will directly communicate (voice and data) with the control centre of the mission.

Experiments that are proposed in the frame of this AO can profit from these simulations to make use of the EVA simulation suits and astronauts (e.g. for experiments on human performance, man-machine interfaces, tools or procedures).

An example of such simulations can be seen at: <https://www.youtube.com/watch?v=-VKhHqeLR-w>



(Left) EVA suit GANDOLFI on the sea floor during the APOLLO XI UNDER THE SEA mission [Photo: A. Rosenfeld/COMEX], (centre) EVA training suit [Photo: M.Delauze/COMEX], (right) EVA training suit - exoskeleton [Photo: R.Benali/COMEX]



Artist's view of the lunar mission simulations underwater (left) and the Martian mission simulations (right) [Images: LSG]



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### 2.2 Human-Machine Interface (HMI)

Different Human Machine Interface (HMI) devices will be installed on the MOONWALK suit with the objective of comparatively testing new ways of improving;

- the exchange of information of an Astronaut with Mission Control during EVAs
- the situational awareness and autonomy of the Extravehicular Crew

The devices are displays with which the suited test subject can interact.

The HMI is designed to work with the constraints of a bulky space suit and will have features such as;

- procedure viewing
- media transfer
- text message delivery
- telemetry display
- video and audio streaming delivery
- voice loop system
- robot control
- communications during emergency situations

The HMI for use in Earth-based Analogue simulations will mimic various flight-like parameters such as;

- planetary mission communications delay
- telemetry
- Cautions/warnings of connected mock radiation sensors and life support system

The HMI will be fully ruggedized and waterproof for operations in water immersion partial gravity conditions, i.e. underwater in a natural setting. The communications system will log all the interactions among the EVA test subjects, and between the EVA test subjects and Mission Control.

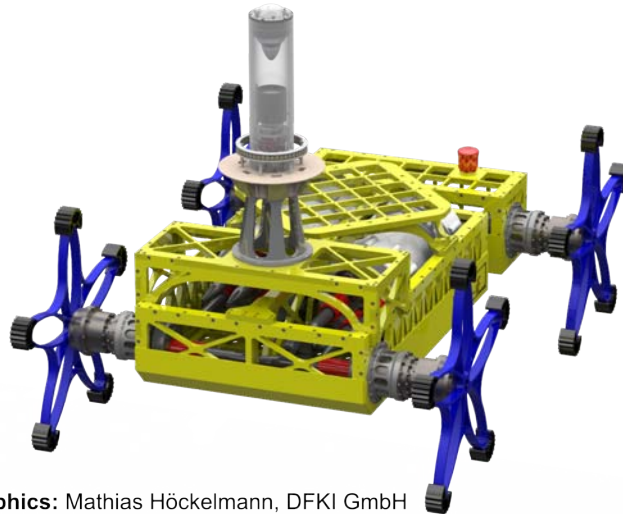
### 2.3 Rover properties

The figure below shows the planned rover of the MOONWALK project. It is designed to be remotely controlled and stream back video data for further analysis. Commands to the rover's system can be given over Wi-Fi. Video data will be available from the omnidirectional camera. This setup provides a 360 degree field of view and allows us to calculate an arbitrary number of virtual pan-tilt units, one for each user. The rover is equipped with LED flashlights to allow operation at night or in caves.

To allow the subsea earth analogue simulation, the rover can operate in up to 50m depth. Usually the payload will be mounted on the rover's back directly behind the camera assembly. Additional sensors may be mounted at different locations, but they must not reduce the rover's operational capabilities (e.g. reduce ground clearance to near zero).



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Graphics: Mathias Höckelmann, DFKI GmbH

### 2.3.1 Payload constraints

- Max. weight of 5kg
- Dimensions:
  - Height: 300 mm
  - Width: 400 mm
  - Length: 350 mm
- Mechanical connection to the rover is achieved over the flat surface behind the omnidirectional camera.
- No direct power and/or communication interface available to the rover. Well-grounded exceptions may be implemented after further consultation with the project team.

### 2.4 Mission Control Centre

The MOONWALK Mission Control Centre (MCC) is located in Brussels, Belgium, and operated by experienced flight controllers that will direct the simulated operations. Indications relevant to the experiments that need to be conveyed to, or obtained from the EVA test subjects will always go through the MCC. Nominally, three flight controllers, namely Flight Director (FLIGHT), Capsule Communicator (CAPCOM), and Robotics Officer (ROBO), will be present at the facility.

Flight controllers receive on-site information via, video feed, text and audio. The contents of this information includes; Cautions and Warnings, and Telemetry. This data is analysed in relation to mission procedures. Flight controllers can send operational data to the test subject, and control the Rover remotely.

PIs may have access to this facility and can interact with the Flight Control Team in connection with their experiment.



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### 2.5 Remote Science Centre (RSC)

A science-oriented node, the Remote Science Centre (RSC), will be implemented. In addition to the MCC, this Centre which consists of a computer running the MOONWALK MCC software, can be placed in a second geographical location other than the MCC. The RSC will be able to provide communications with the MCC, and obtain telemetry from the MCC, relevant to the particular science objectives of a given experiment.

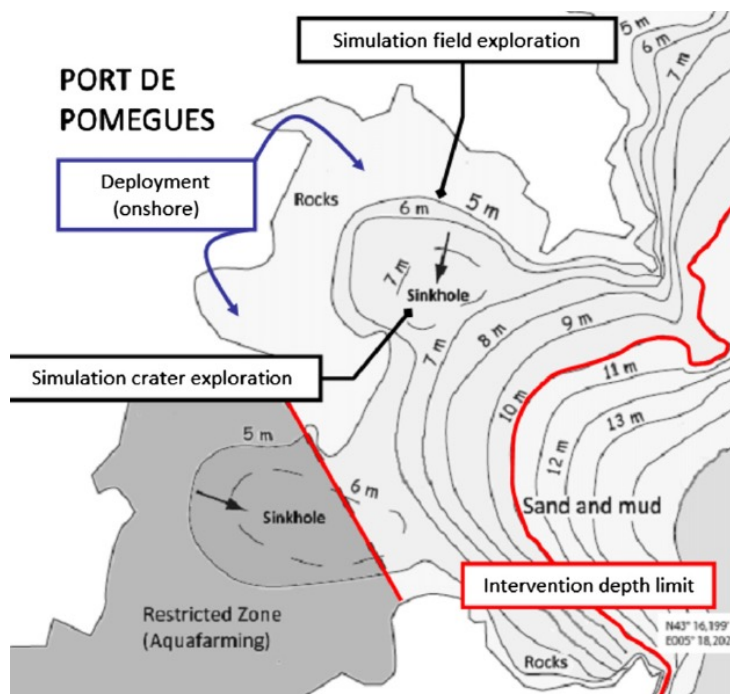
Said Remote Science Centre can be the home institution of a particular PI. The need for a RSC in a particular AO experiment can be proposed and will be assessed on a case-by-case basis.

## 3 Description of Analogue sites

### 3.1 Marseilles, France (Subsea): Lunar Analogue site

The Marseilles subsea analogue will be used in the frame of the MOONWALK project to simulate robotic and human missions to the lunar surface in reduced gravity ( $1/6^{\text{th}}$  G). The tests will be performed in water depths between -5m and -15m; all equipment used shall comply to this water depth. **Experiments that are proposed in the frame of this AO should therefore focus on human or robotic performance in reduced gravity.** Pre-mission tests will be performed in the COMEX pools before the mission at sea.

#### 3.1.1 Geomorphology







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The Marseilles subsea analogue site is located at the Frioul Island, offshore the Southern France city of Marseille. The site offers different types of geological morphologies that can be addressed in the underwater simulations. Examples of geologic features that can be used for the tests are crater-like formations (subsea sinkholes), plains with sediment and cliffs. Subsea caves, rilles and canyons are also present not far from the simulation site, it can however not be guaranteed that these sites can be included in the here proposed simulation.

### 3.1.2 Location and examples for expected terrain morphologies:

**Subsea Marseilles** lunar analogue site - EVA simulation in reduced gravity ( $1/6^{\text{th}}$  G) on a sediment plain.



**Subsea Marseilles** lunar analogue site - EVA simulation of Apollo 11 mission scenarios (top row and bottom left), asteroid mission in microgravity on a cliff (bottom right), Photos: COMEX/A. Rosenfeld

### 3.2 Rio Tinto, Spain: Mars Analogue site



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The Rio Tinto acidic basin is emplaced in the south western area of Spain, in the Huelva province. The most interesting area to test MOONWALK is in the north, which is comprised of Rio Tinto, Nerva, Berrocal, La Palma del Condado and Niebla localities. It is here where the river shows a closest analogy to Mars. This area is characterized by highlands (100 to 660 m) and a high stability in the hydro-chemical parameters such as pH, which remains between 0.9 and 3 (mean value of 2.3), and a high concentration of iron in solution (between 1.5 and 20 g L<sup>-1</sup>).



Rio Tinto field site. 1.5 h from Seville by car.  
Madrid-Sevilla by High Speed train (2 h 20 min)  
Sevilla has international airport



### 3.2.1 Geomineralogy

Previous planetary missions to Mars have conducted extensive studies of different regions of Mars geology and have shown that large areas of this planet were exposed to acidic conditions several billions of years ago. This has been demonstrated by the detection by several mineral phases that are uniquely formed under low pH like jarosite, other Fe-bearing sulphates and high concentration of Fe-oxides. Interestingly, same mineral associations were described in Rio Tinto, which has been used as a chemical analogue of the ancient hydro-chemical processes that produced the same minerals on Mars.

### 3.2.2 Extreme biology

The Rio Tinto area is an excellent natural laboratory to study the microbial life under extreme acidic conditions. The extreme acidic and metal rich waters force microbes to be true poly-extremophiles, that is, they have to deal with multiple extreme physicochemical parameters: extremely low pH, high metal concentrations (up to 10-20% w/v of iron), high oxidative stress, high salt concentration (sulphates >100 g/L) or low nutrient concentration. Nevertheless, a rich microbiology has been described in this region, ranging from chemolithotrophic bacteria to algae and fungi. Primary producers at the sources of the river are chemolithoautotrophic bacteria that obtain energy by the oxidation of electron donating inorganic reduced molecules such as pyrite (FeS<sub>2</sub>), Fe<sup>2+</sup> or SH<sub>2</sub>.

### 3.2.3 Location and examples for expected terrain morphologies:

**Rio Tinto** Mars analogue site - Rugged terrain and landscape as analogue for Mars.





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Top right: **Rio Tinto** Mars analogue site - An abandoned tunnel left by mining activities is an excellent analogue for exploring Martian lava-tubes. The height of the tunnel mouth is about 1.5 m. Photos: V. Parro.

## 4 Research Period(s)

**Rio Tinto, Spain: 16-30 April 2016**

**Subsea Marseilles, France: 28 May-12 June 2016**

Rio Tinto simulation: The Experiments of Opportunity are planned for two days. Each simulation run has a duration of not more than 2 hours.

Subsea Marseille simulation: The Experiments of Opportunity are planned for one day. Each simulation run has a duration of 20-30 min.



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### **5 Preparatory phase**

#### **Rio Tinto**

The opportunity for preparing your experiment on-site can be organized as is required. If needed, a dry-run in the first quarter of 2016 can be organized.

Researchers interested in the Mars analogue site have the ability to make field visits. Sensitivity of the experiments must be considered and ample time scheduled for knowledge impart from researcher to EVA crewmember (if necessary).

#### **Subsea Marseilles**

The opportunity for preparing your experiment on-site is limited. However, if needed, a dry-run in the first quarter of 2016 can be organized.

Subsea Marseilles preparations may only occur on land; it is not possible for researchers to directly visit the Subsea simulation site due to insufficient space on the vessel that will transport all people and equipment to the testing site. Experiments aimed for Subsea Marseilles should be fundamentally self-running experiments. Trained-astronaut-diver(s), or EVA crewmember(s), will carry out guest researcher experiments in the field on the specified date. The equipment for the experiments shall be ruggedized considering the environment in which the simulations are conducted.

### **6 Available Infrastructure**

Infrastructure can be made available to researchers (as approved by the MOONWALK management board) during both simulations and include:

- access to Mission Control Centre, Brussels, Belgium.
- access to the communications loops.
- access to live telemetry at a Remote Science Centre in the premises of the PI or at MCC.

Aforementioned infrastructure will be made available for exceptional proposals and must be coordinated accordingly.



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### 7 Timeline

April 2015	Announcement of Opportunity
<b>31 October 2015 23:59 CEST</b>	<b>Deadline for experiment proposal submissions</b>
November 2015	Clarification and feasibility assessment
7 December 2015	Notification of Acceptance/Non-Acceptance
31 January 2016	Experiments defined in detail, preliminary mission definition and release of the MOONWALK Mission expedition planning reference document
Dry-runs (Q1 2016)	Access to dry-runs can be organized if needed (e.g., COMEX pools for Subsea Marseille).
<b>16-30 April 2016</b>	<b>Field Mission: Rio Tinto</b>
<b>28 May – 12 June 2016</b>	<b>Field Mission: Subsea Marseilles</b>
Aug 2016	MOONWALK final dissemination packet available

### 8 Selection process

Submissions of proposals **MUST** reach [moonwalk@liquifer.com](mailto:moonwalk@liquifer.com) via Email not later than **31 October 2015, 23:59 CEST** in electronic form.

All proposals will be reviewed by a process of peer-review and will be assessed for quality of proposed research and feasibility. All research must be self-funded, however MOONWALK will provide the scientific and logistics infrastructure if possible. At Subsea Marseille, PIs will not be able to be on-board the research support ship due to capacity restrictions. This must be considered in the design of the experiments.

Preference will be given to experiments that;

- respond to the current need of manned space exploration as outlined in ESA, NASA or other pertinent roadmaps; ([http://www.globalspaceexploration.org/wordpress/wp-content/uploads/2013/10/GER\\_2013.pdf](http://www.globalspaceexploration.org/wordpress/wp-content/uploads/2013/10/GER_2013.pdf))
- exploit the environmental, topological, geochemical, biological and/or partial gravity (analogue) aspects of the sites



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- require EVA crewmember(s) to interact with equipment, tools, technology, or to carry out procedures, etc
- exploit the full chain of communication between Mission Control and EVA crew in a purposeful manner
- are in sync with ongoing research at the particular sites of subsea Marseilles and/or Rio Tinto

The selection of proposals will be based on the following criteria:

- technical, operational or scientific merit (intrigue).
- inclusion of a detailed plan that clearly describes the research proposal and (methodology) and states the feasibility and importance of the project.
- offers indication that the project utilizes logistics resources.
- can provide substantial risk assessment in programming, engineering and safety factors and offer proof of ability to mitigate these risks.
- the researcher's intention after the proposed experimentation period to; process, analyse, collaborate and share experiment data and/ or the intent to publish in a timely manner.

Experiment proposals will be selected by the board "as is," "with a request for modifications," or "not selected." The Principal Investigator will have the option to decline in the case modifications are requested.

## 9 Legal Disclaimer

The MOONWALK team reserves the right to cancel or postpone any or some of the field mission(s), although extremely unlikely. Researchers answering to this AO need to consider eventualities and are responsible for their own expenses and risks. The MOONWALK team will ask all selected experiment teams to sign a legal agreement for their experiment. By submitting a proposal, you agree to;

- fulfil the requirements put forward in this Announcement of Opportunity, including indicated responsibilities, deadlines and documentation
- be available during the mission for science support, either in the field, at your home institution, or in the Mission Control Centre in Brussels
- potentially share research data for data fusion and joint experimentation on a case-to-case basis
- be able to cover the funding for your experiment, to deliver the experiment hardware in time to and from the simulation site including its documentation
- participate in any necessary preparatory teleconferences and training workshops
- be willing and able of processing, analysing and publishing the results of your experiment by the end of July 2016
- publish the results of your experiment in the final MOONWALK report



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- Provide adequate insurance coverage for all equipment and personnel involved in the experiment

### 10 Funding

All costs incurred through selected AO-experiments have to be taken care of by the selected researcher/s, including:

- development of the hardware.
- transport of hardware and personnel to and from the mission sites of Marseilles (France) or Rio Tinto (Spain).
- documentation (for the field test and for the final report).

### 11 Submission format (proposals must include the following content)

<b>Title</b>	The title should be informative and relate the goal of the proposed investigation; in addition, a one-word project name or acronym for the (project) proposal.	Cover Page
<b>Summary</b>	The scientific objectives of the proposal should be summarized and the means to achieve them addressed.	≤ 1 page
<b>Team Members Contact &amp; Expertise</b>	An account of every member in the proposing team shall be detailed, including person's name, affiliation, postal address, email and telephone. An outline of the expertise each member can contribute to the investigation shall be included.	≤ one page per person
<b>Scientific description</b>	<p>A detailed description of the proposed project to be carried out during the MOONWALK simulation mission should follow the standard outline for a scientific proposal (and possess):</p> <ul style="list-style-type: none"><li>• Research rationale, including why it is important to (perform) your experiment and the prevalent literature surrounding the subject within its field.</li><li>• A scientific, engineering or operational hypothesis testifying to the core of the experiment.</li><li>• A (short) Risk Analysis based on the proposed simulation scenario (Marseilles or Rio Tinto).</li><li>• A detailed account of proposed methods.</li><li>• Expected results of the experiment.</li><li>• Plan to publish.</li><li>• Summary of outreach activities linked to the experiment.</li><li>• Speculation on collaboration with other research bodies.</li></ul>	≤ 3 pages





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	This part of the proposal should demonstrate that the proposed work is scientifically/technically (relevant) and feasible.	
<b>Technical description</b>	<p>Should include the implementation plan as it applies to the scientific, technical and management (incl. logistics) of the experiment.</p> <p>Indication of which facilities, as made accessible by the MOONWALK mission will be required, including:</p> <ul style="list-style-type: none"><li>• Duration of the experiment —including projected training time and actual test time.</li><li>• Statement of how many persons need to be present on site.</li><li>• Clear description of power requirements and interfaces.</li><li>• Communication requirements.</li><li>• Shipment (and storage) weight and size.</li><li>• Any other special needs and requirements.</li></ul>	≤ 3 pages

**Submission deadline:** [moonwalk@liquifer.com](mailto:moonwalk@liquifer.com) via Email not later than 31 October 2015, 23:59 CEST in electronic form.



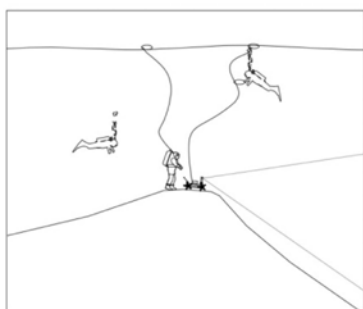
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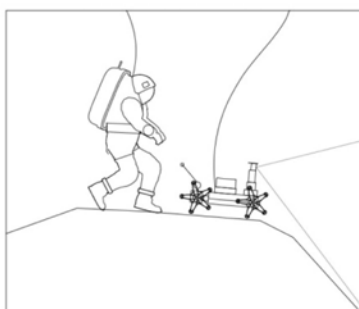
## 12 Appendix Human-Robot collaboration Scenarios

For further information, please see the MOONWALK's scenarios which have been selected as baseline.

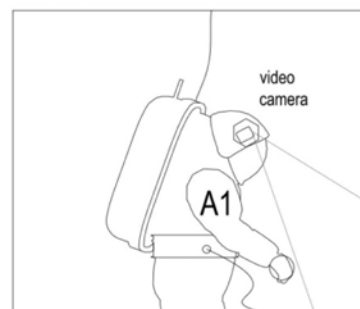
### 12.1 Subsea Marseilles Lunar Analogue site in France: Exploration and scouting of a crater including astronaut and a tethered rover



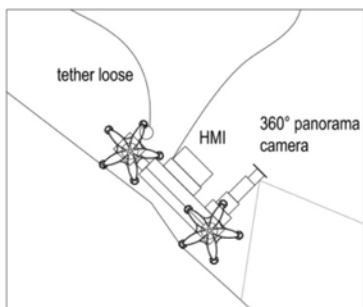
A1 has followed rover to crater rim



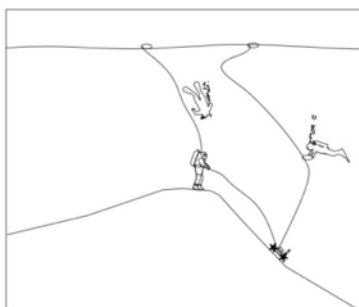
A1 reaches for tether handle at rover



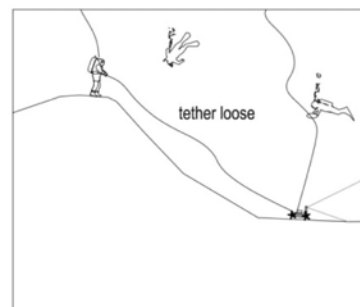
A1 has attached tether to suit and documents rover movement



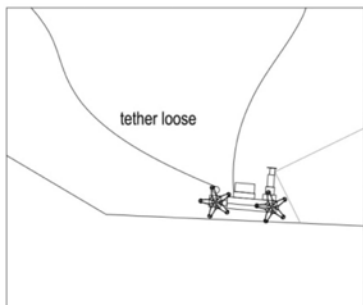
rover descends - tether loose  
rover profiling, reporting



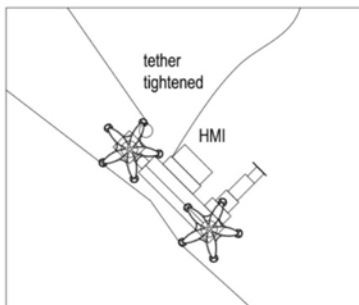
A1 secures rover descending  
a steep, straight line



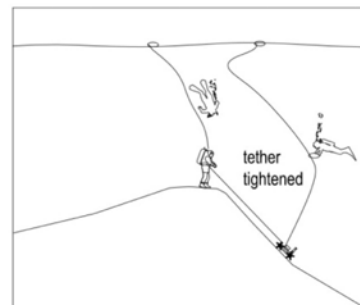
rover documents site



rover goes into reverse



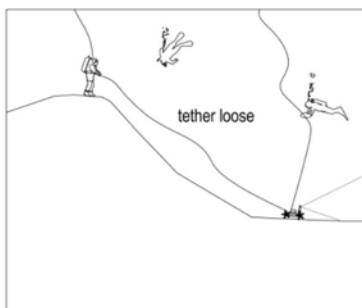
rover ascends in reverse gear -  
tether tightened



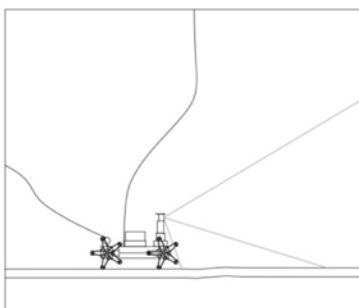
A1 secures rover ascent in  
reverse gear

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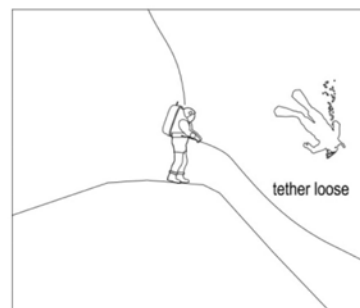
### 12.2 Subsea Marseilles Lunar Analogue site in France: Astronaut takes samples while the rover trenches soil



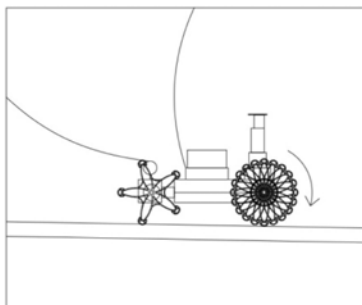
rover explores site inaccessible or too dangerous for A1



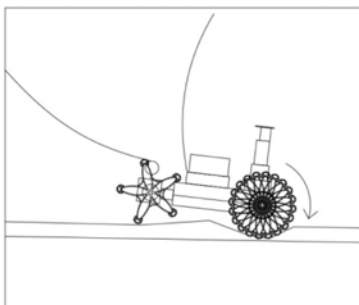
rover transfers images of surface in front of wheels to A1



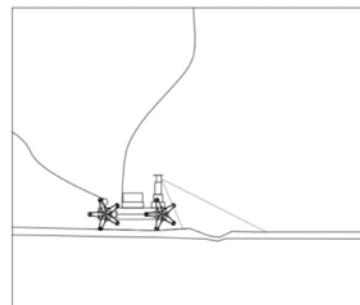
A1 gives command to rover to start trenching for a specified period



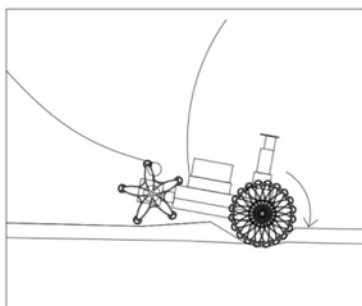
rover front wheels start spinning while the rear wheels are locked



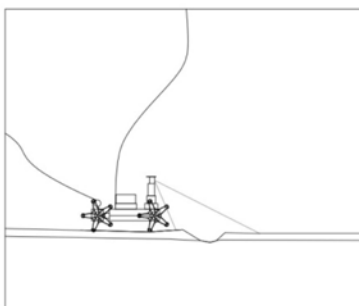
the spinning wheels generate a trenching process



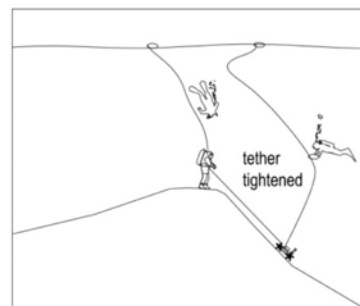
rover goes in reverse and transfers images of manipulated surface to A1



A1 commands to continue trenching operation



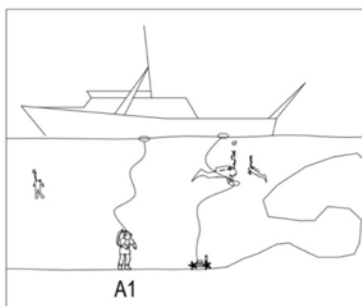
rover goes in reverse and conveys images of manipulated surface to A1



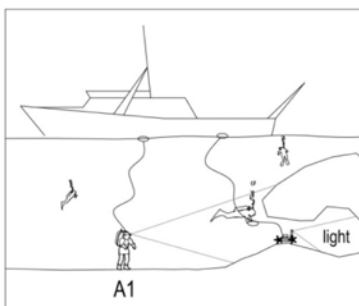
after completion of operation, A1 secures rover ascent in reverse gear

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### 12.3 Subsea Marseilles Lunar Analogue site in France: Exploration and scouting of a cave including astronaut and rover



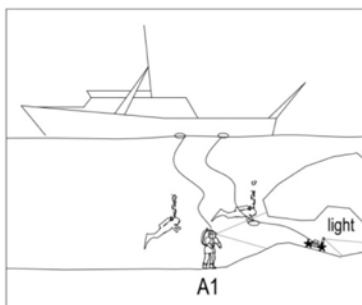
communication A1 - rover, direct  
command: explore cave site



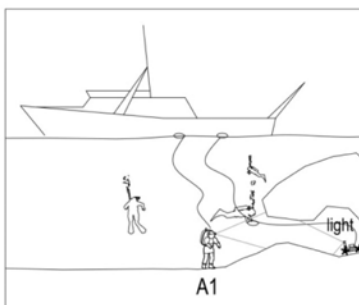
rover turns on light at cave entrance  
to perform exploration with camera



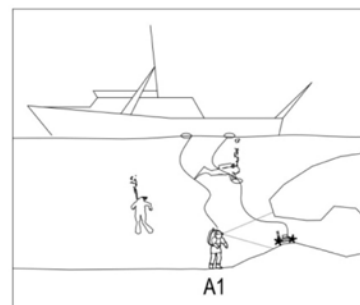
communication CC - A1 / rover,  
A1 or CC gives ok to enter cave



rover proceeds teleoperated into  
cave



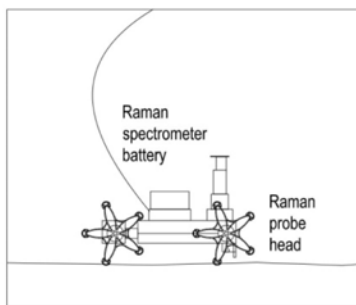
rover performs u-turn or reverses to  
cave entrance



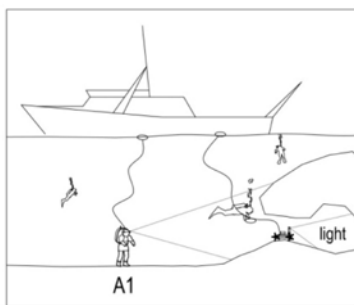
rover leaves cave and follows A1  
back to base or next point of interest

## Announcement of Opportunity (AO)

### 12.4 Subsea Marseilles Lunar Analogue site in France: Astronaut receives information from the rover while the rover collects information with a Raman spectrometer in a cave



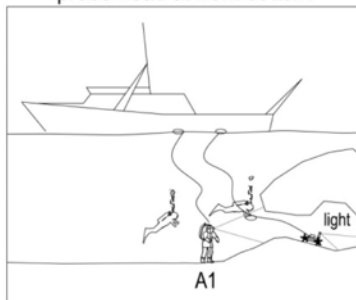
rover outfitted with Raman spectrometer in payload box and probe head at front bottom



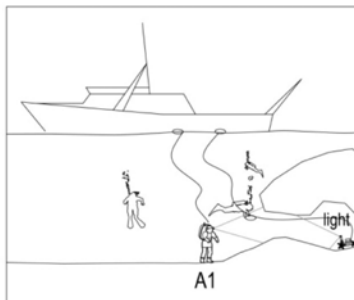
rover proceeds in cave teleoperated by A1 to identify sample



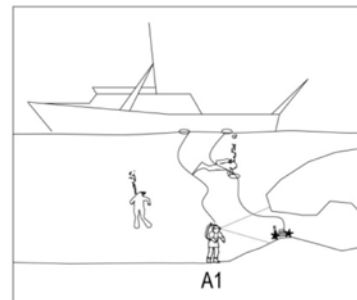
communication CC-A1/ rover



rover performs measurement with Raman probe head positioned on target



rover performs u-turn or reverses to cave entrance

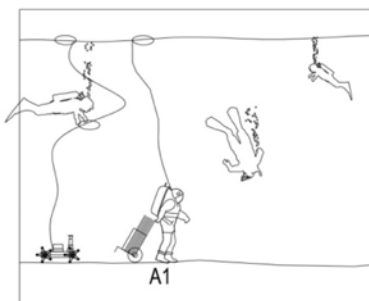


rover leaves cave and follows A1 back to base or next point of interest

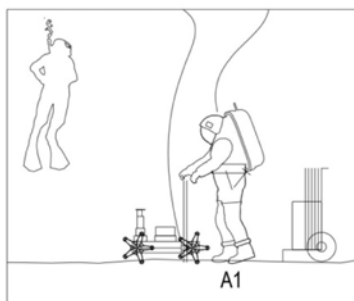


## Announcement of Opportunity (AO)

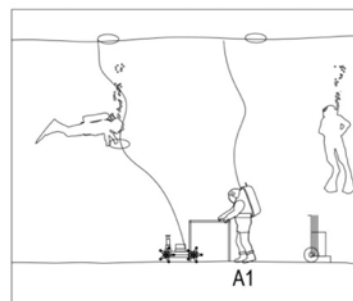
### 12.5 Subsea Marseilles Lunar Analogue site in France: Astronaut and rover construct a tool shed together



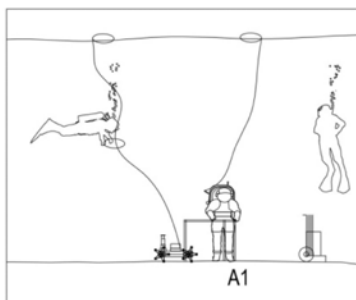
A1 transports small tools on suit and transports construction material



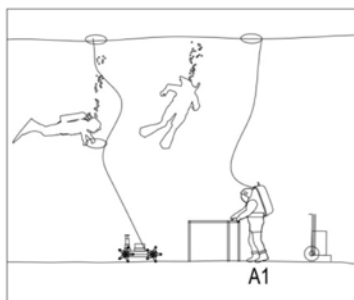
rover functions as support for the first upright beam to be held in position



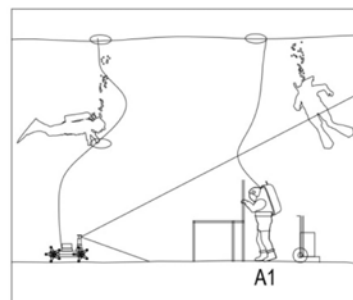
A1 can continue construction with the support of the rover



A1 can continue construction with the support of the rover



when the construction is stabilised through 3 legs, the rover is released



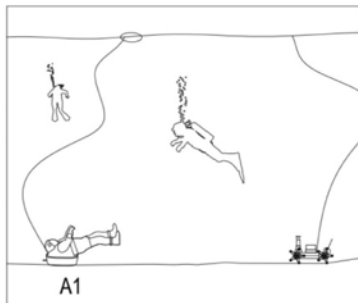
A1 continues construction, the rover documents via camera



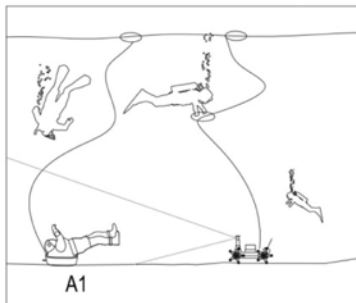
## Announcement of Opportunity (AO)



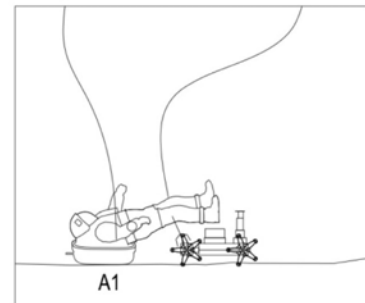
### 12.6 Subsea Marseilles Lunar Analogue site in France: Emergency scenario; Rover helps the fallen astronaut to get up again by bringing a tool to the astronaut



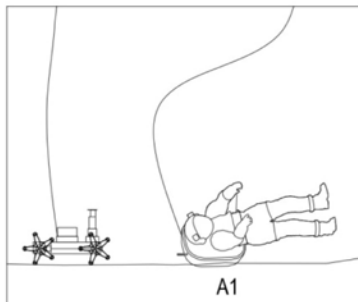
A1 fallen, communicates with rover via gesture control



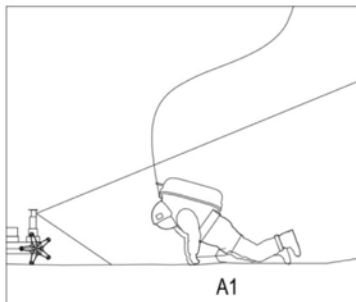
rover brings support tool to A1 and documents



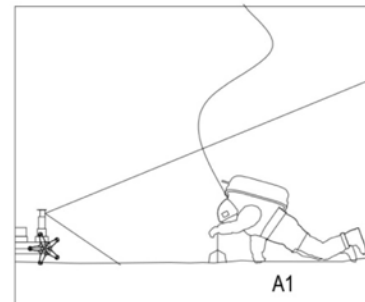
rover approaches slowly close to A1 to supply telescopic support tool



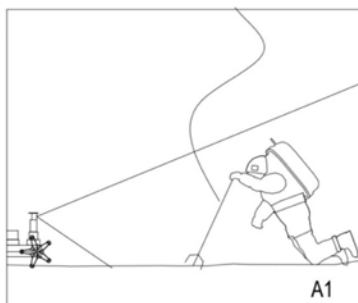
A1 turns around with support of telescopic support tool



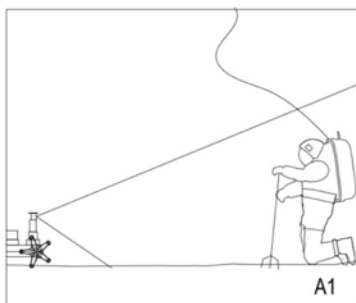
A1 has turned around, rover documents



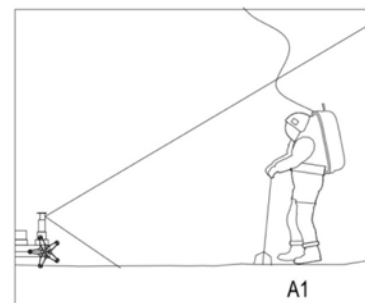
A1 positions telescopic support tool, rover documents



telescopic support tool deployed by A1



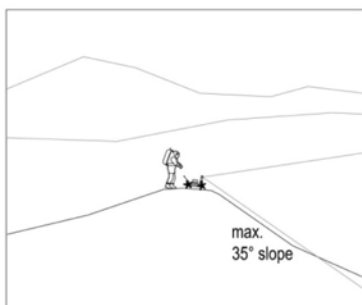
A1 gets on knees with help of tool



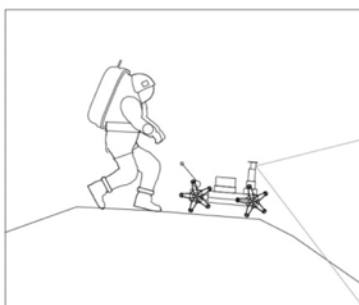
A1 gets up with help of telescopic support tool

## Announcement of Opportunity (AO)

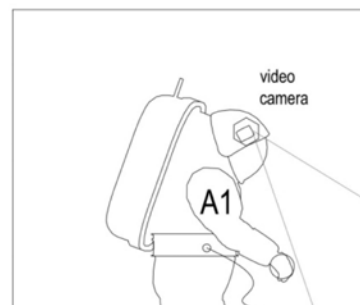
### 12.7 Rio Tinto Mars Analogue site in Spain: Exploration and scouting of a crater including astronaut and a tethered rover



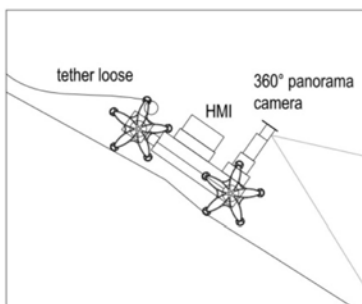
A1 has followed rover to crater rim



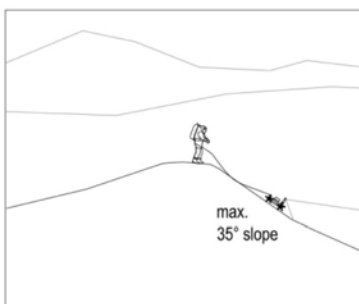
A1 reaches for tether handle at rover



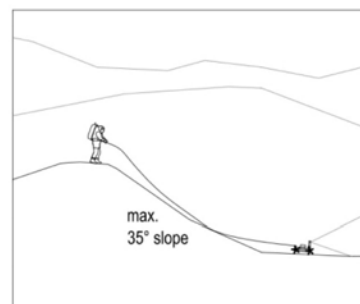
A1 has attached tether to suit and documents rover movement



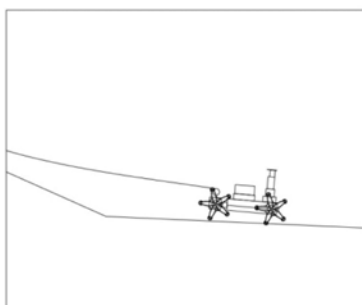
rover descends - tether loose  
rover profiling, reporting



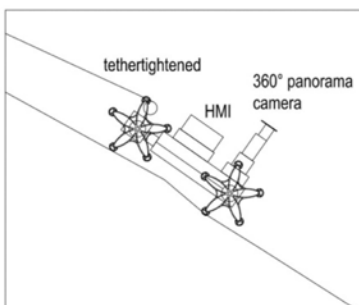
A1 secures rover descending  
a steep, straight line



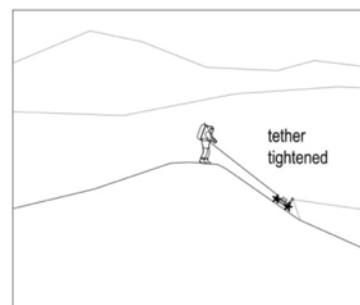
rover documents site



rover goes into reverse



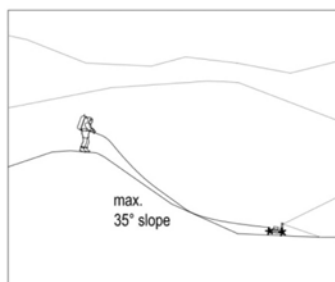
rover ascends in reverse gear -  
tether tightened



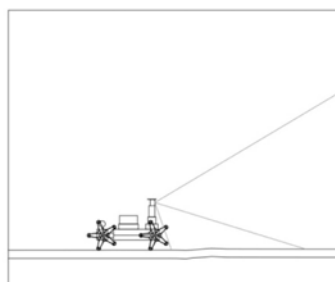
A1 secures rover ascent in  
reverse gear

## Announcement of Opportunity (AO)

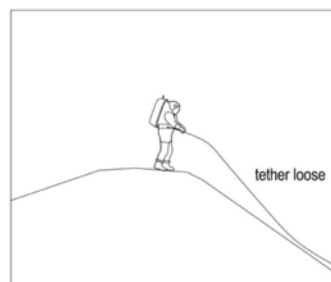
### 12.8 Rio Tinto Mars Analogue site in Spain: Astronaut takes samples while the rover trenches soil



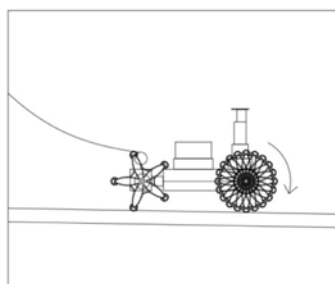
rover explores site inaccessible or too dangerous for A1



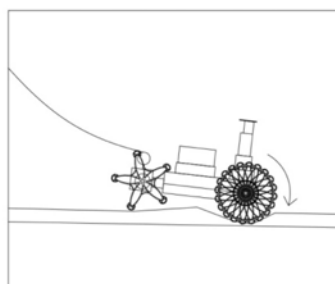
rover transfers images of surface in front of wheels to A1



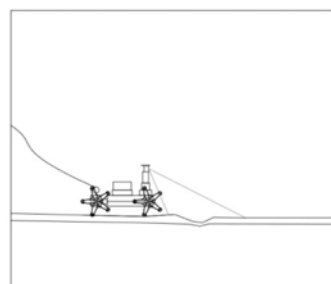
A1 gives command to rover to start trenching for a specified period



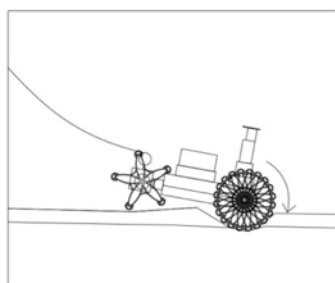
rover front wheels start spinning while the rear wheels are locked



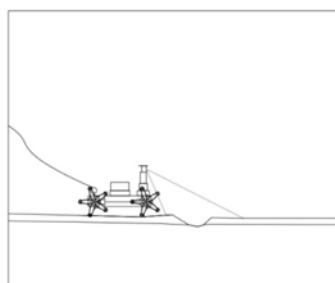
the spinning wheels generate a trenching process



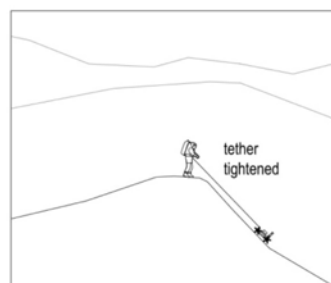
rover goes in reverse and transfers images of manipulated surface to A1



A1 commands to continue trenching operation



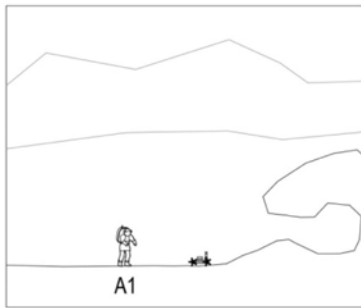
rover goes in reverse and conveys images of manipulated surface to A1



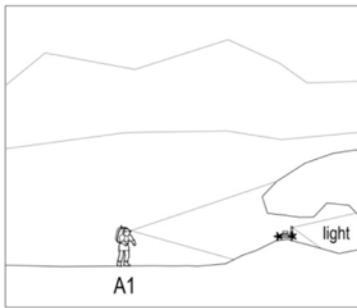
after completion of operation, A1 secures rover ascent in reverse gear

## Announcement of Opportunity (AO)

### 12.9 Rio Tinto Mars Analogue site in Spain: Exploration and scouting of a cave including astronaut and rover



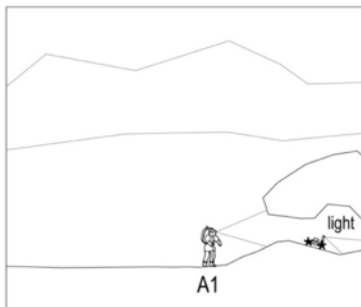
communication A1 - rover, direct  
command: explore cave site



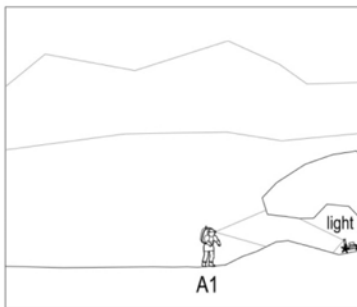
rover turns on light at cave entrance  
to perform exploration with camera



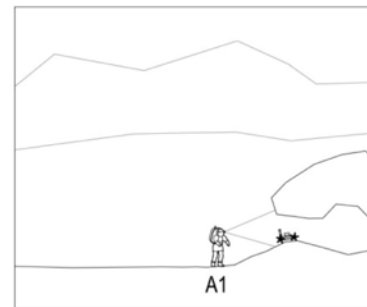
communication CC - A1 / rover,  
A1 or CC gives ok to enter cave



rover proceeds teleoperated into  
cave



rover performs u-turn or reverses to  
cave entrance

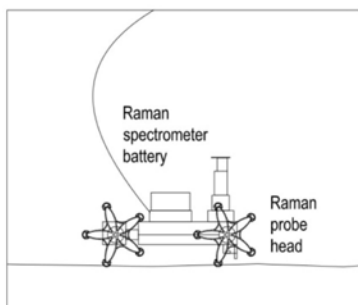


rover leaves cave and follows A1  
back to base or next point of interest

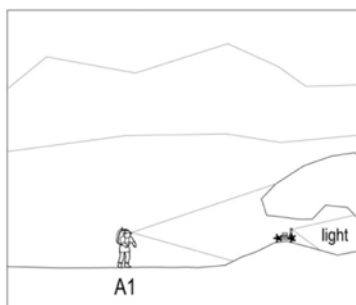


## Announcement of Opportunity (AO)

### 12.10 Rio Tinto Mars Analogue site in Spain: Astronaut receives information from the rover while the rover collects information with a Raman spectrometer in a cave



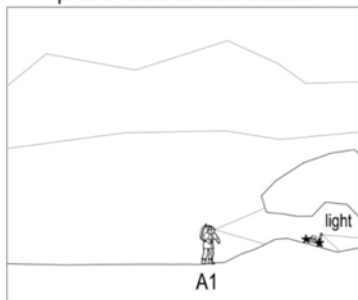
rover outfitted with Raman spectrometer in payload box and probe head at front bottom



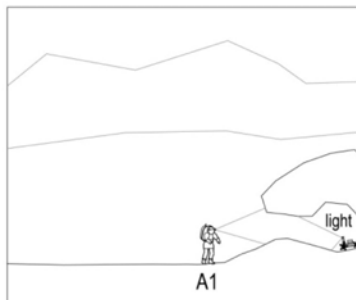
rover proceeds in cave teleoperated by A1 to identify sample



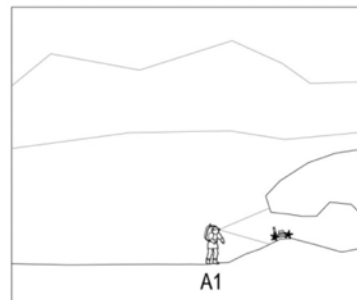
communication CC-A1/ rover



rover performs measurement with Raman probe head positioned on target



rover performs u-turn or reverses to cave entrance



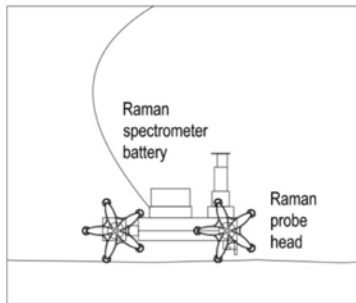
rover leaves cave and follows A1 back to base or next point of interest



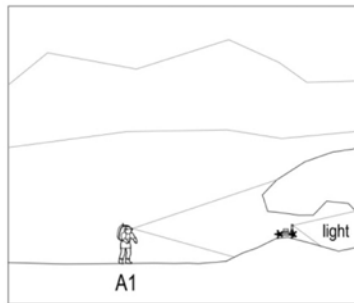
## Announcement of Opportunity (AO)



### 12.11 Rio Tinto Mars Analogue site in Spain: Astronaut and rover construct a tool shed together



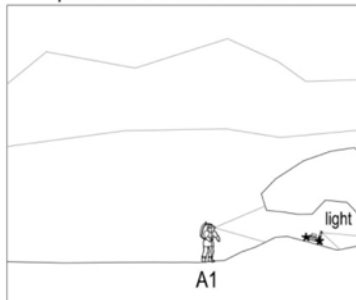
rover outfitted with Raman spectrometer in payload box and probe head at front bottom



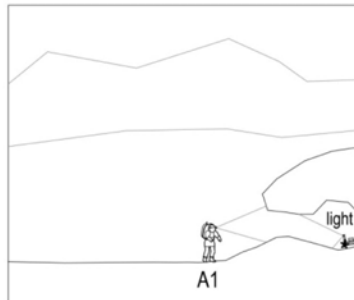
rover proceeds in cave teleoperated by A1 to identify sample



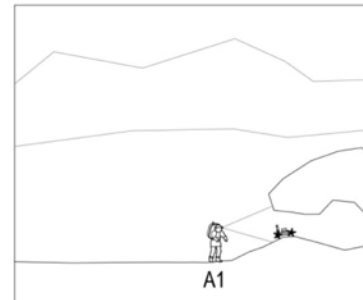
communication CC-A1/ rover



rover performs measurement with Raman probe head positioned on target



rover performs u-turn or reverses to cave entrance



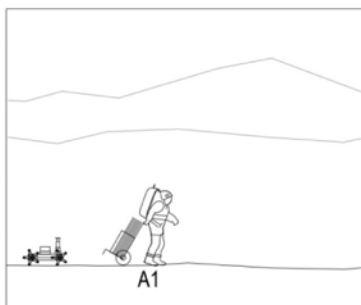
rover leaves cave and follows A1 back to base or next point of interest



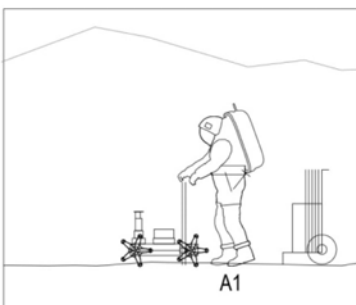
## Announcement of Opportunity (AO)



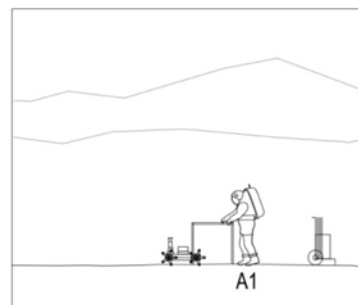
### 12.12 Rio Tinto Mars Analogue site in Spain: Emergency scenario; Rover helps the fallen astronaut to get up again by bringing a tool to the astronaut



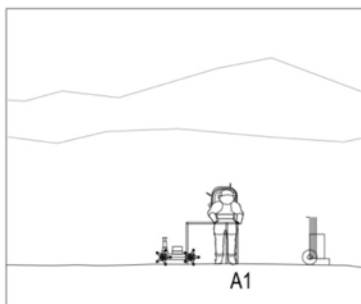
A1 transports small tools on suit and transports construction material



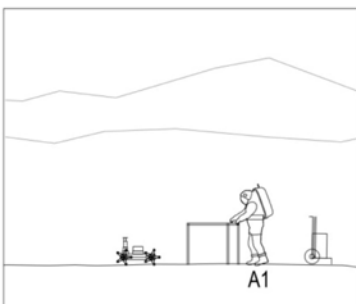
rover functions as support for the first upright beam to be held in position



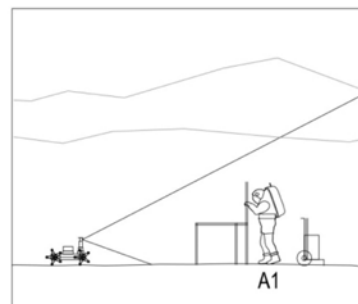
A1 can continue construction with the support of the rover



A1 can continue construction with the support of the rover



when the construction is stabilised through 3 legs, the rover is released



A1 continues construction, the rover documents via camera