AUSTRALIAN ROVER CHALLENGE

AUSTRALIAN ROVER CHALLENGE 2023

RULES AND REQUIREMENTS

THE UNIVERSITY of ADELAIDE

make history.

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For *any* general enquiries about the challenge, please feel free to use the general inbox which is monitored by a range of the staff involved with the challenge.

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Participants in the challenge are also welcome to get in touch with any of the key contacts below via email. Additionally, team leaders have access to the organising team via Slack.

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Changelog

Date	Version	Change notes
24/01/2023	V3	General email added to contact page. Competition start date updated. Total rover mass rule 3.5 clarification made. Post-Landing hose connection appendix clarifications made. Interventions for Mapping & Autonomous task clarifications made. Construction & Excavation Major changes to Activity 4, specifically; **rule 11.8.2.3** - Removed paver airgap definition (previously in appendix) as judges are no longer weighing individual pavers, but the whole solution. This removes ambiguity and opens design freedom. **rule 11.8.3** - Removed dimension and mass constraints on individual pavers. Allow team to choose start location and deployment method. Aimed to remove ambiguity on defining paver boundary and open design freedom. **rule 11.8.5.4** - To be awarded points, pavers must now be driven over **during** the task. This removes issues with broken/replacement tiles. Also more engaging for audience to see rover using the road it built.
18/11/2022	V2	Full specifications of the competition tasks added. Includes clarifications based on team feedback on the V1 release.
09/2022	V1	V1 release. Please read carefully in its entirety. Future versions will include greater detail and address any questions or concerns from the teams.

Vision for the Australian Rover Challenge

The Australian Rover Challenge has been founded with the following four purposes in mind:

- Facilitate 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.

Acronyms and Abbreviations

ARCh The Australian Rover Challenge

AUD Australian Dollars

CDR Critical Design Review

DFT Distributed Field Test

E-STOP Emergency Stop

GLONASS Global Navigation Satellite System

GPS Global Positioning System

ISRU In-Situ Resource Utilisation

QZSS Quazi-Zenith Satellite System

RAZ Regolith Acquisition Zone

RTM Regolith Transfer Mechanism

SAR System Acceptance Review

Glossary

activity An objective of a competition task that awards points for completion

arena A marked area setup to simulate either a lunar or martian surface on which the rovers compete in the competition part of the challenge

competition The main portion of the challenge held over a number of days in Adelaide, in which the rovers compete physically on the challenge arenas

deliverable One of a number of documents or tasks required to be completed by specific due dates prior to the competition part of the challenge

rover The physical entry of a team in the competition portion of the challenge

supply cache One of a number of large artificial props on a challenge arena

task One of four major rounds at the competition part of the challenge

team The set of individuals tasked with operating a rover entry

the challenge The Australian Rover Challenge as a whole

Part I.

General Rules

1. Key Dates

The key dates and deadlines for the 2023 competition are as follows:

Sep 2022 Team registration opens – Complete

Sep 2022 Critical Design Review guidelines released – Complete

30 Sep 2022 Registration closes – Complete

30 Oct 2022 Critical Design Review due – Complete

27 Nov 2022 System Acceptance Review guidelines released

Jan 2023 Distributed Field Test

12 Feb 2023 System Acceptance Review due

17 Mar 2023 Cost Report due

23 Mar 2023 Australian Rover Challenge competition starts

Dates may be adjusted at the organising team's discretion. In this case, an announcement will be made to all registered teams in advance, and a new version of this document with updated dates will be published.

2. Challenge Rules

2.1. This document outlines the rules and regulations that govern the 2023 Australian Rover challenge.

2.1.1. This document can be updated at any time. The publication of a new version will be announced to all registered teams.

2.1.2. Every effort is made to make these rules as clear and specific as possible, but there may still be occasional errors or ambiguities. In these cases, the *spirit* of the rules overrides the exact wording. That is to say, if you *feel* like you are being sneaky or getting by on a small technicality, it may be wise to reconsider.

2.1.2.1. The organising team is readily available to all registered teams to clarify any potential misunderstandings, so please do not hesitate to reach out if anything seems misleading or unclear.

2.1.2.2. If concerns are raised by teams to this effect, every effort will be made to provide an updated version of the rules with clarifications present.

2.1.3. Where specific consequences are not given, a fair penalty for breach of any of the rules and regulations may be determined by the judges and/or organising committee, and may include but is not limited to points penalties, disqualification from the 2023 challenge, and a temporary or permanent ban from future challenges.

2.2. The key words “MUST”, “MUST NOT”, “REQUIRED”, “SHALL”, “SHALL NOT”, “SHOULD”, “SHOULD NOT”, “RECOMMENDED”, “MAY”, and “OPTIONAL” in this document are to be interpreted as described in RFC 2119, even when not rendered in capital letters.

2.3. The term *team* refers to the individuals tasked with operating a single rover entry. A university is not limited in the amount of teams that they may enter, and teams from a single university may include overlapping team members.

2.4. The Australian Rover Challenge (ARCh), also referred to as *the challenge*, is primarily based around the *competition* made up of the four *tasks* set out in part III. Each task is made up of various point scoring *activities*, and is conducted on a competition *arena*. In addition, in the lead-up to the competition portion of the challenge, a series of *deliverables* are required of each team, as set out in part II.

2.4.1. Teams *must* successfully complete each deliverable on time and to an acceptable standard according to the judges in order to compete in the competition.

2.4.2. Teams are *not* required to attempt every task in the competition. Teams must notify the judges of which tasks they intend to compete in as part of the critical design review – see rule 5.6.

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

2.5.1. 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 in this instance.

2.5.2. There is a one year grace period to continue competing in the challenge after graduating. This is to assist with the handover of leadership between years and ensure that students who have made an impact on a rover and team are able to attend the challenge the following year.

2.6. Cross-university hints, tips, tricks, advice and guidance within the spirit of the challenge is permitted and encouraged, however collaboration on detailed design, technical, or assembly work should be minimal.

2.7. All challenge communications and deliverables will be in English. Teams must have at least two members fluent in English to compete.

2.8. Teams are encouraged to review examples of terrain and obstacles in online media of previous iterations of the challenge. This information should be taken as an indication of how previous years have operated, and while changes are made to the rules and challenge from year to year, the essence of the challenge remains similar.

2.9. The tasks, briefings, associated events and presentation will occur at the University of Adelaide (North Terrace campus) in South Australia.

2.10. Up to five members of each Team will be invited to the challenge Slack workspace, which will be used as the primary communication channel between the teams and challenge organisers and judges.

2.11. The Australian Rover Challenge reserves the right to limit the total number of teams invited to the competition part of the challenge based on the outcome of submitted deliverables, at the judges' discretion.

2.11.1. In alignment with the challenge's vision and values, Australian teams may be prioritised in the selection of teams invited to compete in the competition.

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. During a task, teams shall only communicate with, control, and influence the rover from a remote base station, and must do so wirelessly via antennas or equipment near the challenge arena connected to the base station.

3.2.1. The contents of the base station and connected antennas (other than what is provided as per rule 8.6.1) are entirely provided by the team, and although they are not part of the rover itself, they are considered part of the overall rover design.

3.3. 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, however, the platform of the rover must be the same from task to task.

3.3.1. The platform of the rover refers to the systems which make up the core of 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.

3.3.2. The platform of the rover must demonstrate novel design work by the team, and must not consist of a commercial-off-the-shelf unit.

3.4. 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 Post Landing task, which constitutes a 1.6×1.6 m square platform, and be no taller than 1.6 m in its lander orientation.

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

3.4.2. 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, or bends to fit within the lander, the rover must be able to manoeuvre into a position to start the task by itself.

3.4.3. The same rover footprint requirement will be used for all tasks, even if the rover is not required to start on the lander.

3.4.4. Failure to fit within the specified dimensions will result in a **50% penalty** for each task with which the rover is non-compliant.

3.5. The maximum allowable mass of the rover when deployed for the Post-Landing, Space Resources and Mapping & Autonomous tasks is 50 kg. The maximum allowable mass of the rover when deployed

for the Construction & Excavation task is 60 kg. The total mass of all fielded rover parts across all tasks is 80 kg.

3.5.1. For example, 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 or the rover plus sensor must each be under 50 kg. The total rover plus arm plus sensor must be less than 80 kg. The weight limits do not include any spares or tools used to prepare or maintain the rover.

3.5.2. For each task in which the rover is overweight, teams will be subject to a **10% penalty** *per kilogram* over the limit for that task. For example, a 52 kg rover in Post-Landing scoring 80 points will be awarded 64 points after the penalty is applied.

3.6. Throughout the challenge, teams may 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 and the general public), they will be required to make use of transportation equipment provided by the challenge organisers (trolleys or otherwise) to move their rover. This may result in lost time at critical moments of the challenge, and is the team's full responsibility.

3.7. The total cost of the rover (in its final form) and base station systems (that is, everything that is required to operate the rover) must be reported to the judges in the Cost Report – see chapter 7. The total cost of the rover must not exceed $25,000 Australian Dollars (AUD).

3.8. Rovers shall utilise power and propulsion systems that are applicable to off-earth operations. Air-breathing systems are not permitted. No power, propulsion or auxiliary system may ingest ambient air for the purpose of combustion, other chemical reaction that yields energy or to operate any other process requiring the ambient air.

3.8.1. Rovers may carry onboard reservoirs of material to support pneumatic, hydraulic or other systems requiring such materials. teams should take care to minimise outgassing and other loss of material, especially hazardous material.

3.9. All rovers shall have at least one emergency Emergency Stop (E-STOP) switch.

3.9.1. The switch must consist of a red latching button with a yellow surround, that is easily visible and accessible on the exterior of the rover by judges and team members.

3.9.2. 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.

3.9.3. All rovers shall have a clear external indication of powered on/active status, such as an LED strip that can be viewed in broad daylight from all sides of the rover.

3.9.4. Teams maintain responsibility for the safety of their rover, as it pertains to other challenge participants and the general public, at all times.

3.10. The following considerations apply to rover communications:

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

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

3.10.3. Teams should ensure that their communications equipment can automatically or manually switch between frequency bands, should there be any interference from an innocent third party.

3.10.4. Teams will be allocated a frequency range within their operating frequency band(s) which they must operate within at all times. The frequency range will be allocated to teams based on the information collected during the Critical Design Review.

3.10.5. The competition takes place at The University of Adelaide, which is a high RF (particularly WiFi) environment. Teams should consider this when designing their communications systems, and take steps to avoid foreseeable complications.

3.11. The use of any global navigation system (Global Positioning System (GPS), Global Navigation Satellite System (GLONASS), Galileo, Baidou, Quazi-Zenith Satellite System (QZSS)) or any other off-board positioning system is not allowed.

3.12. The following considerations apply to base station antennas:

3.12.1. Base station antennas shall be positioned during the set-up period and shall only be repositioned by a team member during an intervention as in rule 8.10.

3.12.2. Base station antennas must be no greater than 2 m tall.

3.12.3. Teams are required to supply their own cable at least 20 m in length to reach from the base station to their antenna.

3.12.4. Antennas will be placed in close proximity to the competition arenas, in a small area designated by the judges, which means that a wide beam width is required to ensure reliable communication with the rover anywhere on the arena. A minimum beam width of 90 degrees is recommended, unless active tracking technologies are used in combination with a more directional antenna.

3.12.5. Metal crowd barriers and large metal seating may line the arena and surrounds, which can interfere with, or block, some wavelengths.

3.12.6. Teams may use any number of antennas, for example for different bands, as long as they are all positioned within the small antenna area adjacent to the arena.

3.13. The arena can see extreme weather such as hot and dry or cold and wet. Although rain is uncommon, rovers must be able to operate in reasonably wet conditions, such as in a light shower. The judges will place a task on intermission should precipitation be great enough that rovers are at risk of ingesting water.

4. Scoring and Prizes

4.1. The scoring and prizes will be awarded by the panel of challenge judges. The judging panels will be made up of professionals from academia and industry, and will be confirmed closer to the competition.

4.2. Teams are awarded points based on their performance in competition tasks, as well as the assessed quality of some of their provided deliverables.

4.2.1. Each competition task is made up of point-awarding activities, with a total of **100 points** available in each task.

4.2.2. Additionally, up to **100 points** total will be available between the CDR, SAR & DFT, with the points breakdown of these available at a later date.

4.2.3. Hence, the total number of points available across the whole challenge is **500 points**.

4.3. As set out in these rules, teams may receive penalties from the judges.

4.3.1. These penalties are assigned per task, and are generally a percentage e.g. the 50% penalty for overweight rovers as in rule 3.4.4.

4.3.2. These percentage penalties are *additive*, and the sum percentage will be subtracted from the team's total score for the task.

4.3.2.1. Note that this is a percentage of the team's actual *awarded* score, not the maximum available.

4.3.2.2. For example, if a team received a 30% penalty and another 20% penalty for a task in which they scored 60 points, their final score would be $60 \times (1 - (30\% + 20\%)) = 30$ points.

4.3.3. Total penalties are capped at 100%, and teams cannot score lower than zero for each individual task or deliverable.

4.4. A number of prizes will be awarded to teams as follows:

4.4.1. Prizes will be awarded to the Team with the highest score in each task.

4.4.2. An overall challenge prize will be awarded based on the sum of all scoring activities.

4.4.3. Prizes may be awarded for the teams that perform best in certain combinations of deliverables – the details of these will be available at a later date.

4.4.4. Additional prizes may be added to this list or awarded at the competition at the judges' discretion.

Part II.

Deliverables

5. Critical Design Review

5.1. Teams will be required to submit a Critical Design Review (CDR) on 30 Oct 2022.

5.2. The purpose of the CDR is to demonstrate that the maturity of the design is appropriate to support proceeding with full-scale fabrication, assembly, integration, and testing, and that the technical effort is on track to complete the development of the core rover systems to meet the rules and requirements of the ARC, within the teams' identified cost and schedule constraints.

5.3. The CDR is in the form of a written report.

5.4. Core Rover systems to be reported upon include, but are not limited to:

5.4.1. Power systems, power delivery, and power safety

5.4.2. Drivetrain

5.4.3. Chassis construction and materials

5.4.4. Perception systems

5.4.5. Base station design and control

5.4.6. Rover communications

5.4.7. Drive control systems (software based)

5.4.8. Additional hardware and software that is specific to each task the team intends to compete in.

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

5.6. The submission of the CDR is also when teams are required to notify the organising committee of the tasks in which they plan to enter their rover.

5.7. More detailed information regarding the CDR will be provided in September 2022.

6. System Acceptance Review and Distributed Field Test

6.1. Teams will be required to submit a System Acceptance Review (SAR) on 12 Feb 2023.

6.2. The SAR involves teams outlining the design of their systems and their approaches to tasks they wish to compete in.

6.3. The SAR will be in the form of a written report.

6.4. A remote Distributed Field Test (DFT) will be held in the time window specified in chapter 1.

6.4.1. At the DFT, at a minimum, it is expected that a team can set up a base station and tele-operate their rover to drive forward and turn on a simple simulated course environment (i.e, beach or sandy environment).

6.4.2. The purpose of the DFT is to provide Teams a developmental milestone to work toward, and to demonstrate to judges the validity of their SAR submission and readiness of their rover to compete.

6.5. More detailed information about the DFT and SAR will be provided in November 2022.

6.6. Failure to meet the minimum rover requirements specified at the time of the SAR and DFT may result in teams being disqualified from the competition.

7. Cost Report

7.1. Teams will be required to submit a cost report on 17 Mar 2023.

7.2. The total cost of the rover must not exceed $25,000 AUD

7.3. Reportable costs do not include any team labour, team software (unless it is required to run the base station systems), research and development, plant, machinery and tools.

7.4. The reportable cost is that which any member of the public could acquire the components and parts that make up the whole rover system (i.e. not including discounts of any type and including delivery or import fees).

7.4.1. The reportable cost of components manufactured by the team includes the raw material and fees associated with acquiring the material (sales tax, import fees, shipping and handling).

7.4.2. The reportable cost of components manufactured by team sponsors is the cost that the manufacturer would charge to a full-fee paying member of the public or industry. This is the reportable cost and is independent of any discounts or sponsorship (monetary or in-kind) provided to the team.

7.5. More information regarding the Cost Report and reportable costs will be available by 28 February 2023.

Part III.

Competition Tasks

8. Competition Task Logistics

8.1. The 2023 competition will take place on a simulated lunar arena.

8.1.1. The challenge arena is expected to be no smaller than 10×15 m and consist of dry, fine-grained sand.

8.1.2. The challenge arena will have a number of obstacles, as follows:

8.1.2.1. *Supply caches*, which range in height and have footprints varying from 1×1 m to 3×3 m.

8.1.2.2. Rocks, which may vary in size from passable 20 cm objects to 1 m rocks which may be necessary to avoid, depending on the design of a rover.

8.1.2.3. Terrain features made out of the sand, like ridges and craters, which may present a challenge for rovers to pass, or may be impassable.

8.1.3. All challenge objectives and targets will be located such that traversal of large terrain features and obstacles can be avoided.

8.1.4. Small obstacles (such as 20 cm rocks or drops, or embankments of 30° slope and 0.5 m height) may be necessary to traverse to navigate to all task activities during the allocated time period.

8.1.5. Team members must not walk on the arena unless they are carrying the rover to the starting position, or if they are a nominated part of the field team for a given task. There will be sufficient space around the perimeter of the arena so that team members can monitor the rover.

8.2. The times allocated to a team for each task they are competing in will be published in a schedule in advance of the competition.

8.2.1. These times may be adjusted during the competition at the judges' discretion.

8.3. For each team's attempt at a task, there will be a panel of judges assigned to coordinate, provide information to team members, and score.

8.3.1. During a task, there will always be a judge inside the base station who is able to communicate with the other judges.

8.3.2. During a task, there will always be at least one field judge present. For most tasks, these are the judges who are responsible for scoring the rover as it operates and completes the activities.

8.4. Teams will be given a field briefing at least 10 minutes before the start of their setup time for each task, where they will have to nominate their base station and field teams for the task.

8.5. The field team must wear safety glasses at all times during a task. Teams must supply their own safety glasses.

8.6. After the briefing, teams will have at least 10 minutes before the beginning of each task to set up their base station.

8.6.1. The base station will include at least two 6-foot tables, four chairs and power sockets.

8.6.2. The base station will not have any inherent ability to see or communicate outside the base station once a task has commenced.

8.6.3. During this time:

8.6.3.1. Members from the team may move freely between the base station and arena, to ensure their rover is working as planned.

8.6.3.2. The base station may communicate to other team members in the field using hand-held radios provided by the judges, but teams are encouraged to bring their own.

8.6.3.3. The rover must not be operated on the arena. An area adjacent to the arena will be available to teams to operate and test their rover to ensure it is operating as planned prior to the beginning of the task.

8.7. Once the setup is complete, the team will notify the judges, and the judges will instruct the field team to move the rover to the start position for the task. Once all team members are clear of the arena, the task will begin.

8.7.1. A team may start a task before their set-up time elapses. Teams will not be granted additional time to complete the task in this case.

8.7.2. Teams may take longer than the allotted set-up time to ensure their rover is working as planned, consuming their task time. The task timer will begin at the conclusion of the scheduled set-up time in this case.

8.8. Once a team has started a task, team members inside the base station are not permitted to communicate with any team members outside the base station.

8.8.1. This includes that the field team and other team members must not influence the rover's operation or signal to the base station in any way, pursuant to rule 3.2.

8.8.2. Team members not inside the base station at the declaration of the start of the task will never be permitted to enter the base station during that task.

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

8.8.4. Teams can expect a limit to the number of members allowable in the base station at the start of a task. Teams should be prepared to operate, in the worst case, with four base

station members.

8.8.4.1. Base station members will have to comply with COVID regulations and policies, and as such may be required to wear masks while in the base station.

8.9. At any time during the task, the base station team may elect to call the task finished by making this intention clear to the base station judge.

8.9.1. This will also automatically occur at the end of the team's allocated task time.

8.9.2. In this instance, the task is ceased immediately and scored based on the rover's performance up until that point.

8.9.3. Once a task is called finished, under no circumstance shall the task be resumed.

8.9.4. Once the task is over, the base station and field teams are free to move around and communicate with each other.

8.10. An intervention may be called by the base station at any time by clearly indicating this intent to the judges.

8.10.1. The intent of an intervention is to allow teams the chance to pause their task attempt and fix and adjust parts of the rover in-situ so that it can continue in a task where it otherwise couldn't, but during them, teams must not alter the rover's environment or directly influence its task progress.

8.10.2. Teams will receive a **10% penalty** to the current task for each intervention called.

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

8.10.4. The field team must not relay any information describing any part of the arena, nor the rover's position in it, and doing so will result in immediate termination of the task.

8.10.5. The field team (and any base station team member who has exited) are the only people who may tend to the rover during an intervention.

8.10.6. The use of power tools during an intervention is not permitted.

8.11. At any time, the field team may elect to activate the E-STOP switch on the rover. In cases of obvious risk of harm to people or property, field judges may also activate the E-STOP.

8.11.1. This is the only time during a task (outside of an intervention as in rule 8.10) that the field team may enter the arena, and if a team member enters, they must activate the E-STOP immediately.

8.11.2. If the E-STOP switch is activated for any reason, the task is immediately ceased and scored as in rule 8.9.

8.11.3. There is no penalty for activating the E-STOP switch.

8.12. Teams will have at least 5 minutes at the conclusion of the task to vacate the base station for the next team.

8.13. Teams will be required to vacate the arena as soon as the task has finished.

8.14. Teams do not need to return to the start gate, or collect any deployed items (radio repeaters, cameras, tools, etc.) before the end of time for any of the missions. However, they must be collected immediately after the end of the task.

9. Post-Landing Task

9.1. A total of **100 points** will be available to complete this task.

9.2. Teams will have at least 30 minutes to complete this task.

9.3. Your rover has just landed on the surface of Moon. Your team is required to execute a series of activities to work towards establishing an operational In-Situ Resource Utilisation (ISRU) outpost in preparation for an upcoming human landing.

9.4. This is a staged task in which your rover is required to perform a remote asset inspection of the lander module (a supply cache) and site evaluation using images collected from onboard cameras and other sensing instruments of the team's choosing.

9.5. **Activity 1:** Systems Check (**20 points**)

9.5.1. Descend down egress ramp on the Lander (start gate, 1.6 m wide with 20° decline) and circumnavigate the lander, noting any damage that has occurred to the lander during flight and descent.

9.6. **Activity 2:** Site Evaluation (**40 points**)

9.6.1. Navigate to the supply caches designated by the base station judge and verbally relay the status readout message to the judge. Obstacles of a range of difficulties may be encountered (i.e. rocks, bricks, berms, craters, etc.).

9.7. **Activity 3:** Wireless Communication (**10 points**)

9.7.1. Navigate to the processing plant, and use RFID to obtain the status readout message which contains instructions for carrying out maintenance in the subsequent activity. Points will be awarded for this activity when the base station Team verbally relays these instructions to the judge.

9.7.2. If a team fails to retrieve instructions via RFID, the base station judge may provide maintenance instructions for the following activity. In this case, the points for this activity are forfeited.

9.7.3. Additional information regarding RFID for this activity is available in appendix A.

9.8. **Activity 4:** Processing Plant Maintenance (**20 points**)

9.8.1. Perform maintenance as listed in the status readout using a robotic arm, or otherwise, to interact with buttons, switches, dials, keyboard, plugs/sockets, joysticks or other graspable objects at the processing plant.

9.9. **Activity 5:** Propellant Hose Connection (**10 points**)

9.9.1. Your rover is tasked with connecting the processing plant supply cache to a gas line, to support other ISRU operations on the surface.

9.9.2. For this task, a custom outlet hose connection has been designed by the judges and will be present on the processing plant supply cache. Teams must design and manufacture a custom corresponding connection that will be mounted to a provided hose.

9.9.3. Before the start of the task, teams will be required to affix their side of the connection to the end of the provided hose.

9.9.4. The hose will then be placed on the arena surface, within 2 m of the processing plant.

9.9.5. During the task, the rover must connect the provided hose, using their connector, to the provided outlet on the processing plant.

9.9.6. Full points will be awarded for this activity if, at the end of the task, the field judge confirms that the hose is connected securely to the processing plant.

9.9.7. Additional information regarding the hose connection for this activity is available in appendix A.

10. Space Resources Task

10.1. A total of **100 points** will be available to complete this task.

10.2. Teams will have at least 30 minutes to complete this task.

10.3. Your rover has one primary task: to perform in-situ identification and processing of icy regolith (extraterrestrial soil) to determine which unexplored sample site may yield the greatest amount of frozen water (H_2O) contained within the regolith, and extract the frozen water as a liquid.

10.4. **Activity 1:** Leave the start gate and descend the Lander ramp (**5 points**)

10.5. **Activity 2:** Identification and Processing

10.5.1. Investigate three sites of interest to determine if frozen water is present in the regolith, and if so, how much. To receive points teams must show the judges in the base station that the rover has traversed to, and imaged, each site (**30 points**).

10.5.2. Use passive sensors or any other chosen method to investigate the water content of the sample sites. Teams may sample a small amount of regolith from each unexplored sample site to aid in their identification.

10.5.3. Excavate and process regolith from a sample site of their choosing to extract the highest amount of liquid water possible.

10.5.4. Processing must be performed entirely on-board the rover in-situ and within the allocated task time.

10.5.5. Processed water must be collected as a liquid in any container (dimension, material or otherwise) of the team's choosing, however the container must be removable, must allow the water to be poured out and measured, and will be handed to judges promptly at the end of the task. Teams' must also notify judges the mass of the empty container, to assist with determining the mass of water extracted.

10.5.6. **40 points** will be awarded based on the mass of water handed to the judges at the end of the task. See eq. (B.2) in appendix B for a detailed breakdown of scoring for this activity.

10.6. **Activity 4:** Space Resources Presentation (**25 points**)

10.6.1. Based on the data collected by the rover during this task, prepare a presentation for the judges which should address the following questions:

10.6.1.1. How did your rover evaluate the water content of each site, and how is the data collected valid?

10.6.1.2. How much water (by mass wt.%) did each site contain?

10.6.1.3. Which site had the highest water content?

10.6.1.4. Which site did you choose to process water from, and why?

10.6.1.5. What excavation and processing methods were used, and why?

10.6.1.6. How could processing be improved, so that more water by mass and the efficiency of extraction is increased?

10.6.2. The presentation (max 10 minutes in duration and max 5 slides) will begin 10 minutes after the conclusion of the task time and take place within the base station, allowing teams to review data collected by the rover during the field task and prepare slides.

10.6.3. Team members from the field, including those who intervened, are allowed to participate in the presentation. The presentation and discussion with the judges is allowed even if the team was unsuccessful in collecting data with their rover.

11. Excavation & Construction Task

11.1. A total of **100 points** will be available to complete this task.

11.2. Teams will have at least 30 minutes to complete this task.

11.3. The rover mass limit is increased to 60 kg for this task.

11.4. Your rover is expected to conduct a variety of activities including debris clearing, excvataion, and the deployment of artificial structures.

11.5. **Activity 1:** Leave the start gate and descend the lander ramp (**5 points**)

11.6. **Activity 2:** Debris Clearing (**20 points**)

11.6.1. Remove debris from a marked area. Debris will be on the ground and may include 3D printed bricks of varying size and 'rocks' no larger than 30×30×30 cm and no more than 2 kg.

11.7. **Activity 3:** Perform excavation and deposition (**40 points**)

11.7.1. Excavate regolith from a designated Regolith Acquisition Zone (RAZ) and then deliver the excavated regolith to the designated Regolith Transfer Mechanism (RTM) attached to the processing plant. The RTM consists of a metal hopper of dimensions not exceeding 300×300 mm with an opening at a height above the surface not exceeding 100 mm.

11.7.2. Teams may use mechanical means or any other approach chosen by the team to excavate regolith no deeper than 100 mm from the surface of the RAZ.

11.7.3. Due to the structure of the competition arena, teams *must not* excavate any material deeper than 100 mm anywhere on the course, except in the designated sample containers for the Space Resources task.

11.7.4. Points will be awarded according to the mass of regolith which is in the RTM at the conclusion of the task. See eq. (C.1) in appendix C for a detailed point breakdown for this activity.

11.8. **Activity 4:** Construction (**35 points**)

11.8.1. Your rover is tasked with covering a flat 1.2×2 m rectangular strip with rigid, interconnected pavers to build a traffic-bearing road in order to mitigate the kickup of dust during rover traverses, and to support the overall mission goal of establishing a lunar ISRU outpost. Pavers will be placed by rovers on top of a pre-prepared, clearly marked flat surface in the Challenge arena. Up to **30 points** points are available for placing the pavers, see eq. (C.2) in appendix C for a detailed point breakdown for this activity.

11.8.2. Teams must design and build their own pavers.

11.8.2.1. Pavers must consist of individual, rigid pieces that are placed individually or deployed as a pre-connected system by the rover. A pre-connected system may consist of individual pavers that are connected by any means (i.e mechanical) chosen by the team.

11.8.2.2. Adhesives must not be used to connect pavers, either prior to or during deployment. Note that this does not preclude using adhesives within the structure of a *single* paver.

11.8.2.3. Up to **5 points** are available for minimising the mass of your solution to this activity, outlined further in detail in Appendix C.3.

11.8.3. Pavers must start the task in one of two locations; either 1) on the lander in a designated paver box at the rear of the lander (see appendix C for more details), or 2) on the rover. In the context of a lunar mission, the pavers therefore either start as a designated payload in an allocated payload bay, or as an integrated subsystem on-board the rover. Different dimensional and weight constraints are placed on the pavers, depending on where they start.

11.8.3.1. If the pavers start on the lander, the total mass of the pavers and any interconnecting/interlocking mechanisms, if present, cannot exceed 10 kg and it does not contribute to the 60kg rover mass for this task nor the overall 80kg rover mass limit, described in rule 3.5. There are no dimensional constraints for individual pavers, however the combined dimensions of all the pavers and their interlocking mechansisms, if present, must fit within the allocated volume of the paver box located at the rear of the lander, which is 30×120×30 cm (length × width × thickness). Failure to comply within the specified dimensions will result in disqualification of points for this activity.

11.8.3.2. If the pavers start on the rover, they are considered an integrated subsystem and can exist as any dimension or in any configuration chosen by the team, but must conform to the dimension and mass constraints of the rover for this task, as outlined in rule 3.5 and rule 3.4

11.8.4. Prior to the task, teams must demonstrate that the placement of all their pavers fully covers the designated 1.2×2 m construction area, and that all pavers can be successfully placed and interconnected, conforming to rule 11.8.5. For the sake of time, this can be done by hand and will take place on the grass nearby the challenge arena prior to the commencement of the task.

11.8.4.1. If a team cannot cannot demonstrate that they have sufficient pavers to adequately cover the whole build area (i.e cannot demonstrate that achieving full points is feasible), they cannot attempt this activity.

11.8.5. The pavers must be successfully placed, interconnected, and verified (driven over) to be awarded points at the end of the task.

11.8.5.1. The successful placement of a paver is at the discretion of the judges.

11.8.5.2. A paver is considered successfully placed if its entire footprint lies within the

designated build area ±5 cm, it is completely flat on the surface at the end of the task (i.e its entire base is in contact with the ground), it has not suffered any permanent deformation (conforming to Rule 11.8.5.4) and it is ‘interconnected’.

11.8.5.3. A paver is considered interconnected if all its edges are within 5 cm of the nearest edge of an adjacent paver or the boundary of the build area. If any point along the edge of a paver is greater than 5 cm away from an adjacent paver, it is not interconnected, and the paver is not successfully placed. Boundary pavers, specifically those with no other paver directly one or more of their edges and the boundary of the build area, do not require those edges to be within 5 cm of a paver to be interconnected.

11.8.5.4. A paver is considered verified if it can support a traffic load. This is demonstrated by driving onto the assembled pavers using your own rover in two orthogonal directions, within the task time. Any signs of irreversible plastic or brittle deformation (i.e cracking, creasing, bending or buckling) of a paver means the paver is damaged, non-rigid and not placed.

12. Mapping & Autonomous Task

12.1. A total of **100 points** will be available to complete this task.

12.2. Teams will have at least 30 minutes to complete this task.

12.3. **Activity 1:** Mapping (**100 points**)

12.3.1. Map key landmarks in the landing area and surrounds, in support of future autonomous activity execution. Mapping the area autonomously is highly desired due to the low data rate between the rover and the lunar surface.

12.3.2. At the beginning of the task, teams will be provided the details of a global coordinate system and its exact relationship to the task starting area, so teams can measure the location of any part of their rover relative to the coordinate system's origin during the startup time.

12.3.3. Teams will also be provided the coordinates of the boundaries of the challenge course. If the rover leaves the boundaries at any point, the field team must immediately hit the E-STOP.

12.3.4. For this task alone rule 8.11.2 does not apply for E-STOP activation, and instead the remainder of the task time can be taken as "post-processing" time as in rule 12.3.8.3. Even so, the rover shall not be switched back on. This is allowed even if teams are not attempting an autonomous solution.

12.3.5. Once the task has commenced, the base station will be provided a list of 5 target landmarks. Points will be awarded for accurately providing judges with the X-Y (ground plane) coordinates of these landmarks in the specified coordinate frame.

12.3.5.1. Teams will receive a worksheet with the target landmarks at the start of the task time.

12.3.5.2. This worksheet must be filled out with the teams' provided coordinates by the end of the task.

12.3.6. A greater number of points will be awarded for a solution that operates autonomously with no human intervention, and fewer points will be awarded if the rover receives any form of human input from the base station.

12.3.6.1. In either case, the team members in the base station will be able to interact with the controls during the task setup time as in rule 8.6.

12.3.6.2. A maximum of **20 points** are available for each landmark. **20 points** will be awarded for a coordinate guess within 100 mm of the ground truth. **10 points**

will be awarded for a coordinate guess within 300 mm of the ground truth. These point values are halved for a non-autonomous solution.

12.3.7. If attempting a non-autonomous solution, base station team members may continue interacting with the controls without restriction during the task.

12.3.8. If attempting an autonomous solution, base station team members shall interact with the controls *only before* the rover has moved along the ground for the first time.

12.3.8.1. This means that manual control of the arms/camera/etc. is allowed at the start of the task, but interaction must cease when the rover begins driving, and this driving must be fully automatic.

12.3.8.2. At any time the team may resume manual control, but immediately forfeit all points that may have been awarded for a fully autonomous system and will be judged as though it were a non-autonomous solution from the start.

12.3.8.3. The base station team members may at any time choose to enter "post-processing time". In this instance, they may resume interaction with the base station hardware, but the rover must stop all movement within 10 s of entering this time, and no part of the rover must move again for the remainder of the task. If the rover does not stop within 10 s, or it moves again, then the autonomous points are forfeited as in rule 12.3.8.2.

12.3.9. If attempting an autonomous solution, teams are not able to call an intervention. If teams require an intervention, they may do so if they resume manual control, with the same effects as in rule 12.3.8.2.

12.3.10. Teams will incur a **10% penalty** for *each* collision with a supply cache or artificial obstacle.

12.3.11. The total pool of target landmarks will be comprised of the following, and all landmarks will be on the course for all teams:

12.3.11.1. 150×150 mm black-and-white AR tags, which may be attached to new or existing supply caches or obstacles. These will likely be manufactured by printing on standard A4 printer paper, and may or may not have the excess paper trimmed.

12.3.11.2. 100×100×100 mm cubes in bright colours: red, green, blue, yellow, and white. These will likely be manufactured by spray-painting wooden blocks.

12.3.11.3. Particular features and points on certain supply caches. Unlike the previous landmarks, due to how challenging it is to model/collect data to detect these features and provide coordinates fully autonomously, it is recommended that teams make use of the "post-processing time" to locate these features.

12.3.11.4. Teams will be required to provide the coordinates of the *centres* of these landmarks.

12.3.11.5. In the list of 5 landmarks a team will need to detect, each of the above categories will feature at least once: AR tags, coloured blocks, and supply cache features.

12.3.12. The list of target landmarks will be drawn from this pool. Each team will receive a different

list of target landmarks, with an equal distribution of tags/blocks and easy/more challenging locations.

12.3.13. The task is designed to simulate exploration of a previously unexplored area. All data and measurements regarding the arena *must* be collected *only* during the task time. The rover must not make use of any prior knowledge, estimates, or maps of the arena from either earlier tasks or observations made by the team earlier in the competition or during setup. If teams cannot explain to the base station judges how their guesses are derived from data collected by the rover, they may be penalised or disqualified.

Appendices

A. Post-Landing Task

RFID

A.1. A RFID encoded card (approximately 85×54 mm) will be attached to the exterior of the Processing Plant for the duration of the task.

A.1.1. The card will be at a height between 30 and 100 cm from the surface of the arena.

A.1.2. The exterior face with which the card is mounted to will have no protrusions (such as buttons or dials) within 20 cm of the card.

A.1.3. The card will be placed on a face of the processing plant that does not have any obstructions near the surface of the arena such as the processing plant support legs, material conveyor belt or rocks.

A.1.4. The RFID Card will use 13.56 MHz and the SPI communications protocol.

A.1.5. The judges will use the RC522 to write to and read from the RFID Card using the MFRC522 library.

A.1.6. The RFID card contains 64 blocks of 16 hexadecimal bytes. Block 0 contains manufacturer data, while every fourth Block (3, 7, 11, and so on) are sector trailers which contain access bits for read and write access to the remaining three Blocks in that sector. There are therefore 47 Blocks which can be altered on the RFID card to encode a string of text as a message. The status readout message can be obtained by concatenating the data in each of the alterable Blocks, in ascending order (Blocks 1, 2, 4, and so on).

A.1.6.1. The access bits for all sectors will be the factory default: FF 07 80.

A.1.6.2. The authentication key will be the factory default: 0xFFFF FFFF FFFF.

A.1.6.3. The status readout message may not necessarily begin at the first alterable block, and may have null blocks in between blocks containing the message.

Propellant Hose Connection

A.2. Teams must design and manufacture the cognate connector for the hose.

A.2.1. The hose which the interface is to be connected to is a standard garden hose that can be procured from a hardware store, with a cut end, no off-the-shelf adapter or likewise.

A.2.1.1. The inner diameter of the hose is approximately 12 mm and outer diameter is approximately 16 mm.

A.2.1.2. The hose is flexible.

A.2.1.3. The hose must not be damaged in attaching or detaching the interface.

A.2.1.4. The interface must be connected and disconnected in a few minutes – no adhesives are permitted in the connection as it will be used by other teams.

A.2.1.5. The hose connection designed by the team must not protrude from the hose such that the hose is greater than 2cm off the arena surface.

A.2.1.6. The hose connection must not occupy a volume greater than 10×10×10 cm.

A.2.1.7. The hose connection must not physically contact with the processing plant upon connection.

A.2.1.8. The connection needs to be snug, and must not come loose if pulled lightly.

A.2.1.9. The connection must feasibly be able to pass liquid through it (through an obstructed channel through the centre of the connection, or similar). The connection is not required to be water tight.

A.2.2. The processing plant will be fitted with a connector which will be 3D printed with PLA plastic and fastened to one side of the processing plant.

A.2.2.1. The connection will be at a height between 30 and 100 cm from the surface of the arena.

A.2.2.2. The connection will be placed on a face of the processing plant that does not have any obstructions near the surface of the arena such as the processing plant support legs, material conveyor belt or rocks.

A.2.2.3. STL and STEP files for the male processing plant connection can be found here.

B. Space Resources Task

Materials

B.1. To make a simulant lunar regolith sample similar to what will be used for the lunar resources task, the following items are recommended to be used due to their low cost, availability and safety:

- White washed sand
- Tap water
- Oven capable of at least 110 °C
- Large oven trays
- Large ziplock bags
- Containers with maximum dimensions of 162×176×100 mm (length × width × height) such as these containers. Note this is external dimensions, we are waiting on receiving the product to provide exact internal dimensions.

Method

B.2. The preparation of frozen icy regolith shall be performed following a modified method taken from Atkinson *et al.* (2020):

1. Preheat oven to 110 °C
2. Pour and spread the sand evenly onto a baking tray(s).
3. Once the oven is heated and sample trays are ready, bake at 110 °C for at least 4 hours. If possible, do all several trays at once. For optimal results, bake overnight (24 hours). A rapid check to see if material is dry is to place a small strip of torn paper on top of the material while it is in the oven or just upon removal from the oven. If the paper strip curls the material is not dry and requires additional drying time.
4. Once dry, remove tray and immediately close the oven door to prevent moisture absorption if other samples present, and slowly pour the dry sand into a large ziploc bag.
5. Using a measured beaker or syringe, add a known amount of water to the ziploc bag to achieve a target water content between 0 to 30% by mass. The mass of added water is determined by

the formula

$$m_{water} = \frac{mc}{1 - mc} m_{simulant}, \tag{B.1}$$

where mc is the moisture content expressed as a fraction and $m_{simulant}$ is the simulant mass.

6. Seal the bag and then mix the water into the sand by hand, breaking up clumps and evenly distributing so that no dry spots remain.

7. Once mixing is complete, place the ziploc bags somewhere at room temperature and let them cure overnight, allowing the water to evenly distribute via capillary forces.

8. To verify the water content of the prepared simulants, small samples can be removed and measured following ASTM International - D2216-71.

9. Once cured, pour the moist simulant into an empty container and freeze overnight.

10. The target bulk density for frozen samples should be $1.3\,\mathrm{g\,cm^{-3}}$

Processing

B.3. **40 points** are available for this activity and are awarded corresponding to a score which is dependent on the total mass of water given to judges within a container, as per rule 10.5.4, compared to the mass of water processed by other teams, following the equation

$$\text{Points} = 40 \times \frac{M_{YourTeam} - \text{Mparticulates}}{M_{BestTeam}} \tag{B.2}$$

where $M_{YourTeam}$ is the mass (g) of water within the container provided by our team determined by pouring water from the container into a conical flask with filter paper, on a tared, high accuracy scale (0.01 g). $M_{particulates}$ is the mass of particulates determined by weighing the filter paper before and after filtration to determine the mass of residual particulates, and $M_{BestTeam}$ is the highest mass (g) of particulate-free water achieved by any team.

C. Excavation & Construction Task

Excavation & Deposition

C.1. **40 points** are available for this activity and are awarded corresponding to a score which is dependent on the total mass of regolith deposited to the RTM compared to the mass deposited by other Teams, following the equation:

$$\text{Points} = 40 \times \frac{M_{\text{YourTeam}}}{M_{\text{BestTeam}}} \tag{C.1}$$

where M_{YourTeam} is the mass (g) of regolith deposited to the RTM by your team and M_{BestTeam} is the most mass (g) of regolith deposited to the RTM by any team.

Construction

C.2. **30 points** are available for successfully placing pavers as shown by the equation C.2 below.

$$\text{points} = 30 \times \frac{P}{N} \tag{C.2}$$

Where P is the number of pavers succesfully placed at the end of the Task, and N is the number of pavers your team used to demonstrate it can completely cover the designated build area conforming to rule 11.8.4.

C.3. **5 points** are available for minimising the mass of pavers as shown by the equation C.3 below. The purpose of designing your own, lightweight pavers is to demonstrate novel solutions to the construction of roads on the Lunar surface, and to also achieve contribute towards minimising initial launch mass.

$$\text{Points} = 5 \times \frac{M_{\text{BestTeam}}}{M_{\text{YourTeam}}} \tag{C.3}$$

where M_{YourTeam} is the combined mass (g) of all your pavers and their interconnections, if present (i.e what is placed on the ground during the initial demonstration, see rule 11.8.4, by your team, and M_{BestTeam} is the mass (g) of the pavers and their interconnections used by any team, rounded to the nearest 10 g.

C.4. The paver box will consist of a planform area of at least 30×120 cm. The base of the box will be between 30 and 100 cm off the surface. The paver box will not have a lid and the front side will be open, meaning that it can be accessed by the rover from the front or the top.