AUSTRALIAN ROVER CHALLENGE

AUSTRALIAN ROVER CHALLENGE 2024

RULES AND REQUIREMENTS

VERSION 1 1 AUGUST, 2025

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Contacts

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.

Australian Rover Challenge – General Inbox
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This is the best way to connect with the judging committee who develop and manage these rules.

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Changelog

Release date	Version	Change notes
8 August 2024	1	Please read this entire document carefully. Contacts have been simplified to streamline responses and ensure consistency. Entry conditions have been added to the Critical Design Review and System Acceptance Review and Distributed Field Test. Reports missing the identified elements will be rejected, with teams able to resubmit them within 48 hours. This is intended to ensure all teams are following a structured engineering process, such as that needed for all space-related projects. Several rulings, task activities and point allocations are modified compared to 2024. These include additional details or revisions of; rule 10.5.3.3 and equation(s) eq. (3.0), rule 9.9 and rule 9.10, rule 11.6. Existing rules have been overhauled and some new rules regarding multiple robotic platforms, field-briefings and radio-communications have been introduced including; rule 3.1.2, rule 8.4.2, rule 3.10.1, rule 3.10 and 8.6.3.3. Please carefully read the intended changes for future rules in preparation for ARCh2026 and pathways to visit NASA Kennedy Space Center, see rule 3.15. Rules or decisions made at prior challenges (i.e 2024) do not serve as precedence for future challenge (i.e 2025).

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

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 2025 competition are as follows:

14 August 2024 Team registration opens. Rules and Requirements, and Critical Design Review (CDR) guidelines released

11 September 2024 Team registrations close

30 October 2024 CDR due, System Acceptance Review (SAR) and Cost Report Guidelines guidelines released

5 February 2025 Distributed Field Test (DFT)

12 February 2025 SAR and Video due

12 March 2025 Cost Report due

27 March 2025 Australian Rover Challenge competition starts

30 March 2025 Australian Rover Challenge competition ends

Dates may be adjusted at the discretion of the judges. 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 2025Australian 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 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 5.8.

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 and associated events will occur at the University of Adelaide Roseworthy campus in South Australia.

2.10. 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.

2.10.1. 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.

3.1.1. Specific activities may allow for the pre-placement of additional payloads or components outside of the designated start area – the specific rules in these cases are found under each task.

3.1.2. Multiple robot systems are allowed (i.e microrover), but the total mass and starting dimensions of all system(s) must comply within the mass and volumetric dimensions given in rules 3.4 and 3.5. Similarly, any powered external systems (i.e external processing plant, microrover, deployed relay antenna, ect) must conform to the E-STOP and LED requirements in rules 3.9. A single, connected system must leave the start gate. All systems must be fully under the team's control at all times, and all communications must adhere to rules given in 3.10. The robot does not have to re-assemble prior to the end of the competition run.

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 system 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 – or in the case of some specific activities, off 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 typically 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 on-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 and Mapping & Autonomous tasks is 50 kg. The maximum allowable mass of the rover and payloads when deployed for the Space Resources and Construction & Excavation task is 60 kg. The total mass of all fielded rover parts across all tasks is 90 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 90 kg.

3.5.1.1. The weight limits do not include any spares or tools used to repair, prepare or maintain the rover – e.g., swapping out a 1 kg wheel for an identical spare between tasks because it broke in an early task still only counts as 1 kg towards the fielded parts limit, not 2. Swapping out the wheels for a slightly different design that is better suited to a specific task, however, *would* include the weight of both sets of wheels towards the limit. Ultimately, what counts as a spare vs. an alternate part is up to the judges' discretion.

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.

3.5.3. Teams will not be allowed to attempt a task if the fielded parts would cause them to exceed the 90 kg limit at weigh-in. If time permits, they may remove or adjust parts of their rover and have it re-weighed until they are below this limit – but no extra time will be allocated to their task attempt in this case.

3.6. Throughout the challenge, teams may be required to carry their rover up to 200 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 fielded form, all additional payloads/components and base station systems (i.e., everything that is required to operate the rover), and the value of all manufacturing, labour, and in-kind support must be reported to the judges in the Cost Report. Additionally, a cost limit for the entire fielded rover and related systems is in effect – see chapter 7 for details.

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 independent electrical subsystems on the rover or any other payloads must have at least one emergency Emergency Stop (E-STOP) switch.

3.9.1. There should be at most one independent electrical subsystem per discrete system, e.g. one for the rover and all on-board payloads, one for a separate resource processing payload, etc.

3.9.1.1. It may be allowable to have more than one electrical subsystem per discrete system if required and appropriate at the judges' discretion, but in this case, the E-STOP switches must be co-located so that all power draw can be easily stopped simultaneously in the case of an emergency.

3.9.2. 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.

3.9.3. This switch shall immediately stop the all movement and cease all power draw from batteries in the event of an emergency such as a battery fire.

3.9.3.1. The button should disconnect the batteries from all controllers (high current, forklift type button) and it should isolate the batteries from the rest of the active sub-systems as well.

3.9.4. All independent electrical subsystems shall have a clear external light-based indication of powered on/active status, such as an LED strip or rotating beacon light that can be viewed in broad daylight from all sides of the rover.

3.9.4.1. This light must be visibly and clearly on if the subsystem is powered, and visibly and clearly off if the subsystem is unpowered.

3.9.4.2. Other decisions about e.g. the colour of the light are left to the teams' discretion, for example if they wanted to use different colours to indicate different rover states.

3.9.5. 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 communications:

3.10.1. It is expected that teams bring their own two-way handheld radios (i.e walkie-talkies) for the base-station and field teams to communicate during setup and packdown. To reduce radio-communication interference, teams muste nsure these radios operate on Ultra High Frequency Citizen Band (UHF CB) frequencies (476.4250 to 477.4125 MHz) to reduce radio-interefence with competing rovers, as many cheap off the shelf radios may operate on 2.4 Ghz and not appear on spectrum analyzers.

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

3.10.3. Teams may operate on either 900 MHz, 2.4 Ghz or 5 Ghz, but are responsible for ensuring

that they comply with ACMA regulations for the frequency band in which they operate.

3.10.3.1. The use of specific low power (these power consumers are not part of the total powerconsumed COTS meter) Bluetooth transmission equipment in the 2.4 GHz range is allowed for sensors and other robot communications. Bluetooth is allowed only at power levels of Classes 2, 3, and are limited to a maximum transmit power of 2.5 mW EIRP. Class 1 Bluetooth devices are not allowed.

3.10.4. As there will be two pitches, two teams will be attempting a task concurrently. To minimize interference between competing teams and nearby non-competing teams, specific 'competition' and 'practice' non-overlapping 20 MHz bands will be allocated to teams.

3.10.4.1. Prior to competition, each team will be assigned either an odd or even number (i.e Team A is 1, Team B is 2, Team C is 3, Team D is 4, ect).

3.10.4.2. For 2.4 GHz during competition, even teams will compete on channel 1 (2412 MHz) and odd teams will compete on channel 11 (2462 MHz), See fig. 3.1. This leaves Channel 6 (2437 MHz) available for teams to practice. Whilst competing, a team is permitted to bond two 20 MHz channel to form a 40 MHz band (i.e Channel 1-5 or Channel 9-13) however they do so at their own choice and increased risk of interference. During practice or setup teams are not permitted to bond two channels, for risk of interfering with a competing team.

3.10.4.3. Although teams can occupy channel 6 on 2.4 GHz for practice under remote control, it is strongly recommended that teams use a hardwired connection, to reduce congestion on the network and out of respect for competing teams.

3.10.4.4. For 900 Mhz, teams are permitted to occupy 1, 3, 6 or 13 (915–928 MHz) but must adhere to ACMA regulations regarding power (-dB) and frequencies occupied.

3.10.4.5. For 5 GHz, teams are permitted to channel hop and use parts of U-NII-2A (5260-5350 MHz), U-NII-2C (5470-5710 MHz) or U-NII-3/4 (5730-5850 MHz) however it is the teams' responsibility to adhere to ACMA regulations. As per AS/NZS 4268 B1 and B2, transmitters designed to operate in any part of 5250–5350 MHz and 5470–5725 MHz bands shall implement dynamic frequency selection (DFS) in accordance with sections 4.7 and 5.3.8 and Annex D of ETSI EN 301 893 or alternatively in accordance with FCC paragraph 15.407(h)(2). Also as per AS/NZS 4268 B3 and B4, transmitters designed to operate in any part of 5250–5350 MHz and 5470–5725 MHz bands shall implement Transmit Power Control (TPC) in accordance with sections 4.4 and 5.3.4 of ETSI EN 301 893 or alternatively in accordance with FCC paragraph 15.407(h)(1).

3.10.4.6. Teams are permitted to power on and occupy their allocated competition band at the start of their setup time, and must power down and fully disconnect at the end of their task time. Teams are not permitted to occupy their competition band during the brief and weigh in, or during the base station clear out. See Figure 8.1.

3.10.5. 2.4 and 5 GHz channels will be monitored by judges, however frequencues outside this range (i.e 900 Mhz) will not be monitored.

3.10.5.1. The competition takes place at the University of Adelaide Roseworthy campus, which can be highly congested RF (particularly WiFi) environment. Teams should consider this when designing their communications systems, and take steps to avoid foreseeable complications.

3.10.5.2. Teams shall ensure that their communications equipment can automatically or manually switch between frequency bands, should there be any interference. Interference from sources not related to, or under control of the ARCh judges will not be grounds for protest by any team.

3.10.5.3. Teams shall be prepared to adjust their communications in the scenario that 'competition' or 'practice' bands need to be reallocated by judges due to an unforeseen event.

3.10.5.4. Each team must clearly state their team name as their SSID when using wireless equipment to facilitate judges monitoring interference and to ensure teams are occupying the correct band, at the correct times.

3.10.5.5. If a team is found to be on the wrong channel during their competition attempt, they will be required to power down and re-start the task with no time extension. If a non-competing team is found to be occupying a competition band as another team is competing, they will be given one strike. Any further strikes will suffer a 50% point penalty to their subsequent competing task.

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. Similarly, the use of magnetometers is not allowed for any kind of positioning or orientation-based application.

3.12.1. They may be used as part of the ilmenite sensing for the Space Resources task.

3.12.2. Otherwise, commercial off-the-shelf components that contain magnetometers may still be used, so long as no data from the magnetometer is collected and this can be demonstrated to the judges.

3.13. The following considerations apply to base station antennas:

3.13.1. 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.

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

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

3.13.4. 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.

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

3.13.6. 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.

3.14. The challenge arena may experience different forms of extreme weather (hot, dry, cold, windy or wet). Although rain is uncommon at this time of year in Roseworthy, rovers must be able to operate in variable conditions, such as in a light rain shower.

3.14.1. Judges will reserve the right to consult to decide any amendments related to adverse weather implications that rovers are at risk of significant damage from the weather event e.g. rain. This could include postponement or cancellation of an entire day. Judges may consult and confer with team leads to evaluate their preference to compete even in inclement weather, however judges are not responsible if a rover becomes nonfunctional for the remainder of the competition if a team chooses to continue.

3.14.2. If, because of weather, one team cannot compete for the full duration of a task, judges will endeavour to defer them to another time. Please note, this may not be possible dependant on site access, safety and after-hours facility and judge availability.

3.14.3. If, because of weather, two or more teams cannot compete fully in a task, that task will not be included in overall scoring for all teams competing. Please note, for teams on the day who are still able to compete in that task, a score will still be calculated with the sole intention of providing a metric of performance, but will not contribute towards points for that task.

3.14.4. In the scenario of a catastrophic fire warning by the South Australian Country Fire Service, which are published daily (and communicated to the University of Adelaide by the Bureau of Meteorology) at approximately 4:30 pm AEST, Roseworthy Campus will not be accessible for any teams and non-critical staff. Due to the unpredictable nature of fire warning, conditions may change at any instant. Teams are required to explicitly follow the directions of judges and university staff if on campus. Teams must have their own fire-safety plan related to their operations and management of their team.

3.15. In preparation for upcoming changes to the ARCh ruleset which focus on increasing the fidelity of a commerical lunar simulation mission, the following changes are expected to be implemented but will not be enforced - this serves as a one year grace period before the ARCh2026 ruleset will be introduced where teams will be expected to consider several design and operational factors which may include; efficient communications, minimizing vehicle mass, minimizing power consumption, maximizing autonomy, dust tolerance, minimizing dust disturbance/lofting,

3.15.1. The energy consumed by the rover (or any independantly powered system, adhering to rule 3.1.2) must be recorded with a “Commercial Off-The-Shelf” (COTS) electronic data logger device, such as this, or some other alternative that allows judges to clearly record the power consumed during each task. Actual energy consumed during each attempt must be shown to the judges on the data logger immediately after the attempt.

3.15.2. The bandwith used by the rover (or any independantly powered system, adhering to rule 3.1.2) must be recorded by the team with a COTS device, or some alternative method of the teams’ choosing that allows judges to clearly record the average, peak and total bandwith consumed during each task.

3.15.3. To increase alignment with the NASA Lunabotics competition, an Australian team *may* receive a letter of invitation to spectate the Lunabotics finals at the NASA Kennedy Space Centre, and attempt excavation and berm construction within the NASA KSC 'Big Bin' facility - depending on their performance in the **Berm Construction** activity in the Excavation & Construction Task.

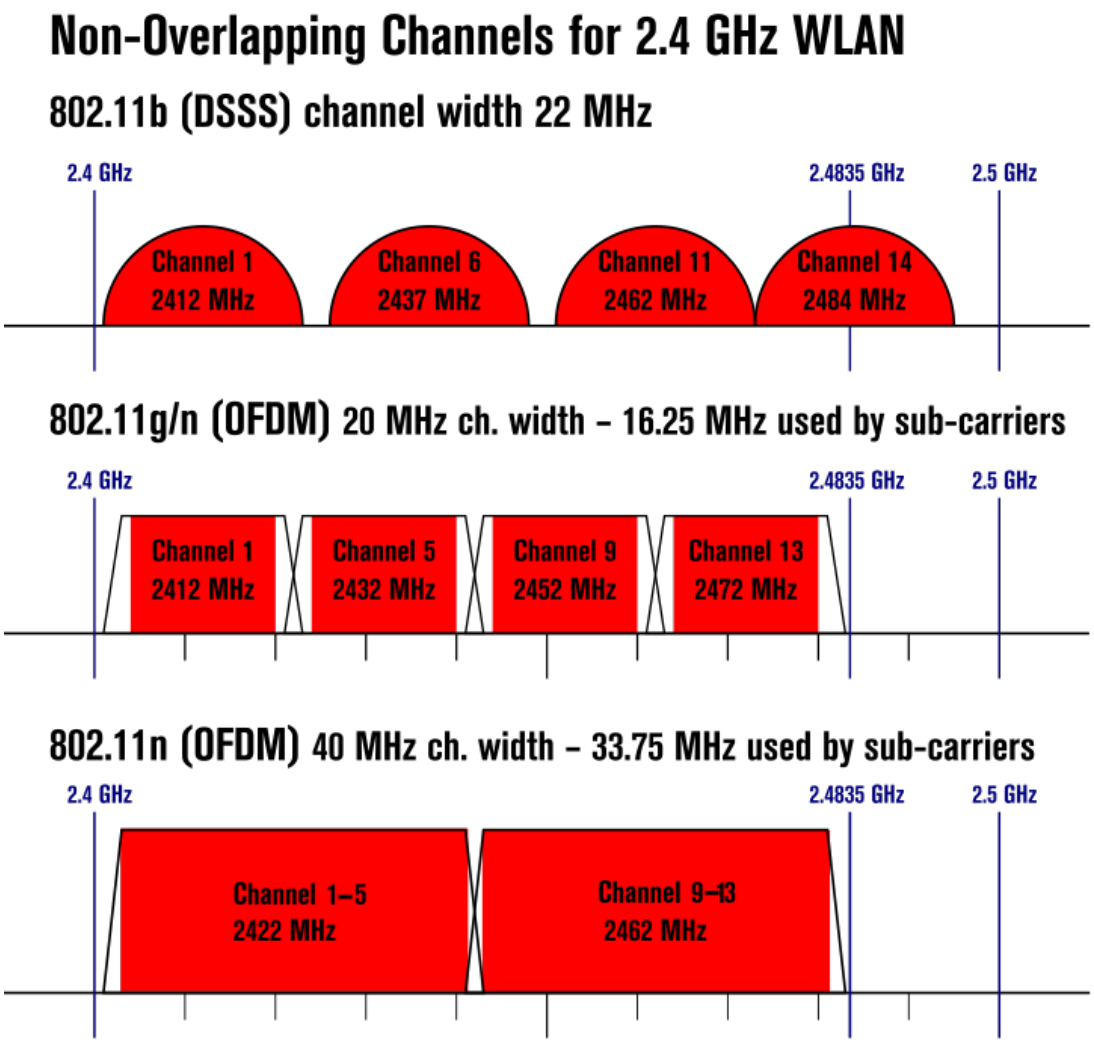

Figure 3.1.: 2.4 GHz Frequency Diagram

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. 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.

4.3.1.1. In rare cases, these penalties are assigned per activity. In these cases, similar rules to below are used to determine the score for each activity, and then task-level penalties are applied to the sum of the adjusted activity scores.

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

4.4.2. Best team culture and display of camaraderie throughout the event.

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

4.5. The design of each task and the point distribution for each activity has been curated to accommodate teams of varying experience levels - from new teams to more advanced and mature teams. In general, each task's activities can be categorized based on their complexity levels: basic, intermediate, and complex. Activities in a task are sequenced from least to most difficult.

4.5.1. Basic activities: These activities are designed to assess the fundamental capabilities of the rovers. They typically involve basic navigation and sensing tasks, such as driving forward, backward, turning, and utilizing cameras for visual feedback. These activities serve as a foundation for all teams and should be achievable by even the newest participants.

4.5.2. Intermediate activities: The intermediate activities require teams to integrate a dedicated subsystem or component into their rovers. Examples of these subsystems could include a robotic arm, construction payload, or processing unit. This level of complexity allows teams to demonstrate their ability to incorporate specialized functionalities into their rover design.

4.5.3. Complex activities: The complex activities are intended to challenge experienced teams and their rovers. These activities involve using the integrated subsystems in more intricate and sophisticated ways. Teams need to demonstrate not only technical proficiency in dealing with obstacles and executing complex tasks but also strong operator training and time management skills.

4.5.4. In general, the first 25 to 50 points of a task consist of basic activities, with the subsequent 25 to 50 points consisting of intermediate activities, and the final 25 points being complex activities. A single activity can also be broken down into basic, intermediate and complex segments, in order to provide greater distribution of points.

4.5.5. The organising committee strongly recommends that new or novice teams focus on mastering basic activities and rover functionality before progressing to intermediate or complex activities. It is essential to prioritize achieving full points in fewer tasks rather than spreading a team's time and resources thinly across multiple, difficult activities, as has occurred in the past. This approach will allow teams to build confidence and expertise iteratively, making their overall experience in the competition more rewarding and successful.

4.5.6. Teams must nominate in the SAR which tasks they intend to compete in, and demonstrate that their rover will be ready for that task. On the basis of the SAR submissions, judges have the final say of which teams may compete in each task. This is to streamline scheduling, avoid scenarios of a non-functional rover, and can result in additional task time for all teams.

Part II.

Deliverables

5. Critical Design Review

5.1. Teams will be required to submit a Critical Design Review (CDR) on 30 October 2024.

5.2. The purpose of the CDR is to show that teams are taking a systems engineering approach to their project, demonstrating 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. NASA videos explaining key project management and systems engineering concepts created for their Lunabotics challenge, along with advice on how to apply them to a university-level design project such as this one are available at https://www.youtube.com/watch?v=7ieMjLO8cMI&list=PLStC43yAV6zRhiTcHM4x5pF1e-ODXs2Ht&index=1. You do not have to use this specific approach, but it expected that there is clear evidence of selection of a systems engineering approach and tailoring to your situation.

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

5.5. Each CDR report shall contain an identified and tailored systems engineering lifecycle, a clear system hierarchy, mention of identified essential requirements driving design, and indication of tasks the team intends to compete in as entry conditions for the review. Each report will undergo an initial review entry conditions check within 48 hours of the submission deadline. CDR reports addressing all expected elements will receive an "Accepted" message. Any CDR missing these elements upon first submission will receive a "Rejected" message, with the team then having a further 48 hours to update and resubmit the report. Rejected reports will incur a 20% penalty for this element.

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

5.6.1. Power systems, power delivery, and power safety

5.6.2. Drivetrain

5.6.3. Chassis construction and materials

5.6.4. Perception systems

5.6.5. Base station design and control

5.6.6. Rover communications

5.6.7. Drive control systems (software based)

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

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

5.8. 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.

5.9. Teams are required to nominate the details of the frequency bands that they plan to communicate in.

5.10. More detailed information regarding the CDR will be released according to dates specifed in 1.

6. System Acceptance Review and Distributed Field Test

6.1. Teams will be required to submit a System Acceptance Review (SAR) on 12 February 2025.

6.2. The SAR involves teams explaining their executed systems design process, outlining their final implemented design, and their planned approach to each ARCh task in which they intend to compete.

6.2.1. Teams will not be permitted to revise their decision to not compete in a task after the submission of the SAR.

6.3. The SAR will be in the form of a written report, with associated ”proof of life” supporting video.

6.4. Each SAR report shall contain clear evidence of attempted verification for identified essential requirements with associated ”proof of life” video supporting this verification as entry conditions for the review. All rovers shall be capable of manoeuvring on sand at this point, though additional consideration will be given to new teams at judges discretion.

6.5. Each report and video pair will undergo an initial review entry conditions check within 48 hours of the submission deadline. SAR report and video pairs addressing all expected elements will receive an “Accepted” message. Any SAR report and video pair missing these elements upon first submission will receive a “Rejected” message, with the team then having a further 48 hours to update and resubmit the report and video. Rejected report and video pairs will incur a 20% penalty for this element.

6.6. Teams are to organise their own remote Distributed Field Test (DFT) in the time window specified in Section 1.

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

6.6.2. 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.

6.7. More detailed information about the DFT and SAR will be provided in the SAR guidelines document, which will be made available prior to submission.

6.8. 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.

6.8.1. Failure to meet minimum requirements for each task may result in teams being disallowed from competing in those tasks.

7. Cost Report

7.1. Teams will be required to submit a cost report on 12 March 2025.

7.2. The total cost of the rover (in its final form) and base station systems (that is, everything that is fielded/required to operate the rover) must not exceed $35,000 Australian Dollars (AUD).

7.3. The cost limit does not include any team labour, team development software (unless it is also required to run the base station systems), research and development, plant, machinery, or tools.

7.3.1. Although these costs do not count towards the cost limit, you must keep track of them regardless as they will still be a required inclusion in the Cost Report.

7.4. The reportable cost for each component is that which any member of the public could acquire the components and parts that make up the whole rover system.

7.4.1. This means that the retail value of components provided as in-kind support must be included.

7.4.2. Costs must not include discounts of any type, but must include the delivery and import fees paid, regardless of the location and jurisdiction in which the components were delivered.

7.4.3. The cost of transporting the complete rover to Adelaide to compete in the challenge does not need to be included.

7.4.4. 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.)

7.4.5. For purchases in any currency other than AUD, any widely-available currency conversion rate from the date of the purchase to the date of the cost report submission may be used to find the equivalent value in AUD. All such costs must be reported in both their original currency and in AUD with the purchase date and conversion rate and date included. Only the AUD value will be used for assessing the value of the rover.

7.5. More information regarding the Cost Report and reportable costs are in a separate document, to be made available from February 2025

Part III.

Competition Tasks

8. Competition Task Logistics

8.1. The 2024 competition will take place on a simulated lunar arena.

8.1.1. The challenge arena is expected to be no smaller than 15 × 15 m, and up to 35 × 35 m and consist of dry, fine-grained sand.

8.1.2. The challenge arena may have any number of the following obstacles:

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.

8.4.1. Teams must make themselves available to the judges at their scheduled briefing time, or risk forfeiting their attempt of that task.

8.4.2. During the field brief, teams must clearly demonstrate that the E-Stop and signal light (i.e LEDs) are functional, in addition to size and weight requirements from rule 3.4.

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. Teams may begin operating in their allocated radiocommunications competition band

8.6.3.4. 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 could not. 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. A rover reposition may be called by the base station at any time by clearly indicating this intent to the judges.

8.11.1. The intent of a rover reposition is to allow teams to attempt point-scoring activities even if their rover is or becomes immobile.

8.11.2. Teams will receive a **40% penalty** for any activities attempted after one or more repositions. Note this applies to *whole* activities, even if part of an activity was attempted or scored points prior to the first reposition.

8.11.3. During a reposition, the base station may communicate to the field team using hand-held radios provided by the judges.

8.11.4. 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.

8.11.5. The base station must instruct the field team where to reposition the rover, which they must do while the rover is inactive. The rover must not become active again (control any actuation) until the reposition is has been concluded, as declared by the base station.

8.11.5.1. Any rover activity during the reposition may be grounds for the E-STOP to be activated.

8.11.6. Activities which allocate points based on navigation or way-finding are not eligible to score penalised points after a reposition.

8.12. 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.

8.12.1. 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.

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

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

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

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

8.15. 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.

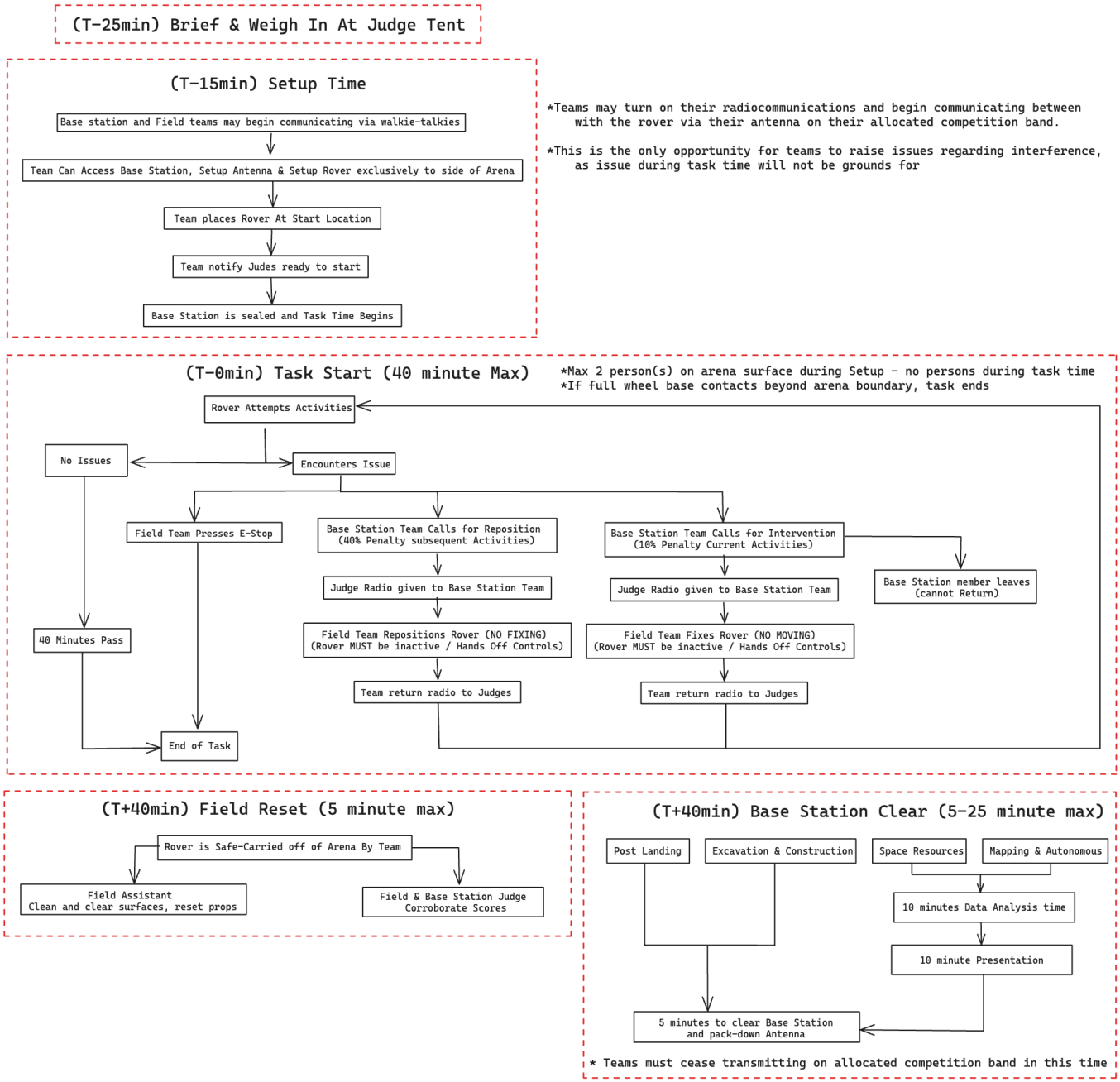

Figure 8.1.: Logistics Flowchart

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 40 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. Tasks may be done in any order after completing the Systems check.

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) **5 points** awarded once all wheels contact the ground. **10 points** are awarded for circumnavigate the lander, and **5 points** are awarded for noting any damage that has occurred to the lander during flight and descent to the judges.

9.5.1.1. Visual asset inspection can be done using images collected from onboard cameras and other sensing instruments of the team's choosing.

9.6. **Activity 2:** Site Evaluation (**30 points**)

9.6.1. **10 points** are awarded for navigating to and relaying the status readout of three supply caches around the arena to the judges. Obstacles of a range of difficulties may be encountered (i.e. rocks, berms, craters, etc.)

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

9.7.1. **10 points** are awarded for navigating to the processing plant, and using 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 a series of 4 maintenance jobs 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. **5 points** are awarded for completing each maintenance job.

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

9.9.1. Your rover is tasked with connecting the lander to a gas line, to support refuelling on the surface. Given the connection is not part of existing lunar infrastructure, teams are required to design and utilise both sides of the connection.

9.9.2. Before the start of the task, teams will be required to affix both sides of the connection to the relevant hardware. One end to the propellant hose, and one end to the lander.

9.9.3. The lander side of the connector must be designed to be affixed to the lander. The lander will provide an interface (which must be used) of 4 x M4 threaded bolt holes, where the centres of the bolt holes on the lander form the corners of a 10 cm square.

9.9.3.1. As the interface consists solely of the bolt holes, teams will need to bring their own bolts.

9.9.3.2. The bolt holes will be configured to allow bolts of any reasonable length to be used.

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

9.9.5. During the task, the rover must connect the provided hose, to the lander.

9.9.6. **5 points** are awarded if the hose connector makes any physical contact with the lander side of the connector. 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 lander.

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

9.10. **Activity 6:** Modular Propellant Hose Connection (**10 points**)

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

9.10.2. For this activity, a custom outlet hose connection has been designed by the judges to support a modular approach to lunar settlement, whereby any lunar explorer may interface with the connection. The connection 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.

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

9.10.4. The hose will then be placed on the arena surface, within 2 m of the processing plant. This is the other end of the same hose used in activity 5.

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

9.10.6. **5 points** are awarded if the hose connector makes any physical contact with the lander side of the connector. 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.

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

10. Space Resources Task

10.1. Towards the goal of supporting future astronauts which need breathable oxygen, potable water and construction materials, your rover must now begin the evaluation, collection and extraction of critical lunar resources including frozen volatiles like H_2O, and metals like Titanium (Ti) and iron (Fe) from ilmenite ($FeTiO_3$)-enriched soils. To do this, your rover has two primary tasks to perform; 1) *in-situ* resource prospecting, 2) then the excavation and processing of a target resource to hand to judges. There will be two types of resource deposits your rover must investigate; dry ilmenite-doped soil representing ilmenite-rich regolith on the Moon, and frozen ice-cemented soil representing deposits of frozen volatiles in persistently shadowed regions (PSRs). Your rover is only expected to process frozen water to extract liquid H_2O.

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

10.3. Teams will have at least 40 minutes to complete this task.

10.4. **Activity 1:** Prospecting (**20 points**)

10.4.1. Visit two sites of ice-cemented regolith and two sites of ilmenite-enriched regolith. To receive points, teams must demonstrate to the judges in the base station that the rover has successfully traversed to and captured images of each site. **5 points** are available for imaging each site up to a total of **20 points**.

10.4.2. Both ice-cemented sites will be located within an easily accessible large crater in the challenge arena, representing a lunar PSR. Both mineral-enriched deposits will be located in a relatively flat, easily accessible region of the challenge arena.

10.4.3. Passive sensors or any other chosen method to investigate each site. Teams may sample a small amount of regolith from each site to aid in their identification.

10.4.4. An additional **20 points** are available for quantifying; (1) the amount of ice and, (2) the amount of ilmenite in each of the respective deposits, as part of the Space Resources Presentation. See rule rule 10.6.1.2.

10.5. **Activity 2:** Excavation & processing (**50 points**)

10.5.1. Excavate regolith from an icy sample site of the team's choosing with the aim of extracting the highest amount of liquid water as possible. Teams may use mechanical means or any other approach chosen by the team to excavate the material.

10.5.2. Processing can be performed on-board the rover and/or by a separate standalone processing unit. Processing must be done entirely within the allocated task time.

10.5.2.1. The maximum dimensions of the standalone processing unit is 40 x 40 x 40 cm.

10.5.2.2. The standalone unit will be weighed with the rover prior to the task start time. The combined weight of the unit and rover must be below the allocated 60 kg for this task, and below the total weight for the challenge, as specified in rule rule 3.5.

10.5.2.3. The unit must be a standalone, self-powered, untethered system. It must be placed and initialized by the team immediately prior to the task start time in the allocated payload zone in the challenge arena.

10.5.2.4. If a rover fails to extract or deliver material for processing, teams can nominate to manually load a sample with known mass and ice content to attempt processing. Teams will receive a **60% penalty** for processing if they required a manual loading.

10.5.2.5. Up to **50 points** will be awarded based on the recovery (total mass) and grade (purity) of processed material handed to judges at the end of the task. See equation eq. (3.0) in appendix B for a detailed breakdown of materials and methods for sample preparation, and point breakdown allocation for this activity.

10.5.2.6. Chemical solvents cannot be used in this activity.

10.5.3. Processed material must be collected in a container (dimension, material or otherwise) of the team's choosing.

10.5.3.1. The container must be removable, must allow the material to be poured out, and must be handed to judges promptly at the end of the task.

10.5.3.2. Only material that can be poured out of the container will be measured and used for calculating scores, manual removal (i.e using a spatula or card) will not be allowed.

10.5.3.3. Teams' must notify judges of the tare masses of the empty containers, to assist with determining the mass of material extracted.. Any residual material in the container represents loss, indicating poor efficiency.

10.6. **Activity 3:** Space Resources Presentation (**30 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. What prospecting tools were used to evaluate each of the sites, and how is the data collected valid? Up to **5 points** available depending on the quality of answer.

10.6.1.2. How much water (by mass wt.%) did each ice-cemented site contain, and how much ilmenite (by wt.%) did each site contain? Up to **5 points** per site are available depending on the accuracy of obtained resource estimates, for a total of **20 points**. See rules rule B.5 in appendix B for a detailed breakdown of scoring for this activity.

10.6.1.3. What excavation and processing methods were used, and why? Up to **5 points** available depending on the quality of answer.

10.6.2. The presentation (max 10 minutes in duration and max 5–10 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. Your rover must now scale-up operations and prepare the site for a future human landing by conducting some foundation services which include; removing hazards by clearing rocks, excavating and transporting regolith to construct a berm, and constructing a feature of the team's choosing using dust-mitigating pavers brought from Earth.

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

11.3. Teams will have at least 40 minutes to complete this task.

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

11.5. **Activity 2:** Rock Clearing (**30 points**)

11.5.1. Rocks must be removed from a designated area and placed into a collection zone, no more than approximately 5 m away. To receive points, the entire top-down projected view of the rock must not be overlapping the marked boundary for the collection zone. For example, if at the end of a task, a rock has an outer edge still overlapping the marked boundary from the collection zone, then no points are awarded. Rocks of basaltic composition varying size and weights will be used, with bulk densities of approximately 2.5 g cm^{-3} to 2.9 g cm^{-3}.

11.5.1.1. Two small rocks will be no larger than 8 × 8 × 8 cm and weigh less than 1 kg.

11.5.1.2. Two medium rocks will be no larger than 11 × 11 × 11 cm and weigh between 1 kg to 3 kg

11.5.1.3. A large rock will be no larger than 15 × 15 × 15 cm and weigh between 3 kg to 5 kg

11.5.1.4. Huge rock will be no larger than 17 × 17 × 17 cm and weigh between 5 kg to 10 kg

11.5.1.5. For each small and medium-sized rock, a total of **4 points** are available. **2 points** for moving the rock any distance from its starting position, and **2 points** are awarded for placing the rock in the collection zone.

11.5.1.6. For each large and huge rock, a total of **7 points** are available. **3 points** for moving the rock any distance from its starting position, and **4 points** are awarded for placing the rock in the collection zone.

11.6. **Activity 3:** Excavation & Berm construction (**30 points**)

11.6.1. Excavate regolith from a designated Regolith Acquisition Zone (RAZ) and then deliver the excavated regolith to a designated marked area (2 meter length and 0.7 m width) near the

processing plant. Markers will conist of red/white vertically buried striped sticks.

11.6.2. Teams may use mechanical means or any other approach chosen by the team to excavate regolith.

11.6.3. A volumetric scan before and after the run will be performed. Only the berm volume within the designated marked area will be counted. Points will be awarded according to the berm volume at the conclusion of the task.

11.6.3.1. **5 points** will be awarded for depositing any volume of material

11.6.3.2. **10 points** will be awarded for depositing at least 50 cm^3

11.6.3.3. **15 points** will be awarded for depositing between 50 cm^3 to 500 cm^3

11.6.3.4. **20 points** will be awarded for depositing between 500 cm^3 to 1000 cm^3

11.6.3.5. **25 points** will be awarded for depositing between 1000 cm^3 to 2000 cm^3

11.6.3.6. **30 points** will be awarded for depositing at least 2000 cm^3

11.7. **Activity 4:** Paver construction (**35 points**)

11.7.1. Begin construction of a dust-mitigating feature of the team's choosing, using individual pavers that can cover an area of up to 1.1 m^2. No penalties are applied for covering a larger area.

11.7.2. Individual pavers must start disconnected in one of two locations; either 1) on the lander in a designated paver box at the rear of the lander, or 2) in a dedicated payload made by the team.

11.7.2.1. The paver box will consist of a planform area of at least 25 × 110 cm (Width x Length). The base of the box will be between 10 and 50 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.

11.7.2.2. If pavers start in a dedicated payload, teams will be directed to place the payload on the challenge arena surface in an allocated area before the beginning of the task by the judges.

11.7.2.3. If pavers start in the paver box on the lander, the total size of objects placed in the box must not exceed 110 x 25 x 25 cm (Length x Width x Height)

11.7.2.4. If a paver payload is used, the maximum dimensions of the payload must not exceed 120 x 35 x 35 cm (Length x Width x Height). During the task, the rover is free to interact with the paver payload in any way.

11.7.3. Teams must design and build their own pavers.

11.7.3.1. Pavers must consist of individual, rigid, stiff pieces that do not experience permanent deformation. Any signs of irreversible plastic or brittle deformation (i.e

cracking, creasing, bending or buckling) of a paver at the end of the task means the paver is damaged and non-rigid.

11.7.3.2. Adhesives, meshes and magnets must not be used to connect pavers or pre-attach pavers either prior to or during deployment. Note that this does not preclude using adhesives or magnets within the structure of a *single* paver.

11.7.3.3. Pavers may be any mass, as long as the mass for all objects fielded for this task (rover + pavers + payload to store pavers, if applicable) conforms to the task mass limit.

11.7.3.4. Pavers may be any size or shape, as long as the dimensions of an individual paver conforms to rules rule 11.7.2.1 to rule 11.7.2.4

11.7.4. Teams can choose to cover any area of the challenge arena, in any shape with their pavers to receive the points for paver placement as long as the pavers are flat and connected at the end of the task. **30 points** will be awarded at the end of the task for the proportion of the 1.1 m^2 area that is covered.

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

11.7.4.2. A paver is considered successfully placed if it is completely flat on the surface at the end of the task (i.e its entire base is in contact with the ground).

11.7.4.3. Pavers cannot overlap in a way that means they do not lie flat (small areas of overlap are permitted as part of connection mechanisms, if applicable).

11.7.4.4. Pavers are considered connected if a light tug on any other paver translates that force through the connected tiles.

11.7.4.5. The maximum allowable gap between the edges of any two connected pavers cannot exceed 1 cm. If any point along a paver's edge or interlocking mechanism of a paver is greater than 1 cm away from an adjacent paver, it is not interconnected, and the paver is not successfully placed.

11.7.4.6. Pavers have to be contiguous. If they are not, the largest contiguous set of connected pavers will be awarded points.

11.7.4.7. At least one paver must be placed in order to be eligible to score this activity.

11.7.5. Up to **5 points** are available for justifying to judges the relevance and utility of the constructed feature using pavers (size, location, context, etc.)

11.7.6. Prior to the task, teams must demonstrate that the placement of all their pavers covers 1.1 m^2, and that all pavers can be successfully placed and interconnected. For the sake of time, this can be done by hand and will take place nearby the challenge arena prior to the commencement of the task.

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

12. Mapping & Autonomous Task

12.1. Your rover now needs to explore a new area given a rudimentary map, perhaps derived from data collected by orbiters. This map will contain a series of landmarks that scientists are interested in imaging in more detail, and the rover will need to navigate to these without human intervention. Then, either autonomously or under operator control, a larger-scale map of the arena will need to be constructed, and the locations of previously-unknown landmarks will need to be determined.

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

12.3. Teams will have at least 40 minutes to complete this task.

12.4. All data and measurements regarding the arena *must* be derived from data provided by the judges or 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 outputs are derived from data collected by the rover during only this task, they may be penalised or disqualified.

12.5. As the purpose of this task is exploration, teams may not call for a reposition of the rover during it.

12.6. This task is split into two distinct phases – the autonomous phase, and the non-autonomous phase.

12.6.1. Some points for this task are available only during the autonomous phase.

12.6.2. The tasks starts during the autonomous phase, in which base station team members shall interact with the controls *only before* the rover has moved along the ground for the first time.

12.6.2.1. 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.

12.6.2.2. During the autonomous phase, teams are not allowed to call an intervention. If they do call an intervention, this will immediately move the task to the non-autonomous phase.

12.6.2.3. During the autonomous phase, teams will incur a **10% penalty** for *each* collision with a supply cache or artificial obstacle.

12.6.2.4. If the rover leaves the arena bounds, the E-STOP must be immediately pressed.

12.6.3. At any time the team may resume manual control and enter the non-autonomous phase by interacting with the controls.

12.6.3.1. Teams may remain in the autonomous phase and interact with the controls (e.g. for downloading and processing rover data) if and only if the rover stops moving

within 10 seconds of resuming control. In this instance, if at any point the rover does move again, the team will automatically enter the non-autonomous phase.

12.6.4. Teams may elect to skip either phase – either beginning immediately in the non-autonomous phase, or end the task by shutting down the rover in the autonomous phase.

12.7. **Activity 1:** Leave the start area autonomously (**5 points**)

12.7.1. The points will be awarded if the rover entirely exits the starting square (which will be on the ground, not on the lander) during the autonomous phase.

12.8. **Activity 2:** Autonomous landmark navigation (**30 points**)

12.8.1. Prior to the start of the competition, teams will be provided a schematic showing the approximate locations (with dimensions) of the key supply caches and obstacles on the field. This schematic will also include the approximate locations and heights off the ground of 5 postcard-sized placards that contain some kind of text or figure.

12.8.2. Teams will be awarded **6 points** for each placard they can traverse to and whose content they can successfully image and relay to the base station judge *while in the autonomous phase*.

12.8.3. The schematic will not necessarily include details of every single obstacle (especially the smaller ones), and nor will it include details of the cubes in activity 3, so the rover should be designed to handle such obstacles autonomously.

12.8.4. No further points will be awarded for this activity once a team has entered the non-autonomous phase.

12.9. **Activity 3:** Exploratory mapping (**40 points**)

12.9.1. Teams must explore the broader arena, beyond the landmarks provided for activity 2.

12.9.2. Spread throughout the arena, there will be four 100 × 100 × 100 mm cubes in bright colours: red, green, blue, and white. These will likely be manufactured by spray-painting wooden blocks.

12.9.3. Teams must report the coordinates of these blocks in a coordinate system defined relative to the rover's starting area, the details of which will be provided to teams in the task briefing.

12.9.4. For each block, **5 points** are available for reporting its location to within 300 mm of the ground truth value as determined by the judges. **2 points** will be awarded for less-accurate solutions that are still within 600 mm.

12.9.5. These point values are increased to **10 points** and **5 points** respectively for coordinates reported to the judges during the autonomous phase.

12.9.6. The base station team may remain in the base station and continue the task time if the E-STOP is hit, but in this case an intervention is unable to be called and the rover is unable to be switched back on. This is to allow teams to continue to process data they have already downloaded to get coordinates to submit to the judges.

12.9.7. Teams should also use this activity time together with the data from the previous activity to collect data to construct a map of the whole arena to present to the judges in activity 4.

12.9.7.1. The precise format and features included in the map is entirely up to the team.

12.9.7.2. As part of selecting the format and features to include in the map, teams should consider the purpose of mapping in planetary exploration, and potential downstream applications of the data.

12.10. **Activity 4:** Autonomous and mapping presentation (**25 points**)

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

12.10.1.1. The design and justifications thereof for the autonomous landmark navigation system, and the advantages and limitations of such a design. Up to **5 points** will be awarded for the quality of the answer.

12.10.1.2. The design and justifications thereof for the navigation component of exploratory mapping system, and the advantages and limitations of such a design. This should include a discussion of the choice of an autonomous/non-autonomous system, and the key considerations involved in this choice. Up to **5 points** will be awarded for the quality of the answer.

12.10.1.3. The details and visualisations of the map of the whole arena that teams have constructed in the previous two activities as per rule 12.9.7. Up to **5 points** will be awarded for the quality of the design and justifications for the format and features of the map. Up to a further **10 points** will be awarded for the quality of the map itself as expressed through visualisations included in the presentation, based on criteria including coverage, completeness, resolution, and accuracy.

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

12.10.3. 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 mapping with their rover.

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 & Method

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 (like this 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.

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

$$M_{water} = \frac{MC}{1 - MC} M_{regolith}, \tag{1.0}$$

where MC is the moisture content expressed as a fraction and $M_{regolith}$ 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 between 1.3 g cm^{-3} to 1.5 g cm^{-3}

B.3. For testing, the preparation of ilmenite-enriched regolith can be performed as per the following methods:

1. The mass of ilmenite ($FeTiO_3$) to add is determined by the formula

$$M_{FeTiO} = \frac{En}{1 - En} M_{regolith}, \tag{2.0}$$

where En is the degree of enrichment expressed as a fraction and $M_{regolith}$ is the regolith mass.

2. Combine the sand and ilmenite in a ziplock bag or container of your choosing, mix evenly for atleast 2 min to achieve homogeneity

3. To verify the ilmeneite content of the prepared simulants, once can utilize a Marcy pulp density scale to determine the specific gravity of the material, and then calculate the enrichment.

4. Pure Ilmenite sand (mesh size 30) will be used to prepare samples, and can be purchased here or here.

5. The target bulk density for frozen samples should be between 1.3 g cm^{-3} to 1.5 g cm^{-3}, with ilmenite enrichment of between 0 to 15 wt.%.

Processing

Icy regolith

B.4. Up to **50 points** are available for processing water from ice-cemented regolith and are awarded corresponding to a score which is function of the total mass and purity of water given to judges within a container, as per rule 10.5.3.3, and also in comparison to the total mass and purity of water processed by other teams.

B.4.1. **30 points** are awarded for collecting any mass of liquid H_2O, regardless of purity.

B.4.2. Only material that can be poured out of the container will be weighed.

B.4.3. Up to an additional **20 points** are awarded for collecting larger quantities processed material as a function of purity following the equation

$$\text{Points} = 20 \times \frac{M_{\text{YourTeam}} - M_{\text{Particulates}}}{M_{\text{BestTeam}}} \tag{3.0}$$

Where:

$$M_{\text{YourTeam}} = M_{\text{Beaker}} + M_{\text{Residual}} \tag{3.1}$$

$$M_{\text{Residual}} = FP_{\text{Wet}} - FP_{\text{Dry}} \tag{3.2}$$

$$M_{\text{Particulates}} = FP_{\text{Dry}} - FP_{\text{Clean}} \tag{3.3}$$

M_{Beaker} is the mass of water provided by your team, determined by pouring water from the provided container into a conical flask with qualitative Grade 1 filter paper, on a tared, high accuracy scale (0.01 g).
M_{residual} is the mass of residual water trapped in the filter paper during pouring, calculated as the difference in mass between the wet filter paper immediately after filtration (FP_{wet}) and the dry filter paper after all the water has evaporated (FP_{dry}).
$M_{\text{particulates}}$ is the mass of solid particulates, calculated by subtracting the mass of the clean, dry filter paper (FP_{clean}) from the mass of the dry filter paper after filtration (FP_{dry}).

Space Resources Presentation

B.5. **5 points** points are available for determining the mass (by weight %) of resource enrichment at each site, up to a total of **20 points** across the four sites.

B.5.1. Points will be awarded based on the accuracy of the team's estimate according to the following criteria:

B.5.1.1. If the team's estimate is within 0.50% of the true value, **5 points** will be awarded.

B.5.1.2. If the team's estimate is within 2.00% of the true value, **3 points** will be awarded.

B.5.1.3. If the team's estimate is within 5.00% of the true value, **2 points** will be awarded.

B.5.1.4. If the team's estimate is greater than 5.00% away from the true value **0 points** will be awarded.

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We acknowledge and pay our respects to the Kaurna people, the original custodians of the Adelaide Plains and the land on which the University of Adelaide's campuses at North Terrace, Waite, and Roseworthy are built. We acknowledge the deep feelings of attachment and relationship of the Kaurna people to country and we respect and value their past, present and ongoing connection to the land and cultural beliefs. The University continues to develop respectful and reciprocal relationships with all Indigenous peoples in Australia, and with other Indigenous peoples throughout the world.