Australian Rover Challenge 2021

Rules and Requirements

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Australian Rover Challenge Vision

- Enable the growth of multidisciplinary student teams within Australia.
- Provide a platform for national collaboration towards technological innovation and development within the space industry.
- Pioneer full scale planetary simulation missions to validate new technologies towards resource utilisation on the Moon and Mars.
- Promote collaborative learning and friendly competition for new and growing Australian student teams.

Revision History & Changelog

06/08/2020 : V1 release.
23/08/2020 : V2 release. Timeline updated. Rule 11.9.1 added. Rule 11.3 clarified. Minor changes in wording throughout (no change to the meaning of the rules where this has occurred.)
21/09/2020 : V3 release.

- Naming of the competition deliverables has been changed. The Preliminary Submission is now known as the Preliminary Design Review (PDR) and the Design Report is now known as the System Acceptance Review (SAR).
- Clarification to regolith identification and extraction during the Lunar Resources task (Rule 9.5.).
- Prizes have been updated. The SAR is no longer scored jointly with the Design Presentation. Scores (and hence prizes) for each task now only depend on the task score itself. An award for the best documentation will be awarded to the highest cumulative score of the PDR and SAR. There will be an award for the best Design Presentation. There is no change to the overall award which is the sum of all scoring components. More information can be found in Section 4.
- Removed annotated satellite image portion of the challenge (used to exist under the heading “tasks”).
- Added a requirement for teams to demonstrate in the SAR that they meet the “minimum requirements” as outlined in this document (Rule 6.4.).
- Added a “safe carry” rule (Rule 7.2.).
- Added a rule regarding permitted university staff involvement in teams (Rule 1.2.).
- Added a rule for the same rover platform to being each task (Rule 3.2.).
- Added time limits for the Lunar Construction (Rule 10.2.) and Sensor (Rule 11.10.) tasks.

31/10/2020 : V4 release.

- Timeline updated.
- Clarification that the Lunar Resources Task is focusing *exclusively on* the identification and extraction of frozen water, not volatiles, hydrocarbons or metals. (Rule 9.1)
- Clarification that sites will be Flagged for the Resources Task (Rule 9.5)
- Added Flags for the Resources Task to signal where each sample 'site' will be located (Rule 9.5)
- Correction to the time allowed for each stage of the Post-Landing Task (Rule 8.4)

03/02/2021 : V5 Release

- The total time limit for all tasks **except Lunar Resources** has been reduced from 45 to 40 minutes. The time limit for Lunar Resources remains unchanged.
- The time hurdles for stages of the **Post-Landing** and **Semi-Autonomous Tasks** have been reduced from 20 to 15 minutes.
- Rule 10.1.3. updated to reflect the new materials provided to teams in the **Lunar Construction Task**.
- Rule 10.3. updated - more clarification regarding the **Lunar Construction Task** scoring will be available to teams as soon as possible.
- Rather than describing the sedimentology of the site and samples, greater focus should be paid to the larger structural features and topology of the site, and the location of the samples within it. This is because the material used to cover the ground, as well as the material used to create the Lunar Samples **will not accurately reflect Lunar regolith** (Grain size, shape, particle size distribution, colour) this is a budgetary limitation.
    - Revised **Lunar Resources** Stage 3.1 (Rule 9.3.).
        - (Removed original Stage 2) replaced with "traversing to and imaging" each sample site. This is to place more focus on the characterization of the field site and data analysis during the provided discussion time (15 minutes) in preparation for the **Lunar Resources Presentation.**
    - Revised wording of Rule 9.7.2. to refine one of the **Lunar Resources Presentation** marking criteria to focus more on the *In-Situ* resource potential rather than the sample description
- Rule 11.6. clarified - the starting position for subsequent stages of the **Autonomous Task**.
- Rule 7.1.1. added - maximum number of team members allowed in the base station.

22/02/2021 : V6 Release

- Appendix A Lunar Resources Task added.
- Rule 10.3. and 10.4. added - Lunar Construction scoring breakdown and materials.
- Rule 9.7. reworded - Teams will be required to answer questions during the Lunar Resources Presentation.

1. Challenge Rules

1.1. "Team" refers to the individuals tasked with operating a Rover entry. A University is not limited in the amount of teams that they may enter, and teams from a single University do not have to contain unique team members.

1.2. The individuals making up a team shall be students of any study level. Guidance and assistance from university staff should be drawn upon, however direct, dedicated involvement from university staff is prohibited.

1.2.1. University staff in this respect refers to any university employee who is not actively studying to attain a higher level of education than they already hold. Students who hold casual or part time positions such as, but not limited to, demonstrating, tutoring or assisting research, are excluded from the definition of university staff as it applies in Rule 2.1.

1.3. It is highly recommended to have unique team members with distinct roles and responsibilities *at the challenge tasks* to avoid confusion between operational requirements and procedures for each Rover, should a University submit multiple entries.

1.4. Cross-University hints, tips, tricks, and advice within the spirit of the challenge is permitted and encouraged, however *collaboration* should be minimal.

1.5. Teams must complete a Preliminary Design Review, System Acceptance Review and Design Presentation throughout the Challenge, however teams are not required to take part in each *task* during the challenge. In the Preliminary Design Review, teams are required to notify the organising committee of the tasks that their Rover plans to contest.

1.6. Awards will be given out for each task, the best documentation, the best presentation, and the highest total score for all scoring activities. See section 4 for more details.

1.7. The location of Challenge briefings and events not associated with the tasks are expected to take place within metropolitan Adelaide - most likely at a campus of the University of Adelaide (unconfirmed). The tasks during the Challenge will occur at the University of Adelaide (North Terrace).

2. Key dates

2.1. August 23 : Team registration opens

2.2. August 28 : Requirements of Preliminary Design Review outlined

2.3. September 5 : Registration closes

2.4. September 28 : Preliminary Design Review Due

2.5. November 2 : Team registration re-opens

2.6. December 4 : Team registration closes

2.7. December 18 : SAR Guidelines released

2.8. January 8 : Preliminary Design Review Due for new teams

2.9. February 19 : SAR Due for all teams

2.10. March 6 : Design Presentation guidelines released

2.11. March 26 : Event registration, safety briefing, and industry engagement
2.12. March 27-28 : Australian Rover Challenges competition dates

3. Rover Rules

3.1. The Rover shall be a stand-alone, off-the-grid, mobile platform. Tethered power and communications are not allowed. A single connected platform must leave the designated start gate.

3.2. The essence of the Rover system shall be the same for all of the tasks that a team participates in. Different payloads and sensing systems may be present on the Rover in compliance with Rule 3.4. however, the platform of the Rover must be the same from task to task.

3.2.1. In this sense, the “platform” of the Rover refers to the systems which make up the Rover and cannot easily be changed or adjusted. This includes, but is not limited to, the chassis, suspension, core computing, power systems, and drive systems.

3.3. Rovers shall be weighed by the judges during the set-up time of each task. The Rover must be able to fit on the lander at the beginning of the first task (Post-Landing Task) which constitutes a 1.75m diameter circle.

3.3.1. Rovers may articulate/fold/bend to fit within the lander, but may not be disassembled to do so. This includes wheels, antennas, and any other system protruding from the Rover.

3.3.2. There is no vertical height limit, and the Rover may be placed in any orientation.

3.3.3. Once a Rover is positioned on the lander in a configuration which meets the size requirements, interference from team members is not permitted. That is, if the Rover articulates/folds/bends to fit within the lander, the Rover must be able to maneuver into a position to start the task by itself.

3.3.4. The same Rover footprint will be used for all challenges.

3.3.5. Separate payloads may be attached in accordance with the weight guidelines in Rule 3.4. however the *vertically projected area* (shadow cast by a Rover with the sun directly overhead) of the Rover and all systems must not increase by more than 10% when compared to the Rover configuration as present on the lander.

3.3.6. If a team does not elect to compete in the first task, they will be subject to the same size limitations for the tasks that they do compete in.

3.3.7. Failure to fit within the specified dimensions will result in a 40% penalty for each task that the Rover is non-compliant. Failure to meet the 10% projected area (Rule 3.3.5.) in subsequent tasks will result in a 20% penalty for that task.

3.4. The maximum allowable mass of the Rover when deployed for any competition mission is 50 kg. The total mass of all fielded Rover parts for all events is 70 kg.

3.4.1. A modular Rover may have a robotic arm and a sensor that are never on the Rover at the same time. The combinations of Rover plus arm and Rover plus sensor must each be under 50 kg. The total Rover plus arm plus sensor must

be less than 70 kg. The weight limits do not include any spares or tools used to prepare or maintain the Rover.

3.4.2. For each task in which the Rover is overweight, teams will be subject to a penalty of 5% per kilogram over 50kg. This penalty will be applied to the score that the team obtains during the task. For example, a 52kg Rover scoring 80 points will be awarded 72 points after the penalty is applied.

3.5. The total cost of the Rover and base station systems (that is everything that is required to operate the Rover) shall be no more than $25,000AUD.

3.5.1. This price should be the price at which any member of the public could acquire the components and parts that make up the whole Rover system (i.e. not including any discounts of any type).

3.5.2. Teams will not be required to submit a financial report detailing the costs of these systems.

3.5.3. Teams may be subject to investigation by the judges, should their system appear to cost more than the limit.

3.6. Rovers shall utilise power and propulsion systems that are applicable to operations on the Moon. Air-breathing systems are not permitted: No power or propulsion system may ingest ambient air for the purpose of combustion or other chemical reaction that yields energy. There are no other requirements for which a Rover may adhere to Lunar conditions, however additional design features which adhere to operation on the Lunar surface may be looked upon favourably by the judges in the Design Presentation.

3.7. All Rovers shall have at least one “e-stop switch” that consists of a red latching button with a yellow surround, that is readily visible and accessible on the exterior of the Rover. This switch shall immediately stop the Rover’s movement and cease all power draw from batteries in the event of an emergency such as a battery fire. All Rovers shall have a clear external indication of powered on/active status.

3.8. Communications

3.8.1. It is recommended that at least one member from each team obtains an amateur radio licence.

3.8.2. Teams are responsible for ensuring that they comply with ACMA regulations for the frequency band in which they are operating.

3.8.3. No two teams will be on the challenge course at the same time, so no interference is to be expected. It is, however, good practice to ensure that your communications equipment can automatically or manually switch between frequency bands, should there be any interference from a third party.

3.8.4. Based on information collected during the Preliminary Design Report, the organising committee will take further steps to ensure that interference during the Challenge tasks is minimised.

3.9. Base Station Antennas

3.9.1. Base station antennas may be positioned during the set-up period and may only be repositioned by a team member adhering to Rule 7.3.2.

3.9.2. Base station antennas may be no greater than 3m tall.

3.9.3. There are no further geometric requirements of base station antennas, however teams should consider the logistics and set up time of large systems to ensure that they comply with Rule 7.1.

3.10. The task areas are yet to be confirmed, but are expected to be hot and dry. There may be copious amounts of loose soil, rock, and sand, which a Rover should be able to navigate. Although rain is uncommon, Rovers should be able to operate in reasonably wet conditions - a light shower or two. The judges will place a task on intermission, should precipitation be great enough that ingestion of water by Rovers would be difficult to avoid.

3.11. Rovers will not be expected to traverse more than 200 m from the base station. Obstacles may exist which obscure the line-of-sight to the Rover, but they will consist of small-sized, artificial obstacles.

4. Scoring and Prizes

4.1. The scoring and prizes will be awarded by the judging panel for each task. The judging panels will be made up of professionals from academia and industry, and will be confirmed closer to the date of the Challenge.

4.2. Scores will be awarded for the Preliminary Design Review (as outlined in section 5), the System Acceptance Review (as outlined in section 6), the Design Presentation (as outlined in section 12) and each task (as outlined in sections 8-11).

4.3. Prizes will be awarded to the team with the highest score in each task.

4.4. A prize will be awarded to the team with the best documentation; the highest total score for the Preliminary Design Review and System Acceptance Review.

4.5. A prize will be awarded to the team with the highest score in the Design Presentation.

4.6. An overall Challenge prize will be awarded based on the sum of all scoring activities.

4.6.1. The Preliminary Design Review, System Acceptance Review and Design Presentation scores will only be included once in this score.

4.6.2. The challenge score will be out of 450; 4 x 100 task points + 15 Preliminary Design Review points + 25 System Acceptance Review + 10 Design Presentation points.

5. Preliminary Design Review

5.1. On September 28 teams will be required to submit a Preliminary Design Review outlining core Rover systems, their readiness, and work expected to be completed before the Challenge.

5.1.1. Teams in the November registration will be required to submit a Preliminary Design Review on January 8.

5.2. Core Rover systems which will have to be reported upon include, but are not limited to:

5.2.1. Power systems, power delivery, and power safety

5.2.2. Drivetrain

5.2.3. Chassis construction and materials

5.2.4. Camera systems

5.2.5. Base station design and control
5.2.6. Rover communications
5.2.7. Drive control systems (software based)
5.2.8. Additional hardware and software that is specific to each task the team intends to compete in.

5.3. Teams will also be required to supply a timeline, highlighting consequential tasks, and contingency plans for delayed completion of said tasks.

5.4. More detailed information and the Preliminary Design Review will be provided at the latest, by the 28th of August.

5.5. A prize will be awarded to the team with the highest cumulative score for the Preliminary Design Review and System Acceptance Review in accordance with Rule 4.4.

6. System Acceptance Review

6.1. On February 19 teams will be required to submit a System Acceptance Review outlining the design of their systems, and approach to tasks they wish to compete in.

6.2. More detailed information about the System Acceptance Review will be provided in December.

6.3. A prize will be awarded to the team with the highest cumulative score for the Preliminary Design Review and System Acceptance Review in accordance with Rule 4.4.

6.4. Teams are required to demonstrate that their systems meet the minimum requirements to compete in the Challenge as outlined in this document. Failure to meet the minimum requirements may result in disqualification.

Tasks

Each team can opt to attempt one or more of the proposed tasks. Teams are not expected to compete in every task.

7. Task Logistics

7.1. Teams will have 30 minutes before the beginning of each task to set up their base station. The base station will include at least two 6-foot tables, four chairs and four power sockets. During set-up, members from the team may move freely between the base station and task area, to ensure their Rover is working as planned. Once the set-up is complete, the team will notify the judges, upon which the task timer will begin. Teams may take longer than the allotted 30 minutes to ensure their Rover is working as planned, however once the 30 minutes is over, the task timer will begin. The Rover must not move out of the starting area until the team has designated to the judges that their set-up is complete.

7.1.1. Throughout each task, a maximum of four team members are allowed in the base station to adhere to COVID safe practices.

7.2. Throughout the competition, teams will be required to carry their Rover up to 100 m. If teams are unable to demonstrate that they are able to perform a safe 2-person carry of their Rover with minimal risk of injury (to those carrying or others in the vicinity), they will be required to make use of transportation equipment provided by the Challenge organisers (trolleys or otherwise) to move their Rover. This will result in lost time at critical moments of each task.

7.3. Once a team has started the challenge, team members inside the base station are not permitted to communicate with team members outside the base station in any way.

7.3.1. Team members not inside the base station at the declaration of the start of the challenge, will never be permitted to enter the base station.

7.3.2. Team members inside the base station may leave at any time, however they will not be permitted to re-enter.

7.3.3. There is no limit to the number of team members inside the base station at the start of the challenge, however, the space available for the base station may prohibit the number of members present. At the least, four members will be able to fit comfortably within the base station.

7.4. An intervention may be called by the base station team by clearly indicating this intent to the judges.

7.4.1. Teams will receive a 10% deduction in points earned from the task for each intervention called.

7.4.2. During an intervention, the base station may communicate to other team members in the field using hand-held radios provided by the judges.

7.4.3. Team members in the field must not relay any information describing any part of the task area, and doing so will result in immediate termination of the task.

7.4.4. During an intervention, base station team members are able to leave in accordance with Rule 7.3.2.

7.5. Teams will have 10 minutes at the conclusion of the challenge to vacate the base station and task area.

8. Post-Landing Task

8.1. Your Rover has just landed on the surface of the moon, and your team is required to execute a task list to work towards establishing a remote mining operation.

8.2. This is a staged mission in which the Rovers shall be required to perform a systems check of the Lander and site evaluation.

8.3. Each stage shall progressively get more difficult, with increasing distance to cover, larger obstacles (i.e. rocks, bricks, berms, craters, etc.)

8.3.1. Teams are expected to complete each stage in order, however there is no threshold score or requirement for a team to be able to reach the next stage.

8.3.2. If a team chooses to abandon a stage and move onto the next stage, they will not be permitted to return to this previous stage to gain any further points.

8.4. Teams will have 40 minutes to complete this challenge. A maximum of 15 minutes may be spent on any single stage of the challenge. That is, if, after 15 minutes of competing,

a team has not attempted all of stage 1, they must move on to stage 2. Or, after 30 minutes of competing, a team has not attempted all of stage 2, they must move on to stage 3.

8.5. **Stage 1. :** Leave start gate (Lander) and descend down ramp **(10pts)**

Stage 2. : Circumnavigate lander, begin **Systems Check (Stage 2.1 - 2.4) (10pts)**

Stage 2.1 : Find Status readout at rear of lander **(5pts)**

Stage 2.2 : Relay information to judges **(5pts)**

Stage 2.3 : Navigate to lander damage/issue on lander **(10pts)**

Stage 2.4 : Identify and point out Lander damage/issue to judges **(10pts)**

Stage 3 : Navigate to and identify location of Supply Caches, begin **Site Check** which includes finding the Power Station, Radio Tower and Processing Plant **(10pts each)** whilst traversing over (5 - 30cm) vertical height obstacles and drops.

Stage 4 : Judges will inform teams which Supply Cache will be required to be set-up / unpacked / debugged. The Rover must then navigate to the designated supply cache.

Stage 4.1 : The Rover must initiate startup protocol by pressing buttons/flipping switches/moving joystick as directed by the judges. **(20pts)**

9. Lunar Resources Task

9.1. Rovers will conduct in-situ resource **identification** and **extraction** at a given sample site. The primary objective is to determine which location may yield the greatest amount of **Frozen Water (H_2O)** contained within the regolith, and to deliver the extracted ice-bearing regolith to the *Processing Plant Cache* identified in Post Landing and Systems Site Check.

9.2. Teams will be given a field briefing by judges and will be missioned with investigating multiple sites of interest within a 0.2 km radius of the start gate.

9.3. **Task Stages :**

Stage 1 : Leave start gate (Lander) **(5pts)**

Stage 2 : Lunar Resources Identification Stage

Stage 2.1 : A total of **15pts** is available for traversing to and imaging each of the three different sample sites (5 pts is awarded for each site). Teams must show the judges that the Rover has traversed to, and imaged, each site to receive points and progress to Stage 3.

Stage 3 : Lunar Resources Extraction Stage

Removal of any material from any site **(5pts)**. Delivery of any material to processing plant **(15pts)** (distribution of 15 points in accordance with Rule 9.6. below)

Stage 4 : Lunar Resources Presentation. A total of **60pts** is available and will be awarded according to Rule 9.7.

9.4. Teams will be given a maximum of 30 minutes to collect data with the Rover in the field, with 15 minutes allocated for data analysis and review. Based on the onboard analysis, teams will prepare a presentation for the judges to be given at the field site. Presentation and discussion with the judges will be between 10 – 15 minutes.

9.5. Using on-board cameras and sensors, Rovers are expected to investigate up-to three potential sample sites (within 20m of each other) to determine if frozen water is present in the samples, and if so, to what extent.

9.5.1. Potential sample sites will consist of containers of Lunar regolith simulant mixed with a given proportion of water (H_2O) (**Appendix A**), which will be frozen and then buried beneath a thin overburden so that the uppermost edge of the container is level with the ground. Each sampling site will be flagged to indicate the location of the buried container.

9.5.2. Each sample site will aim to reflect a unique geological feature on the Moon (e.g Lunar Mare, ejecta blanket, impact crater, etc).

9.5.3. The Rovers may use cameras, passive sensors or ***any other chosen method*** to investigate the sample sites and similarly, may use mechanical means or any other approach chosen by the team to extract regolith from the ground.

9.5.4. The goal is to then transport and deliver the regolith to a metal hopper (30 x 30cm opening) at the Processing Plant Cache Site identified in the Post Landing Task. The opening of the metal hopper will be 10cm off the ground.

9.6. Teams may select any one, or a combination of sample sites to extract regolith, to then deliver to the processing plant. Points are awarded corresponding to a *base score* which is dependent on the total mass deposited to the processing plant, and the *multiplier* based upon the sample site which the regolith is extracted from.

9.6.1. The maximum amount of points available for delivery of material is 15 points, respectively, as outlined in Stage 4 below.

9.6.2. Teams may collect and deposit samples from multiple sites.

9.6.3. The *base score* will be the amount of material delivered to the processing plant by your Rover, divided by the most amount of material delivered by *any* Rover.

9.6.3.1. If your Rover deposits the most amount of material to the processing plant, your base score will be 15.

9.6.3.2. If the most amount of material deposited is 400g (deposited by a different rover), and your Rover is able to deposit 200g of material, your base score will be 7.5.

9.6.4. The multiplier is distributed based upon the sampling site and grade of frozen water present in each. Your base score will be multiplied by 0, 0.5, or 1, based upon the quality of the sample.

9.6.4.1. If your Rover deposits material from the high quality site, your multiplier will be 1, and the total points for the deposit stage will be equal to your base score.

9.6.4.2. If your Rover deposits 200g of material (in the same scenario as 9.6.2.2. above) from the medium quality site, your multiplier will be 0.5, and your total points awarded for the deposit stage will be 3.75/15.

9.6.4.3. If a Rover deposits material from different sites, the multiplier will be applied to the respective fraction of material that was collected from each site.

9.7. Based on the data collected by the Rover, teams will prepare a **Lunar Resources Presentation** for the judges to be given at the task site which will be 10 – 15 minutes in duration and will begin 15 minutes after the conclusion of the physical task. The presentation and discussion with the judges is allowed even if the team was unsuccessful in collecting data with their Rover. Teams are expected to answer questions and focus their presentation on the following topics ;

9.7.1. Description of what each sample site represents in the context of Lunar surface geology and their potential for frozen water to be present

9.7.2. Detailed site descriptions, justifications of site selection relating to the Moon, and discussions on the characterisation and extraction methods used.

9.7.3. Meaning of data collected with respect to the *In-Situ* resource potential of the samples and the field site being suitable for further exploration and utilization.

9.7.4. Scientific knowledge of Space Mission Design, Space Resources and knowledge of the Moon and its surface processes based on responses to judges' questions.

10. Lunar Construction Task

10.1. The primary objective of this task is for teams to utilize the Rover and its subsystems to interact and alter the local Lunar environment in order to support the mission goal of establishing a surface mining outpost in preparation for permanent Human settlement.

10.1.1. It is up to teams to identify what aspect of the environment will be altered and to justify how it supports the mission goal.

10.1.2. The Rovers may use cameras, robotic arms, bulldozing blades, drills or any other means deemed appropriate by the team to interact with the environment for a beneficial purpose.

10.1.3. The Lunar environment will consist of bricks that have been 'manufactured' by the Processing Plant, loose regolith, rocks and geological debris.

10.1.3.1. Teams will be provided with models of the Lunar bricks which are the focus of the Construction Task as soon as possible.

10.1.3.2. The bricks will be 3D printed by the Challenge organisers.

10.1.4. The Rover may construct any feature, required it serves a justifiable purpose. Points will be awarded for the ingenuity, structural integrity, complexity and size of the built structures.

10.2. Teams will have 40 minutes to complete this task.

10.3. Points will be awarded as follows:

10.3.1. **10pts** is available for leaving the Rover start area.

10.3.2. **10pts** is available for beginning construction.

10.3.3. **5pts** awarded for moving a block from the "Starting Area" into the marked "Construction Area". A total of **35pts** is available for moving blocks. More blocks may be moved to earn points in other criteria.

10.3.4. **7.5pts** awarded for placing blocks on top of eachother in a "layer/storey". A total of **15pts** is available for stacking blocks (**7.5pts** for a structure two blocks tall, **15pts** for a structure three blocks tall).

10.3.5. **20pts** available for justifying/describing a feature or features that is/are created and its utility in the Lunar context.

10.3.6. **10pts** available for the use of the "Mystery Block/s" in a structure.

10.4. There will be several copies of each construction material. All construction materials will be printed at 20% infill using 1.75mm PLA filament. The following materials will be used during the Lunar Construction Task:

10.4.1. **Cube** - 30 x 30 x 30mm, approx weight 9g.

10.4.2. **Rectangular Prism** - 30 x 30 x 60mm, approx weight 18g.

10.4.3. **Mystery Block** - ? x ? x ?mm, approx weight ?g.

11. Sensor Task / Semi-Autonomous

*Please refer to **Appendix B** for further clarification regarding the Sensor Task / Semi-Autonomous*

11.1. This task is intended to demonstrate the Rover's ability for semi- to fully-autonomous traversal. In the early stages, an operator may be present in the control loop but all planning and estimation operations must be done by the Rover itself. This limits the operator to navigate the Rover blindly (i.e. without access to visual or other spatial information.) The smart navigation strategy, sensor fusion and image data processing are the essence of this challenge.

11.2. On-board data processing should be used for Rover localisation based on natural terrain, features and landmarks in the task area.

11.3. Use of GNSS (GPS, GLONASS, Galileo, Baidou, QZSS) or any other off-board positioning system is **not** allowed. In addition, any sensors which rely on earth characteristics (such as magnetometers/compass etc.) are **not** permitted. The aim of the challenge is to simulate the conditions on the lunar surface.

11.4. Any other types of sensors (i.e. Camera, LiDAR, RADAR, IMU, odometer, sonar, etc.) can be used for on-board localisation.

11.5. At any time during the challenge, the only data that may be transmitted from the Rover to the base station are position ([x, y, z]) and orientation (Euler angles or quaternion). If teams are utilising ROS, this is the equivalent of only sending pose messages (ROS geometry_msgs/Pose) from the Rover to the base station.

11.6. The Rover's start position and target landmark's coordinates will be given in the local coordinate frame, at the beginning of the base station set-up. The starting position for subsequent stages will be the position of the Rover at the conclusion of the previous stage (unless a team is unable to complete a stage and their Rover has to be repositioned in accordance with Rule 11.8.).

11.7. The Rover may be tele-operated but only with position and orientation estimates available to the operator. This data can be visualised in any form (i.e. projecting Rover

position on provided arena map or top view picture etc.) The operator is not permitted to view the output of a sensor (i.e. LiDAR, Stereocamera, etc.) in accordance with Rule 11.4.

11.8. If for some reason the Rover has to be moved, it can only be moved back to the last “safe point” as deemed by the on-course judges. This point is likely to be the start of the stage that the Rover is currently attempting to complete.

11.8.1. Teams will receive a penalty of 33% of the *available* points for the stage they are currently completing for each move of the Rover.

11.8.1.1. For example, a Rover is moved back to the start of a stage after reaching a point which is deemed by the operating team as not recoverable. If the Rover, on its second attempt at the stage, positions itself where it would have received a score of 8/10, 6.66 points will be awarded.

11.8.2. If a Rover is unable to complete a stage after it has been repositioned twice (in accordance with Rule 11.8.), the Rover may be repositioned a third time to a point where it may attempt the next stage. The team will receive no points for this repositioning.

11.8.2.1. The location of the Rover after the repositioning has occurred will be deemed the position at the conclusion of this stage. This is where the Rover will attempt the following stage.

11.9. Task area:

11.9.1. A list of landmarks which may be placed on the task area will be given to the teams no later than 30 days before the task.

11.9.1.1. The list of possible landmarks is present in the Appendix.

11.9.2. A map with base fiducial locations, grid coordinates and landmarks will be provided no later than 3 days before the task.

11.9.2.1. An example of the map is provided in the Appendix.

11.9.3. Most landmarks will be visible from the starting point but it must be taken into account that a portion of the markers may be obscured by terrain or other objects during traversal.

11.9.4. Two types of landmarks are foreseen: natural landmarks which are elements of landscape placed on the map (craters, small embankments, hills) and artificial landmarks (artificial points for localisation purposes.) Artificial landmarks may contain characteristic hi-visibility labels, unique geometric figures, alphanumeric signs, AR/QR tags or April tags.

11.9.5. Artificial landmarks will be visible from different directions and will be situated upon a physical platform which will be able to be detected by proximity/range sensors (placed on an element of infrastructure or natural landmark).

11.10. Teams will have 40 minutes to complete this challenge. A maximum of 15 minutes may be spent on any single stage of the challenge. That is, if, after 15 minutes of competing, a team has not attempted all of stage 1, they must move on to stage 2. Or, after 30 minutes of competing, a team has not attempted all of stage 2, they must move on to stage 3.

11.11. Task Stages :

Stage 1: Leave the starting area. **(10pts)**

Stage 1.1: Navigate to a target landmark as supplied by the judges on the course map. This target landmark will be within view of, and no more than 25m from the starting position. Points will be distributed as a function of the distance from the target landmark, to the nearest point of the Rover. A Rover which is within 1m of the target landmark will obtain maximum points. Points will decrease linearly (from the maximum points awarded within 1m) to a radius of 5m from the target landmark where 0 points will be scored. **(10pts)**

Stage 1.2: Identical to Stage 1.1 however the target landmark may be farther from the completion of Stage 1.1 (where Stage 1.2 starts), and have more varied terrain between the landmarks. More points are available for this stage, however the allotment of points is identical, up to the maximum distance from the landmark of 5m which will receive 0 points. **(20pts)**

Stage 2: Commence Stage 2 by starting to navigate to the next landmark. **(10pts)**

Stage 2.1: Identical to previous Stages, however the target landmarks may be farther from the starting location or obscured by objects. **(10pts)**

Stage 2.2: Identical to previous Stages with increasing difficulty. **(20pts)**

Stage 3: May only be completed autonomously. There may be no operator present in the control loop, except for entering the Rover into an autonomous mode. The Rover must not move from the final position of stage 2 (or from a repositioning under Rule 11.8.2.) until the Rover has entered autonomous mode and the base station has instructed the judges that it has done so. The Rover must have a clear visual marker which indicates that it has entered autonomous mode.

Stage 3.1: Identical to the previous stages, however the Rover must operate autonomously as set out above. **(20pts)**

12. Design Presentation

12.1. All teams are required to participate in a Design Presentation to succinctly communicate why their Rover design should be chosen for a selected mission profile. Teams are expected to review the performance of the Rover for each of the tasks it participated in, with a focus on addressing problems that were faced, how the team handled them, and the result.

12.2. Presentations will occur after all Challenge tasks are completed.

12.3. Teams will be required to present the information in their System Acceptance Review, and answer questions from the judges.

12.4. A specialist panel including industry partners, scientists and engineers will judge the Presentations, provide feedback and guide the Q&A discussion.

12.5. Teams will be expected to first;

12.5.1. Discuss the overall approach and rover design,

12.5.2. Explain their decision making when approaching challenge tasks,

12.5.3. Reflect on the performance for each challenge to identify aspects of the Rover, operation or otherwise that may be improved for the future, and;

12.5.4. Present information gained about the Lunar environment by their Rover in the field, over the course of the tasks that they have completed. This should be done with the assistance of the landing site map which will be provided to teams at the commencement of the tasks.

12.6. Teams will be subjected to a Q&A at the conclusion of their presentation, and hence, teams shall ensure that their Presentation panel has the required expertise to answer possible questions about the Rover system and approach to challenges.

12.7. There are a maximum of 10 points awarded for the Design Presentation.

12.8. More information about the presentation will be provided no later than March 6

Appendix A: Lunar Resources Task

Sample Preparation Guidelines

To ensure that each team around Australia uses, and has access to, the same material to create the Lunar Resources samples, and to ensure repeatability when competing at the Australian Rover Challenge, the following materials will be used (due to low cost, availability and safety for teams) ;

- 20kg Bag of White Washed Sand | Bunnings Warehouse
- Distilled Water
- Oven & Tray
- 3 x Plastic Containers with lid (At Least 100mm wide x 100mm long x 80mm tall
    - (Decor Match Ups Basics Container Oblong Red 1L | Coles Online)
- Large mixing bowl
- Spray bottle

Methodology

1. Pour sand to fill each of the 3 containers to brim.
    a. This is the maximum volume of material each container requires.
2. Preheat oven to 100℃.
3. Pour and spread the sand from one container evenly onto a baking tray.
4. Once the oven is heated and sample trays are ready, bake at 100℃ ± 5℃ for at least 4 hours.
    a. If possible, do all three trays at once.
5. Once dry, remove one tray and immediately close the oven door to prevent moisture addition.
6. Slowly pour the dry sand into the large bowl, while spraying the water and mixing homogeneously. This method is used to achieve a uniform distribution of water without the simulant ‘clumping’.
7. Once mixing is complete, immediately seal the container with the lid and allow it to freeze overnight.
8. To verify the water content of the prepared simulants, small samples can be removed and measured as per ASTM International - D2216-71.

References

- Kleinhenz, J., & Linne, D. (2013). **Preparation of a frozen regolith simulant bed for ISRU component testing in a vacuum chamber.** 51st AIAA Aerospace Sciences Meeting Including the New Horizons Forum and Aerospace Exposition 2013, January. https://doi.org/10.2514/6.2013-732
- Colaprete, A., Schultz, P., Heldmann, J., Wooden, D., Shirley, M., Ennico, K., Hermalyn, B., Marshall, W., Ricco, A., Elphic, R. C., Goldstein, D., Summy, D., Bart, G. D., Asphaug, E., Korycansky, D., Landis, D., & Sollitt, L. (2010). **Detection of water in the LCROSS ejecta plume.** Science, 330(6003), 463–468. https://doi.org/10.1126/science.1186986

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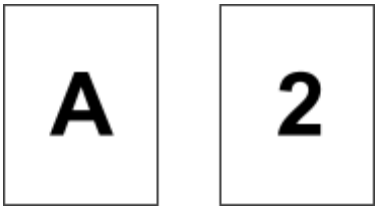
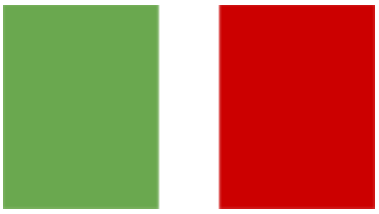
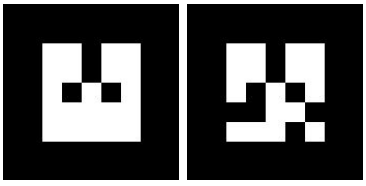
Appendix B: Sensor Task / Semi-Autonomous

List of artificial landmarks which may be present on the task arena for localisation

Notes:

- The following list does not include the physical or natural landmarks that may be present on the task arena and may also be used for localisation.
- The following list encapsulates all artificial landmarks that could be present, but not all *will* be present during the task.
- All artificial landmarks will be positioned no lower than 30cm from the ground, and no higher than 1.2m above the ground.
- Landmarks will either be;
    - Affixed to a solid object on one or more faces of said object, or,
    - Present on all four sides of a box positioned on a pole away from any task arena infrastructure.

Name	**Example**	**Notes**
A single letter or number on an A4 page.		Possible letters will include “**A**”, “**B**”, and “**C**”. Possible numbers will include “**1**”, “**2**”, and “**3**”.
An A4 page with a solid, bright colour.		Possible colours are green, blue, orange, and red.
AR Tags 0-8.		AR tags 0-8 are available here.

An example map with grid and landmarks

Notes:

- This example map is in no way an accurate representation of the task arena geometry or layout.
- The true map for the task will be provided to teams no later than 3 days prior to the Task - Thursday the 25th of March, 2021.

Legend:

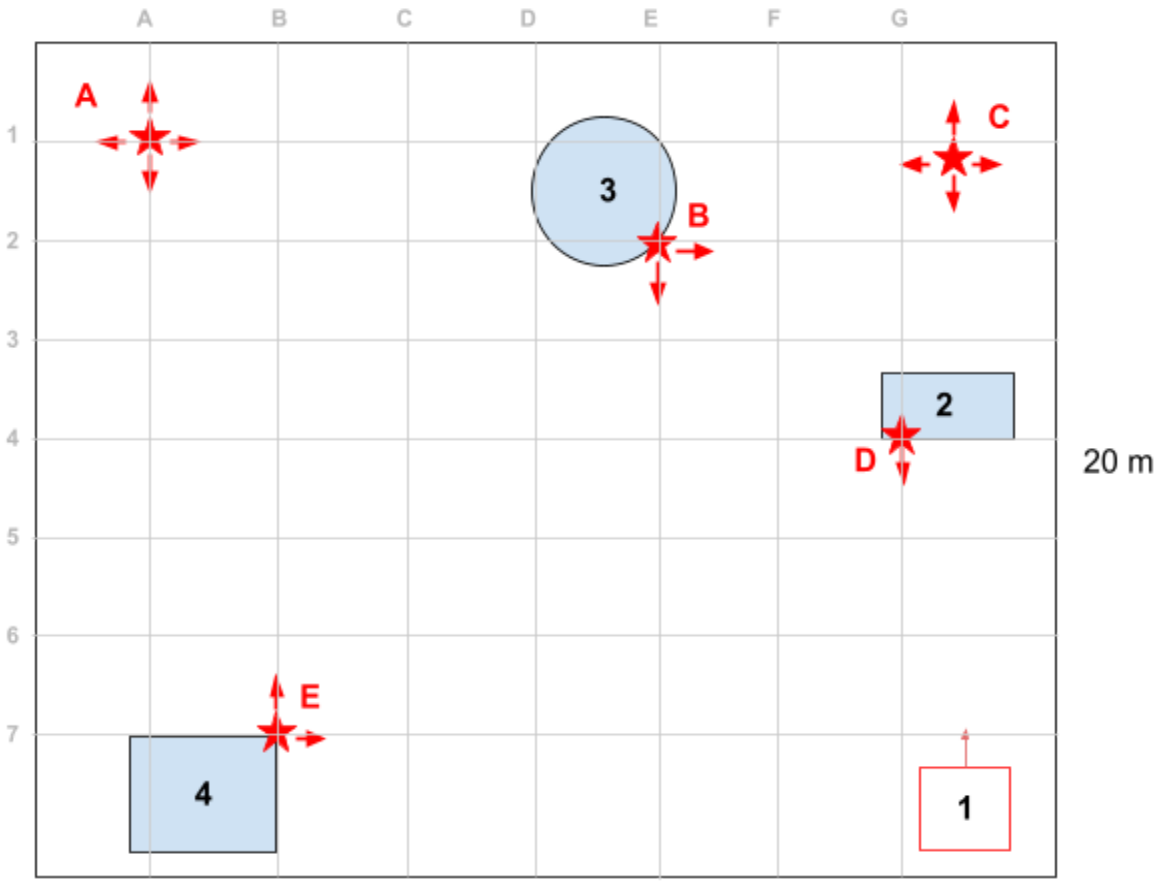
- **1** - Rover starting position (orientation is shown by the arrow)
- **2** - Communications Tower
- **3** - Lander
- **4** - Lunar Processing Plant

Markers:

- The arrows specify a vector which is normal to the marker. For example, marker “A” is a square with the same marker printed on four sides, marker “B” is affixed to the Lander and has the same marker on two sides.
- **A** - AR Tag 3
- **B** - The colour red
- **C** - The colour blue
- **D** - AR Tag 5
- **E** - The number “**2**”

Example task stages:

- Rovers will start the task in the starting position as shown by the label “**1**”. Subsequent stages start from the Rover’s position at the conclusion of the previous stage in line with Rules 11.6. and 11.8.2.1.
- **Stage 1.1** - Navigate to local coordinate “**G4**”
- **Stage 1.2** - Navigate to local coordinate “**E2**”
- **Stage 2.1** - Navigate to local coordinate “**B7**”
- **Stage 2.2** - Navigate to local coordinate “**A1**”
- **Stage 3.1** - Navigate to local coordinate “**G2**”


A
B
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G
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