

UK Lunabotics 2026



Rule Book

v 0.3

20th October 2025

Table of Contents

UK Lunabotics Robot and Facility Technical Specification and Requirements...	4
RoboPits.....	4
The RoboPits	4
RoboPits Check-in Procedures	4
Moon Yard Arena Specifications.....	5
Arena Composition and Dimensions.....	5
Moon Yard Arena Layout.....	7
Moon Yard Arena Protocol	8
ROBOTS AND ROBOTIC OPERATIONS	10
Robots.....	10
Robot Requirements.....	10
General.....	10
E-STOP Button	13
Power Meters/Data Loggers	14
Battery Protocol	15
Robotic Operations	16
SCORING, CONSTRUCTION, NAVIGATION, and AUTONOMY.....	17
Construction Points	17
Example Scoring Sheet.....	18
Construction Protocol.....	19
Navigation Protocol	21
Autonomy Rules and Operations	22
Autonomy Rules.....	22
Autonomous Operations	23

MISSION CONTROL CENTER	29
General Guidelines	29
Mission Setup	30
Mission Operations	31
Mission Anomalies	32
Mission Conclusion	32
UK Lunabotics Communications Operations	33
UK Lunabotics General Communication System Requirements.....	33
General Radio Frequency and Communications Approval (Comm Check)	34
RoboPits Comm Rules	35
Moon Yard Arena Comms Rules.....	35
Communications between Moon Yard Arena and Mission Control Center	35

UK Lunabotics Robot and Facility Technical Specification and Requirements

This is a draft issue of the UK Lunabotics Rule Book. It will be up-issued as preparation for the competition progresses.

RoboPits

The RoboPits

TBD – This section will give an overview of the Robot Pits where students will be able to setup and make repairs/modifications to their robot.

RoboPits Check-in Procedures

TBD – This will define the Procedures relative to the Robot Pits. (Check-In, PPE, Pit Specifications, etc.)

Moon Yard Arena Specifications

Arena Composition and Dimensions

1. The interior dimensions are approximately 7.9 m long × 4.4 m wide).2.The arena contains sand to a depth of approximately 21.5 cm in traversal and deposition areas and 51.5cm in excavation areas. **[Photo to be provided]**

2. Obstacle Zone

The obstacle zone is designed to test:

- a) Obstacle detection capabilities
- b) Mapping functions
- c) Navigation planning abilities

3. Obstacle Types

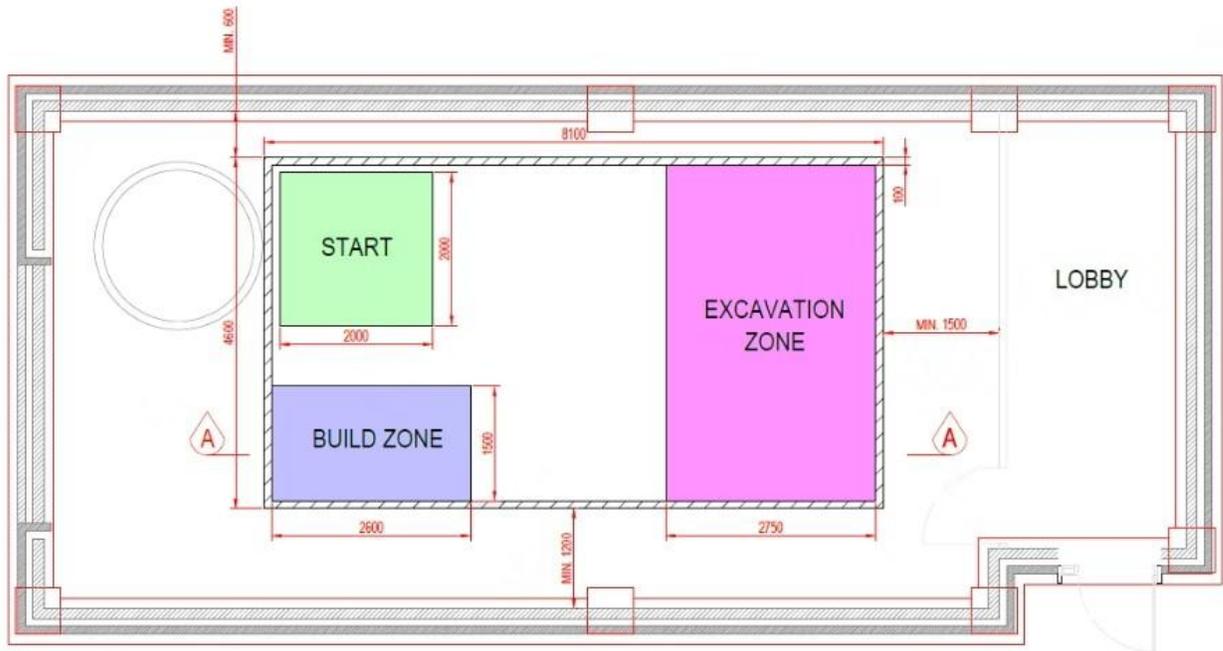
The Moon Yard may include a number of the following obstacles to tackle/navigate as teams see fit:

Boulder Obstacles:

- a) Placement: Randomly positioned before each competition round
- b) Size: Approximately 30-40 cm in diameter with varying heights
- c) Note: Boulders may also appear in the excavation zone but will not exceed the dimensions of those in the obstacle zone

Crater Obstacles:

- a) Dimensions: Varying depths and widths, not exceeding ~ 40-50 cm in either measurement.



MARS ROVER - WALL CONSTRUCTION
SCALE - NTS

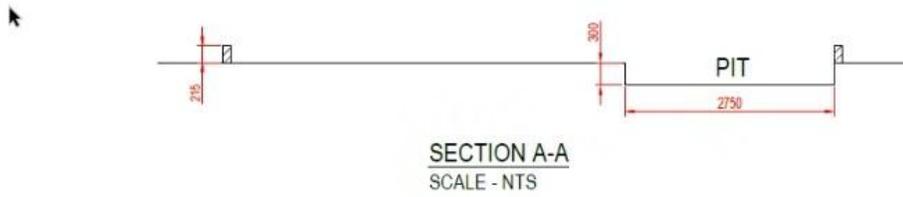


Figure 1 - Moon Yard dimensions and camera layout [Draft – to be updated]

Moon Yard Arena Layout

Mounting of Beacons for Navigation: The Yard will include a mounting point for teams to attach a navigation beacon. The mounting point will be on a single side of the yard, close to the start zone and facing the construction zone, emulating a lander craft module.

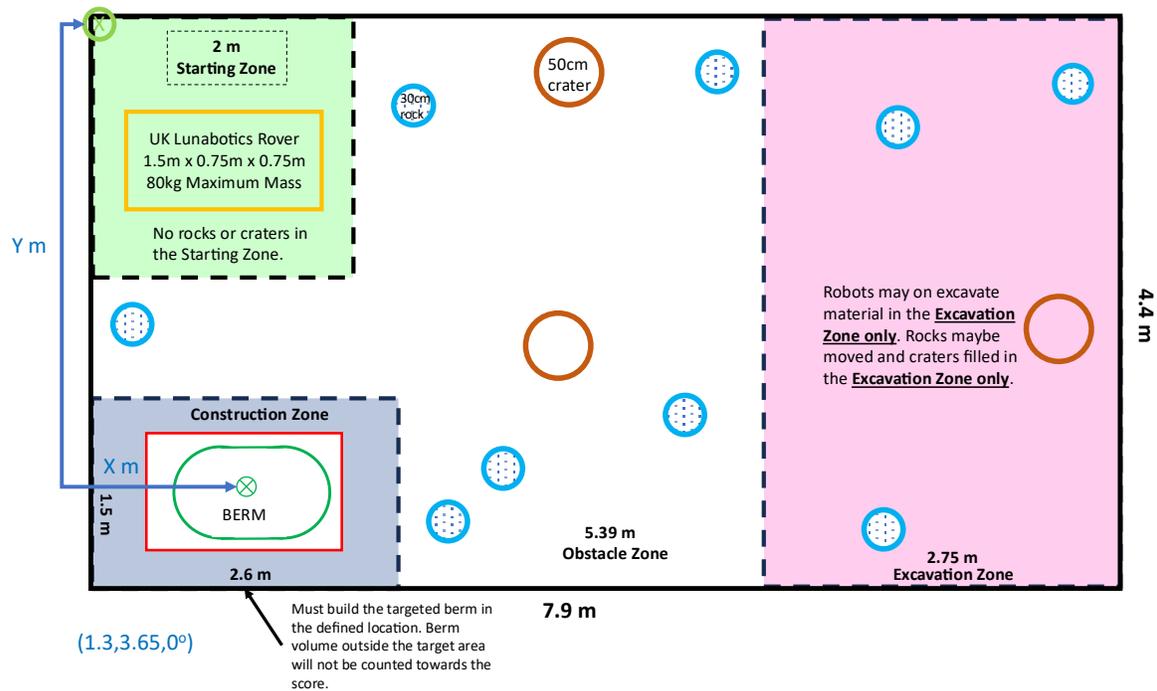


Figure 2 - Moon Yard Layout for competition [Draft - to be updated]

Moon Yard Arena Protocol

1. Once competition runs begin, the Moon Yard Arena is considered an operational area with restricted access.
2. Students shall follow the instructions of the Arena Chief and Arena personnel promptly.
3. Faculty / advisors are not permitted in the Arena during the competition.
4. Access is restricted to currently active competing team members only. If the team's robot is not in the arena or arena staging area, team members are not permitted in the Moon Yard Arena.
5. The Moon Yard Arena is defined as all areas within the Moon Yard building. The Arena staging area, Competition Arena, and Arena Chief's station are located within the Moon Yard Arena.
6. For Arena operations, the currently active competing team members are defined as the team members that are tasked with placing the robot in the arena during the setup period and removing the robot from the arena after the run has ended (max of 4 people) and the corresponding Mission Control team members (max of 4 people).
7. Photography and personal electronic devices (smart devices, tablets, cell phones, etc.) will be restricted in the Moon Yard Arena.
8. Team members placing the robot in the Competition Arena will don PPE in the RoboPits staging area. **[PPE Specifications TBD]**
9. When properly attired, they and Mission Control teammates will be escorted to the Moon Yard Arena entrance.
10. The Arena Chief will grant access to Moon Yard Arena staging area when ready.
11. Student cell phones, cameras, tablets, and other restricted electronics devices brought into the Moon Yard Arena shall be placed on the Arena Chief's station to be retrieved later. No exceptions.
12. Team members will be given a Pre-Task Briefing (PTB) containing specific information needed for the run.

13. At the end of the PTB, the Mission Control team members will immediately exit the Arena staging area and proceed directly to the Mission Control staging area.
14. Team members shall remain with their robot in the designated Arena staging area until directed otherwise by the Arena Chief or designated representative.
15. Approaching the Competition Arena before instructed to do so by the Arena Chief or designated representative is not permitted.
16. The Arena Chief will inform the team members in the staging area when the Competition Arena is ready for the team.
17. At the direction of the Arena personnel, the team members will place their robot in the Arena and perform setup activities necessary to establish communication with Mission Control. The construction robot will be placed in the arena in a randomly selected starting position and direction within the Starting Zone.
18. When complete or directed by Arena personnel, the team members will promptly exit the Arena.
19. Only the team members in setup and removal may observe the competition run from a designated area in the Arena. The team members must remain in the designated area for the duration of the run.
20. When the competition run has ended, the team members shall promptly retrieve their robot and equipment from the Arena and proceed to the clean up station.
21. At the cleanup station, team members shall:
 - a. Vacuum excess sand from their robot.
 - b. Doffing Protocol in the Moon Yard Arena After completion of the Robot Run
22. Remember, the Moon Yard Arena is an operational area during competition days. There are many activities occurring in series and in parallel. It is very important that everyone in the Arena practice situational awareness at all times.

ROBOTS AND ROBOTIC OPERATIONS

Robots

Lunar bulk regolith construction requires teams to consider several design and operation factors such as high robot dust tolerance and minimizing dust projection, efficient communications, minimizing vehicle mass, minimizing energy/power required, and maximizing autonomy. Each team will have the opportunity to complete two construction competition runs to demonstrate their design.

Students on the team shall perform 100% of this project (including design, construction, and operations task components of their vehicle and deliverables, and including performing or supervising work that is supported by a professional machinist for the purpose of training or safety. Students may provide their designs to external fabricators for components where required e.g. Laser cutting, 3D printing, CNC machining, PCB fabrication or similar). Components (i.e. electronic, mechanical, etc.) are not required to be space qualified for atmospheric, electromagnetic, thermal, or Lunar environments.

Robot Requirements

General

Components (i.e. electronic, mechanical, etc.) are not required to be space qualified for atmospheric, electromagnetic, thermal, or off-world environments. Bulk regolith construction requires teams to consider several design and operation factors such as high robot dust tolerance and minimizing dust projection, efficient communications, minimizing vehicle mass, minimizing energy/power required and maximizing autonomy.

1. The robot(s) shall be contained within a payload envelope measuring 150 cm length x 75 cm width x 75 cm height. The orientation of these dimensions may be chosen by the team.

2. The robot may deploy or expand beyond the envelop after the start of each attempt but shall not exceed 175 cm in additional height (which is 250 cm above the surface of the regolith).
3. Multiple robot systems are allowed but the starting dimensions of the whole system (all the robots) shall comply with the volumetric dimensions given in this rule.
4. Robots will be inspected for the volumetric dimensions in the stowed configuration during the safety Inspection. No modifications or team robot interaction is permitted during this verification.
5. The robot shall have a maximum mass of 80 kg. Subsystems/equipment on the robot that are used to transmit commands / data and video to the telerobotic operators are counted toward the mass limit.
6. The mass of the navigational aid system, including any beacons or targets not attached to the robot, is included in the maximum mining robot mass limit of and must be self-powered.
7. Equipment not on the robot used to receive data from and send commands to the robot for telerobotic operations is excluded from the mass limit.
8. Multiple robot systems are allowed but the total mass of the whole system shall comply with the mass given in this rule. Lower masses will result in lower mission costs so this competition rewards teams that have a lower robot mass.
9. The launch volume dimensions of the robot may be oriented in any way (length, width, height can be defined along any of the X, Y and Z-axis. Dimensions correspond to the typical payload volume available on today's Lunar landers.
10. The team must declare the robot orientation to the inspection judge by:

Arrow 1 – length, Arrow 2 – width and Arrow 3 – marking the forward direction of the robot in the starting position. (the reference location and arrow pointing forward can point any direction of the team's choosing, except up or down. The arrow is used only to orientate the robot prior to starting the robot run to face the robot arrow either north, east, south, or west after spinning the direction wheel).

11. The judges will use Arrow 3 to orient the robot in the randomly selected direction and position (permanent-type markers can be used) indicating the team's choice of forward direction on any location on the robot is acceptable if multiple arrows do not conflict.
12. Teams may use honeycomb structures as long as they are strong enough to be safe and the edges sealed to prevent regolith intrusion, a wheel with a large honeycomb structure that is open on both sides is allowed as long as the edges are not so sharp that they would be a cutting hazard.
13. Teams may not use global positioning systems (GPS), rubber pneumatic tires; air/foam filled tires; open or closed cell foam, ultrasonic proximity sensors; or hydraulics because use of these on an off-world mission is not viable. This will not pass inspection.
14. Robots shall have a minimum of four (4) designated lifting points, safe for human hands and clearly marked for students and staff to use. Teams are responsible for placement and removal of their construction robot onto the sand surface. There must be one person per 20 kg of mass of the construction robot, requiring a minimum of four people to carry the maximum allowed mass of 80 kg.
15. The robot can separate itself intentionally, if desired, but all parts of the robot must be under the team's control at all times. Unintentional breakage will not be counted against the team. The robot does not have to re-assemble prior to the end of the competition run.
16. The robot can run either by telerobotic (remote control) or in autonomous operations.
17. External robot antennas are recommended to reduce potential interference problems.
18. The robot cannot have any touch sensors to sense and avoid obstacles.
19. Pneumatic systems are permitted, provided they are fully self-contained (i.e., all gases are supplied by and stored on the robot). The intent is to demonstrate off-world plausible functionality, though components do not need to be space-qualified.
20. Examples of allowable components include: Lithium-Ion (Li-ion), Nickel-

Cadmium (Ni-Cad), Sealed Lead-Acid (SLA), or Nickel Metal Hydride (NiMH) batteries; composite materials; rubber or plastic parts; actively fan-cooled electronics; motors with brushes; and various sensors (e.g., infrared, IMUs, proximity, Hall Effect).

E-STOP Button

1. The robot shall be equipped with an E-STOP button. An unmodified “Commercial Off-The-Shelf” (COTS) red button is required. Failure to do so will result in a safety disqualification. The E-STOP button shall have a minimum diameter of 40 mm and require no additional steps to access it.
2. The E-STOP button shall be placed on the highest practical location on the robot. There shall be only one E-STOP button per robot and in the case of multiple robots, each robot shall have its own E-STOP button.
3. Disabling the E-STOP button without authorization from the Staff shall result in a safety disqualification.
4. Only onboard laptop computers may stay powered on if powered by its own, independent, internal computer battery. For example: it is acceptable to have a small battery onboard that only powers a Raspberry Pi control computer, and whose power does not flow through the main robot E-STOP button.
5. The Provision and Use of Work Equipment Regulations 1998 (PUWER) requires that machinery has a clear and easily identifiable means to be stopped in a safe manner. Supporting standards, such as BS EN ISO 13850 (Safety of machinery - Emergency stop function) and BS EN 60204-1 (Safety of machinery - Electrical equipment), state that an emergency stop must be clearly visible, identifiable, and readily accessible to the operator. It must be unobstructed and located so it can be actuated without the operator having to reach over, under, or around any part of the machine.
6. UK regulations, including the Supply of Machinery (Safety) Regulations 2008 and BS EN ISO 13850, state that resetting the emergency stop shall not by itself resume operation. The reset action (e.g., twisting or pulling the mushroom button) shall only permit the machine to be restarted by a separate, deliberate start command (such as pressing a 'start' or 'reset' button). The e-stop must latch in

the "stop" position until it is intentionally reset and cannot reset itself automatically.

7. The E-STOP button shall stop the construction robot's motion and disable power with one push motion on the button. It shall be reliable and instantaneous. A closed control signal to a mechanical relay is allowed as long as it stays open to disable the robot. This rule exists in order to have the capability to safe the construction robot in the event of a fire or other mishap. The button shall disconnect the batteries from all controllers (high current, forklift type button) and it shall isolate the batteries from the rest of the active sub-systems as well.

Power Meters/Data Loggers

1. Power Meters / Data Loggers - devices shall be placed on the highest practical location on the robot and be easily visible.
2. The robot shall provide its own onboard power. No facility power will be provided to the robot during the attempt. There are no power limitations except that the robot must be self-powered and included in the maximum mass limit. The power meter shall be schematically located between the battery and kill switch, so the readings are not erased if the E-STOP button is activated. A 30 point reduction to **Berm Construction Productivity – Normalized for Energy (BCP Energy)** will be accessed if the robot is not wired in accordance with this requirement. This will be checked at Inspection. Also, if a robot is not wired in accordance teams run the risk of scoring zero if the E-STOP must be triggered.
3. The energy consumed shall be recorded with a "Commercial Off-The-Shelf" (COTS) electronic data logger device. Actual energy consumed during each attempt shall be shown to the judges on the data logger immediately after the attempt ('immediate' includes time for the judge climbing into the arena, finding the logger, and recording the power reading). If the logger is independently powered, then the robot can be remotely powered off after the run. Although this is acceptable, it is not recommended in case the robot needs to be commanded to complete an operation so that it can be removed from the arena.
4. An example is the PZEM-051 DC Digital Ammeter Voltmeter. [Amazon link.](#)

5. If a laptop is used on-board the rover, the power usage during an attempt must be able to be measured through logs from a hardware monitor program for example HWINFO. [Link](#).

Battery Protocol

1. Batteries used in robots must be attended while charging. Chargers shall be unplugged overnight.
2. Battery containers must be designed for safely storing, charging, and transporting lithium-ion batteries, or approved equivalent.
3. Batteries must be stored in upright containers; batteries cannot be in contact with each other.
4. Batteries that have been dropped must be inspected for damage and replaced as needed.
5. Do not store batteries that are hot to the touch after charging.
6. If a battery continues to feel hot after charging, if possible, remove from the building and place outside and notify a member of event staff as a non-emergency issue.
7. In the event of a fire, smoke, or if you believe there is an immediate and serious danger, activate the nearest fire alarm and call 999 (or 112) from a safe location. You will not be faulted for acting on the side of caution.
8. To ensure the robot is usable for an actual mission, it cannot employ any fundamental physical processes, gases, fluids, or consumables that would not work in an off-world environment. For example, any dust removal from a lens or sensor must employ a physical process that would be suitable for the Lunar surface.
9. Teams may use processes that require an Earth-like environment (e.g., oxygen, water) only if the system using the processes is designed to work in a Lunar environment and if such resources used by the robot are included in the mass of the robot.

Robotic Operations

1. The robot cannot be anchored to the sand prior to the beginning of the demonstration.
2. At the start of the competition run, the mining robot may not occupy any location outside the defined starting position in the Moon Yard Arena.
3. The robot must operate within the Moon Yard Arena; it is not permitted to pass beyond the confines of the outside perimeter of the arena or hit the walls during the competition run or a point penalty **[TBD]** will be incurred.
4. The robot may not use any process that causes the physical or chemical properties of the sand to be changed or otherwise endangers the uniformity between competition attempts. The mining robot may not penetrate the sand surface with more force than the weight of the mining robot.
5. No ordnance, projectile, far-reaching mechanism, etc. may be used. The mining robot must move on the sand surface.
6. Far-reaching mechanism in this context does not include any deployed or extended component as allowed in the dimensions rule above, those will not violate this rule.
7. Beacons or fiducial targets may be attached to the designated arena frame area for navigation purposes only. The frame is mounted to the wall on one side of the starting area – facing the construction zone. Tape, clamps, or rods pushed into the sand may be used, but screws or other fasteners requiring holes may not be used. This navigational aid system must be attached during the setup time and removed afterwards during the removal time. **[Details TBD]**
8. The beacon may send a signal or light beam or use a laser-based detection system which have not been modified (optics or power). Only Class I or Class II laser or low powered lasers (< 5mW) are allowed. Supporting documentation from the laser instrumentation vendor must be provided to the responsible faculty member for “eye-safe” lasers.

SCORING, CONSTRUCTION, NAVIGATION, and AUTONOMY

The mission of this robot system is to provide a berm that protects astronauts and habitat modules from plume ejecta from vehicles lifting off and landing on the opposite side of the berm to be constructed. For this competition, plume ejecta is presumed to move perpendicular to the surface and parallel to the short axis of the berm area. Both mass (or volume) of the berm and the projected area of the berm normal to the plume ejecta provide this protection.

The berm construction and bandwidth scores from each run will be added together for the final score at each venue (final score will be cumulative, not the highest of the two attempts, not an average of the two attempts).

The Caterpillar Autonomy Award will be based on the sum of autonomy scores from both runs.

Construction Points

1. **Pass All Inspections (Comm/Vehicle)** - each team is required to perform a mechanical inspection and communications check prior to the first competition run. This should be performed as early as possible after check-in to ensure compliance to all rules and communication functionality. Neither is optional, if one cannot pass, the robot will not be permitted in the Arena.
2. **Construction Berm Productivity – Normalized for Robot Mass (BP Mass)** – A volumetric scan before and after the run will be performed. Only berm volumes located within the designated target area will be counted. The target area has perimeter dimensions of approximately 1.5 M x 0.9 M. There is no restriction on the shape, height, or number of berms constructed.
3. **Construction Berm Productivity – Normalized for Energy (BP Energy)** - A volumetric scan before and after the run will be performed. Only berm volumes located within the designated target area will be counted. The electrical energy consumed must be displayed by an (commercial off the shelf or “COTS”) electronic data logger and verified by a judge.
4. **Bandwidth Use** - During each competition attempt, the team will be scored on arena camera usage. An example is as follows: 0 cameras = 120, 1 camera = 60, 2 cameras = 0 points. **[precise scoring TBD]**

Example Scoring Sheet

Example actuals based on an experienced US-team 20-minute run at UK Lunabotics

Construction Category Elements	Units	Specific Points	Example Actuals	Example Points
1. Pass All Inspections (Comm/Vehicle).	NA	NA	NA	Allowed to Run
2. Berm Construction Productivity – Normalized for Robot Mass (BCP Mass)	cm ³ berm / min / kg robot mass	4.4	77551 cm ³ / 15 min run / 66 kg 78.33	344.6
3. Berm Construction Productivity – Normalized for Energy (BCP Energy)	cm ³ berm / min / Wh	1.5	77551 cm ³ / 15 min run / 36 Wh 143.6	215.4
4. Bandwidth Use	# cameras	120, 60, 0	1	60
7. Autonomy	task	50, 75, 125, 250, 300, 375, 450, or 600	75.00	75
8. Total Points				695

Construction Protocol

1. The robot will be inspected before each competition attempt. No robot modifications can be made between inspection and competition run. Teams will be permitted to repair or otherwise modify their robots while the RoboPits are open.
2. Teams are responsible for the placement and removal of their robot onto the arena surface. There shall be one person per 20 kg of mass of the robot, requiring a minimum of four people to carry the maximum allowed mass of 80 kg. Assistance will be provided if needed.
3. Each team is allowed **up to** 10 minutes to place the construction robot in its designated starting position within the arena and perform required setups from MCC, and 5 minutes to remove the robot after the attempt has ended as directed by the Construction Judges.
4. The robot's starting direction and location will be randomly selected immediately before the competition attempt.
5. At the start of each competition attempt, the robot shall not occupy any location outside the defined starting position in the arena.
6. The robot shall move from the starting area, across the obstacle zone, and into the excavation zone. The robot shall not acquire sand for the berm from inside the starting area, obstacle zone, or construction zone. All sands for berm construction must be acquired from the excavation zone.
7. The robot shall not push or move any obstacles in the obstacle zone.
8. The obstacles may only be pushed to the side of the arena in the construction zone.
9. The robot shall avoid the craters in the obstacle zone (it shall not fill in any craters).
10. The robot may start excavation operations as soon as any part of it crosses into the excavation zone.
11. The robot may start construction operations as soon as any part of it crosses into the construction zone.

12. The robot shall operate within the arena; no part of it is permitted to pass beyond the confines of the outside wall of the arena during each competition attempt.
13. The robot can separate itself intentionally if desired, but all parts of the construction robot must be under the team's control at all times. The robot does not have to re-assemble prior to the end of the competition run.
14. The robot **shall not**:
 - be anchored to the arena surface prior to the beginning of each competition attempt.
 - ram the wall (may result in a safety disqualification for that attempt).
 - use any aspect of the arena (wall, structure, column, etc.) in attempting any operations.
 - use any process that causes the physical or chemical properties of the sand to be changed or otherwise compromises the uniformity between attempts.
15. Obstacles may not be moved into the excavation zone.
16. Obstacles that are moved from the excavation zone into the target area will count towards these dimensions.
17. The robot shall end operations immediately when the power-off command is sent and/or as instructed by the Construction Judge. After the official competition run ends, the regolith judge will determine if the robot needs to move prior to being removed. The judge will instruct the team members when they can enter to remove the robot after ensuring that the lidar scan of the berm has been completed.

Navigation Protocol

1. The team must declare the robot orientation by length and width to the inspection judge. An arrow on the reference point (the reference location and arrow pointing forward can be any point and direction of the team's choosing, except up) must mark the forward direction of the construction robot in the starting position configuration. The judges will use this reference point and arrow to orient the construction robot in the randomly selected direction and position (you can use a permanent-type marker), indicating the team's choice of forward direction on any location on the robot is acceptable as long as multiple arrows do not conflict. The arrow does not have to indicate the robot's preferred forward direction. The arrow is used only to orientate the robot prior to starting the robot run to face the robot arrow either north, east, south, or west after spinning the direction wheel).
2. Compasses (analog, digital, etc.) are not allowed on the robot.
3. Global Positioning Satellite (GPS) or IMU-enabled GPS devices are not allowed. Teams must explain to the judges how the device will be switched off or the data will be subtracted and ensure the internal calculations do not make use of the GPS or IMU-enabled GPS device.
4. The mass of the navigational aid system is included in the maximum construction robot mass limit of 80.0 kg and must be self-powered.
5. Target Beacons – beacons may be attached to the provided mounting system in the starting area. The beacons may be mounted on rods pushed into the regolith at the starting area for anchoring.
6. The target/beacon may be a passive fiducial, or it may send a signal or light beam or use a laser-based detection system which has not been modified (optics or power). Only Class I or Class II lasers or low-powered lasers (< 5mW) are allowed. Supporting documentation from the laser instrumentation vendor must be provided to the inspection judges for "eye-safe" lasers.
7. Inertial measurement units (IMU) are allowed on the construction robot. Teams have to explain to the judges how the compass feature will be switched off, or the compass data is subtracted to ensure the internal calculations do not make use of the compass (from any magnetic field surrounding the robot).

8. During each competition attempt, the construction robot is limited to autonomous and telerobotic operations only.

Autonomy Rules and Operations

Autonomy Rules

1. Telemetry to monitor the health of the construction robot is allowed during the autonomous period. Teams will need to remain “hands free” of any controls during any attempts at autonomy points but may interact passively with monitoring systems provided no commands are sent to the rover. Teams shall explain to the inspection/attending judge before each competition run how they are interacting with the telemetry system, and the judge will observe to ensure compliance with all competition rules.
2. Teams shall not touch the controls during the autonomous period. Orientation data cannot be transmitted to the construction robot in the autonomous period. See complete details in the Mission Control Center (MCC) and Autonomous Operations.
3. The walls shall not be used for the purposes of mapping autonomous navigation and collision avoidance (there are no walls on off-world locations). Touching or having a switch sensor spring wire that may brush on a wall or any other surface as a collision avoidance sensor is not allowed (this includes touch sensors). Teams shall not use the walls of the construction arena for sensing by the robot to achieve autonomy.
4. The team must explain to the inspection judges how their autonomous systems work and prove that the autonomy sensors do not use the walls. Integrity is expected of all team members and their faculty advisors.
5. Teams are allowed to interact with an interface that allows different pieces of telemetry data to be viewed as long as there is no real-time or other interaction to control or influence the robot.
6. Teams are not permitted to update or alter the autonomy program to account/detect or upload information about obstacle locations.
7. Failure to divulge the method of autonomy sensing shall result in disqualification from the competition.

Autonomous Operations

During each competition attempt, the team will earn up to 600 Construction points for autonomous operation. As MCJs are not intimately familiar with each robot's concept of operations (ConOps) procedures, it is the sole responsibility of the team members in the control room to coordinate with and inform the MCJ of each attempt for autonomy points to make sure their autonomous attempts are recognized and therefore scored correctly. The Caterpillar Autonomy Award will be based on the sum of autonomy scores from both. A tie in autonomy points relative to the Caterpillar Autonomy Award will be broken based on the total berm construction points.

General Rules:

- For clarity, hands-free means that all team members in mission control must be hands-free and not engage any components (e.g. laptops, game controllers, etc.). The team may control the arena camera/s during this time.
- Teams must announce the start and competition of every autonomy point attempt.
- If your autonomy attempt has failed, you must announce your failure before you begin manual control.

Construction points will be awarded for successfully completing the following activities autonomously:

1. Excavation Automation: 75 pts

- a) Teams may excavate material anywhere in the Excavation Zone.
- b) Within the Excavation zone, the team must indicate to the MCJ that they are going hands-free for the excavation attempt.
- c) The robot must execute machine control commands itself during the excavation task.
- d) The robot must demonstrate the ability to excavate and collect sand for transport. A discernable amount of sand must be collected for transport as determined by the MCJ. The MCJ may engage the arena judges for confirmation if camera angle/performance does not allow confirmation in Mission Control. Collection can be in an internal hopper, a bucket, a blade, a bucket drum, etc –

based on the robot design. Hands-free operation must begin before the robot engages the sand to begin the excavation process.

- e) Excavation mechanisms must be completely removed from contact with the sand before returning to remote control operation.
- f) Once excavation is complete the team must indicate they are going to remote control before taking control of their robot.
- g) This level of automation will require teams to master the lower-level machine control of their robot platform associated with excavation. It is noted that NASA Lunabotics teams have proven this capability to be helpful in achieving better excavation results, as the coordination of human commands for the robot for excavation can be difficult to master.

2. Dump Automation - Full Run: 50 pts

- a) Teams are allowed to traverse the Obstacle Zone via remote control.
- b) Prior to crossing into the Construction zone, they must indicate to the MCJ that they are going hands-free for the dump attempt.
- c) The robot must execute machine control commands itself during the dump task.
- d) The robot must place the regolith at the berm construction location. A discernable amount of regolith must be placed at the berm location as determined by the MCJ. The MCJ may engage the arena judges for confirmation if camera angle/performance does not allow confirmation in Mission Control.
- e) Once dumping is complete the team must indicate they are going to remote control before taking control of their robot.
- f) This level of automation will require teams to master the lower-level machine control of their robot platform associated with dumping. In addition, teams will need to master localization in the construction zone as well as path planning to align and place regolith at the designated berm construction location.

3. Travel Automation: 250 pts

- a) Teams may begin in remote control and move the robot within the starting zone only to localize. The teams must indicate to the MCJ that they are going into hands-free mode while still in the starting zone. The robot must remain in hands-free mode while crossing the obstacle field and crossing into the excavation zone. This level of automation will require the team to master the following:
- b) Localization across the entire competition arena

- c) Object detection and location relative to the robot
- d) Navigational planning based on location and obstacles/traversable area
- e) The competition judges will attempt to construct the obstacle field in such a way as to require obstacle detection, mapping, and navigation planning to determine a “slalom” route to reach the construction zone. The teams shall not architect a “Point and traverse” approach for this automation step.
- f) If the robot contacts a rock or drives across a crater in the obstacle zone, as determined by the MCJ/Arena judges, a 30-point reduction will be applied. This is a one-time penalty.
- g) For maximum points, the attempt must be made at the start of the run on the first time leaving the starting zone. To discourage the approach of “breadcrumbs”, a penalty of 50 points will be applied to any attempt that occurs after traversing the obstacle zone in remote control. An attempt after traversing the obstacle zone would require returning to the starting zone before going hands free. If multiple attempts are made, this penalty will only be assessed one time to the successful attempt.

Example: Robot crosses the obstacle course in remote control before the attempt, hits an obstacle, and drives across a crater during the attempt. 250 points - 50 - 30 = 170 points.

4. Full Autonomy (One Cycle): 450 pts

- a) The robot must be in hands free control for one entire cycle.
- b) Attempt must be made at the beginning of the competition run.
- c) Teams may begin in remote control and move the robot within the starting zone only to localize. Teams must begin with hands free control from the starting area and remain in hands free mode while crossing the obstacle field , excavating, , returning across the obstacle field, crossing into the construction zone, and dumping the sand for the berm. Once successfully completing the dump the team may return to remote control. A discernable amount of regolith must be placed at the berm location as determined by the MCJ.
- d) If the robot comes in contact with a rock or drives across a crater, as determined by the MCJ/Arena judges, a 30-point reduction for each occurrence will be

applied up to a maximum of 90 points. This is only true in the obstacle zone. The robot is allowed to move rocks and fill in craters in the excavation zone.

- e) This level requires mastery of all aspects of autonomy associated with this competition.

Example: Robot crossing the obstacle zone hits a rock traveling to construction zone and drives across a crater returning to the excavation zone during the attempt. 450 - 30 - 30 = 390 points.

5. Full Autonomy: 600 pts

- a) The attempt must be made from the beginning of the competition run..
- b) The robot must be in hands free control for the entire competition run.
- c) Teams may begin in remote control and move the robot within the starting zone only to localize. Teams must begin with hands free control from the starting area and remain in hands free mode for the entire competition run. At least two cycles of traversing the obstacle field, excavating, crossing the obstacle field, crossing into the construction zone, and dumping the regolith for the berm must be completed during the competition run. Berm construction points, as determined by the volumetric scan, must be achieved for this level of autonomy.
- d) If the robot comes in contact with a rock or drives across a crater, as determined by the MCJ/Arena judges, a 30-point reduction for each occurrence will be applied up to a maximum of 90 points. This is only true in the obstacle zone. The robot is allowed to move rocks and fill in craters in the excavation zone.
- e) This level requires mastery of all aspects of autonomy associated with this competition and demonstrates a level of robustness to complete at least two full cycles. System robustness is essential for terrestrial and extra-terrestrial construction.

Example: Robot crossing the obstacle zone hits a rock traveling to construction zone in cycle 1, drives across a crater returning to the excavation

zone in cycle 2, and hits a rock returning to the excavation zone in cycle 3 during the attempt: $600 - 30 - 30 - 30 = 510$ points

Allowable Combinations	Excavation	Dump	Travel	Full Autonomy (One Cycle)	Full Autonomy	Total
Ex: 1	75	-	-	-	-	75
Ex: 2	-	50	-	-	-	50
Ex: 3	-	-	250	-	-	250
Ex: 4	75	50	-	-	-	125
Ex: 5	-	50	250	-	-	300
Ex: 6	75	50	250	-	-	375
Ex: 7	-	-	-	450	-	450
Ex: 8	-	-	-	-	600	600

Table 2. Possible scoring combinations for autonomy (without relevant penalties applied)

Any successful completion of the Excavation, Dump, and Travel attempts will be combined for scoring. These could occur over separate passes within the run. Excavation, Dump, Travel automation points will not be combined with Full Autonomy (one Cycle) or Full Autonomy.

MISSION CONTROL CENTER

Mission Control Center (MCC):

Teams will control or autonomously operate their robots from the Mission Control Center (MCC) to simulate operations of a Lunar In-Situ Resource Utilization (ISRU) construction mission. UK Lunabotics Mission Control Judges (MCJs) will supervise team activities in the MCC and assess their performance during each competition run. A Mission Control Director (MCD) will serve as the Lead Judge for the MCC to maintain the integrity of MCC rules outlined in the UK Lunabotics guidebook and ensure consistent interpretation and enforcement for all teams.

General Guidelines

1. Each team will be allowed a maximum of 4 team members in the MCC. All members must enter the MCC together when authorized by the MCJ.
2. Faculty/Advisors are not permitted in the MCC at any time.
3. Teams are responsible for ensuring they enter the MCC with all mission-critical components and spares they require that are not explicitly identified in the rules and rubrics as provided by UK Lunabotics. Once in the MCC, team members will not be permitted to retrieve forgotten items.
4. Teams may only bring electronic devices required for robot operations into the MCC. Extraneous laptops, cell phones, smart devices, etc., are prohibited.
5. Teams that have entered the MCC are not allowed any external communications until the completion of their run. The one exception is communication with their Moon Yard Arena teammates during the setup period, which is only permitted using equipment provided by UK Lunabotics.
6. Teams must resolve all questions and rule clarifications pertinent to a competition run before entering the MCC for that run. The competition schedule will not be delayed accommodating last-minute requests of this nature.
7. MCJs are observers only and are not allowed to provide “help” during robot operations. Mid-run questions, such as whether the robot is in an acceptable position or if certain points have been attained, will not be answered.

8. The Mission Control and Arena judges have the authority to terminate a setup period or competition run at any time if the team is not using them in accordance with the rules and rubrics.
9. Teams are expected to conduct themselves in a professional manner as if executing a NASA Lunar operation.
10. Teams are expected to use sound engineering practices and principles to operate their robot.
11. Team members must comply with all directions from the MCJ.
12. Disputes with MCJ direction or decisions must be elevated through the MCD.
13. Violation of the intent of a rule is a violation of the rule itself. A team found in violation of the rules and rubrics, exhibiting unprofessional behavior or unsportsmanlike conduct, or not following the directions of the UK Lunabotics staff may be assessed penalty points, may be disqualified from a competition run, or disqualified from the entire UK Lunabotics Challenge.

Mission Setup

1. Teams may not connect or interact with any equipment in the MCC until the setup period begins.
2. The setup period is for placing the robot in the Moon Yard Arena and bringing it online for the competition run. Teams are allowed up to 10 minutes to connect their laptops and routers, establish communications with their robot, and perform any initial systems checkout required. Teams must indicate competition readiness to the MCJ as soon as their robot is ready.
3. During the setup period, the MCJ will provide the team with a handheld radio to enable communications with team members in the Moon Yard Arena. Teams must return this radio to the MCJ at the end of the setup period and may not be used during the competition run.
4. Arena team members are prohibited from pointing out obstacles, craters, and other arena conditions to the MCC team members.
5. Teams may use the situational awareness cameras during the setup period without penalty.

Mission Operations

1. Teams are allowed 20 minutes per competition run under nominal conditions.
2. Telerobotic operators will have access to two **[TBC]** situational awareness cameras in the Moon Yard Arena via monitors provided in the MCC. The use of these cameras during the run will factor into the team's construction score. The MCC monitors provided for situational awareness may not be utilized by the team for any other purpose.
3. Telerobotic operators are only allowed to use data and video originating from the robot and the competition video monitors.

It is the sole responsibility of team members in the MCC to communicate effectively with the MCJ to ensure every autonomy attempt is recognized and scored correctly. If the judge is not notified of the attempt in advance of the team initiating its execution, the score will be zero points. Teams are expected to:

- Clearly announce and make eye contact with the MCJ when they are going to autonomous operations.
- Clearly announce when autonomy has begun and has been completed each time they trigger an autonomy cycle.

All autonomy attempts must be "Hands-Free", meaning no team members are permitted to touch any components (e.g., laptops, game controllers) brought into the MCC until the team has declared autonomy completion or autonomy failure.

- If a team member interacts with any equipment while the robot is still moving or before the team has declared the autonomy attempt complete, the team will receive zero points for the attempt.
- In the event of an autonomy failure, the team shall announce that the attempt has failed before resuming manual control.
- Manipulation of the situational awareness cameras, if in use, is permitted during autonomy attempts.

Mission Anomalies

1. Once the competition timer has started, the robot has 5 minutes to move on the mission. If the robot has not moved by the 5-minute mark, the robot is considered inoperable, and the run will end.
2. As responsible engineers, the team should notify the MCJ that they are ending the run if their robot experiences an unrecoverable issue that renders it incapable of executing key mission tasks. Such failures include:
 - Loss of Comms: The robot is functional but can no longer communicate properly with the MCC.
 - Loss of Locomotion: The robot ceases movement or experiences infrequent, non-continuous movements for a period of 5 minutes.
 - Loss of Excavation: The robot can no longer acquire regolith per its design.
 - Loss of Deposition: The robot can no longer offload regolith per its design.
 - Loss of Robot: The robot is fully unable to execute the mission. This scenario could be due to technical issues or unfavorable interactions with the competition arena.
3. In the event a robot experiences a mission-ending anomaly and the team does not voluntarily end the run within a reasonable amount of time, Mission Control and Moon Yard Arena judges have the authority to terminate the attempt. "Reasonable" is at the judge's discretion based on the specific circumstances of the run. Teams "joyriding" or otherwise wasting competition time may be assessed penalty points.
4. It is the team's responsibility to ensure they are executing corrective actions efficiently and communicating properly with the MCJ about long cycle steps, such as full system resets, that will make the robot appear further inoperable. Failure to do so could result in the termination of the run.

Mission Conclusion

1. Teams must cease operations when the competition timer ends. If the robot is in the middle of an autonomous activity, teams must send a command to inhibit their robot from taking any further actions. Regolith offloading is permitted to be completed only if the robot was actively dumping material prior to the expiration of the competition timer.
2. Teams may not disconnect communications with their robot or begin dismantling their MCC equipment until directed to do so by the MCJ. Sustained

operability is necessary in the event the robot must relocate or unload regolith prior to its removal from the Moon Yard Arena.

3. Teams should remain in the MCC until dismissed by the MCJ.
4. Teams are responsible for ensuring they leave the MCC with all equipment they brought into it. Once the next team has entered the MCC, forgotten items cannot be retrieved until that team's run is complete.

UK Lunabotics Communications Operations

UK Lunabotics General Communication System Requirements

1. You must use a standard (IEEE 802.11) dual-band router that supports both 2.4 GHz and 5 GHz. You must be able to turn off the 2.4 GHz band.
2. Each team will be assigned an SSID upon checking in for the competition that must be used for their wireless equipment.
3. You **MUST** broadcast this SSID. Hidden networks are not allowed.
4. You **MUST** use wireless encryption (e.g., WPA2/WPA3).
5. Wireless encryption is required.
6. You may **ONLY** transmit on your assigned SSID.
7. To prevent interference, you **MUST** set your 2.4 GHz channel bandwidth to **20 MHz** (no "channel bonding").
8. All wireless kit must comply with **Ofcom** regulations for legal power limits. All standard, unmodified equipment already meets this.
9. You are **NOT** allowed to add any power amplifiers to your wireless system. This is illegal and will get you disqualified.
10. 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.
11. The use of 2.4 GHz Zigbee/IEEE 802.15.4 technology is prohibited because of the possibility of interference with the competition wireless transmissions.
12. Technology that uses other ISM non-licensed radio frequencies outside of the 2.4 GHz band, such as 900 MHz or 5 GHz frequency bands, are allowed for robot or sensor systems, but these frequencies will not be monitored during the

competition. Interference avoidance will be the responsibility of the team and will not be grounds for protest by any team.

13. Teams can elect to use 5 GHz WiFi during competition for WAP to robot communications, however, this frequency will not be monitored for wireless interference and will not be grounds for a protest or rematch by any team.
14. The communications link is required to have an average data utilization bandwidth of no more than 4,000 Kbps. There will not be a peak data utilization bandwidth limit.

General Radio Frequency and Communications Approval (Comm Check)

1. You must pass a "Comm Check" before you can compete in the qualification or final rounds.
2. This check is used to verify that your setup follows all the Wi-Fi & Network rules.
3. You will have a maximum of 15 minutes at the check station to complete all the required tasks.
4. All Comm Checks are performed on Wi-Fi Channel 1.
5. While you are in the queue, you may set your equipment to Channel 1, but you must then turn all your wireless equipment off until your check begins.
6. During your 15-minute check, you must:
 - Show the judges all wireless components on your robot.
 - Prove that you can successfully connect to and control your robot wirelessly.
 - Demonstrate that you can turn off the 2.4 GHz band on your router.
7. If you use Bluetooth or any other non-Wi-Fi radio (e.g., 900 MHz), you must bring printed manufacturer datasheets. These must clearly show the part number, frequency, power level, and prove your Bluetooth is not Class 1.
8. If you fail to complete all these tasks in your 15-minute slot, you will be disqualified from the competition.

RoboPits Comm Rules

1. All routers in the RoboPits shall turn off 2.4 GHz by default or power down their wireless equipment.
2. The RoboPits will have full access to the 5 GHz band and is the required WiFi frequency band for use in the RoboPits if wireless connectivity is required (alternative is to connect an ethernet cable between the devices).
3. If needed, teams in the RoboPits are able to test their robot using 2.4 GHz with prior authorization from the Pit Boss. These tests are to be conducted only on Channel 11, and will only be allowed for a short period of time.

Moon Yard Arena Comms Rules

Specific comms rules and infrastructure TBD

Communications between Moon Yard Arena and Mission Control Center

Specific comms rules and infrastructure TBD