



**2025 Guidebook**  
**Version 1**  
**September, 2024**

# TABLE OF CONTENTS

## Contents

SECTION 1: APPLICATION AND ADMINISTRATION.....	4
1.1 Lunabotics Objective .....	4
1.2 Lunabotics Events .....	4
Event 2 – University of Central Florida Lunabotics Qualification Challenge .....	4
Event 3 – NASA’s Lunabotics On-Site Challenge .....	4
1.3 Lunabotics Regulations and Policies .....	4
1.4 Roles and Responsibilities .....	5
1.5 Code of Conduct .....	5
1.6 Appeals.....	5
1.7 Participant Waiver .....	5
1.8 Social Media .....	5
1.9 Media Advisory .....	5
1.10 Mentor/Protégé Teams.....	5
1.11 Why the Moon .....	5
1.12 The Lunabotics Awards.....	6
1.13 Eligibility .....	6
1.14 Alignment with National Standards in Engineering and Space.....	7
1.15 Minority Serving Institutions Program .....	8
1.16 Applying on the STEM Gateway Website .....	8
SECTION 2: TECHNICAL.....	8
2.1 RoboPits .....	8
2.2 Check-in and Set-up.....	8
2.3 Transportation .....	8
2.4 Team Spirit .....	8
2.5 Safety (robot) and Communication (comm) Inspection.....	9
2.6 Preparing for the Competition Attempt.....	9
2.7 Clean-up and Check-out .....	9
2.8 Stop Work Order (SWO) .....	9
2.9 Waste Accumulation Protocol .....	9
2.10 Safety in the RoboPits and UCF Arena (participants and other carbon-based life forms) .....	9
2.11 Personal Protective Equipment (PPE) .....	9
2.12 Regolith Simulant – LHS-2E .....	9
2.13 Respirators .....	10
2.14 Eye/Face Protection .....	10
2.15 Hand Protection.....	10
2.16 Hearing Protection.....	11
2.17 Foot Protection .....	11

2.18 Clothing Allowed.....	11
2.19 Clothing Not Allowed.....	11
2.20 Spectators .....	11
2.21 Personal Protective Equipment (PPE) DONN / DOFF.....	11
2.22 Donning Protocol.....	11
2.23 Doffing Protocol in the UCF Arena After completion of the Robot Run.....	12
SECTION 3: UCF ARENA SPECIFICATIONS AND PROTOCOL.....	12
3.1 UCF Arena Specifications .....	12
3.2 UCF Arena Protocol .....	13
SECTION 4: ROBOTS AND ROBOTIC OPERATIONS.....	14
4.1 Robots .....	14
4.2 Robot Requirements .....	14
4.3 E-STOP Button.....	15
4.4 Power Meters / Data Loggers.....	15
4.5 Battery Protocol.....	16
4.6 Robotic Operations.....	16
SECTION 5: SCORING, CONSTRUCTION, NAVIGATION.....	17
5.1 Scoring .....	17
5.2 Construction Points: .....	17
5.3 Construction Points Calculator .....	18
5.4 Construction Protocol.....	19
5.5 Navigation Protocol .....	20
5.6 Autonomy Rules: .....	21
5.7 Fiducials .....	21
SECTION 6: MISSION CONTROL CENTER AND AUTONOMOUS OPERATIONS .....	21
6.1 Mission Control Center (MCC) .....	21
6.1.1 General Guidelines.....	21
6.1.2 Mission Setup .....	22
6.1.3 Mission Operations .....	22
6.1.4 Mission Anomalies.....	23
6.1.5 Mission Conclusion.....	23
6.2 Autonomous Operations.....	23
6.2.1. Excavation & Dump Automation: 150 pts.....	23
6.2.2 Excavation & Dump Automation - Full Run: 300 pts .....	24
6.2.3 Travel Automation: 200 pts.....	24
6.2.4 Full Autonomy: 600 pts.....	25
6.2.5 Autonomous Operations Scoring.....	25
SECTION 7: COMMUNICATIONS .....	25
SECTION 8: UCF ON-SITE WEEK INFORMATION.....	26

# SECTION 1: APPLICATION AND ADMINISTRATION

## 1.1 Lunabotics Objective

The primary objective of Lunabotics is for teams of college students to apply the NASA systems engineering process to design, develop, build, and test a prototype lunar robot. The goal is to construct berm structures that would be useful for blast and ejecta protection during lunar landings and launches, shading lunar housing, cryogenic propellant tank farms, providing radiation protection around a nuclear power plant, and other mission-critical uses.

Lunabotics is a two-semester event that allows selected teams to earn points by successfully completing the STEM Engagement Report, the Presentation and Demonstration (optional), the Systems Engineering Paper, the Proof of Life Video, and developing robots that meet all the challenge criteria.

NASA directly benefits from this competition by annually assessing student designs and data the same way it does for its own, less frequent, prototypes. Encouraging innovation in student designs increases the potential of identifying clever solutions to the many challenges inherent in the Artemis missions. Advances for off-world construction offer new possibilities for the same activities here on Earth, expanding the benefits beyond NASA alone. The skills developed in Lunabotics apply to other high-technology industries that rely on systems engineering principles. These industries will create a workforce posed to lead a new space-based economy and add to the economic strength of our nation.

## 1.2 Lunabotics Events

This is the gateway to the overall challenge. Applicants will follow the directions listed in “Applying on the STEM Gateway Website.” You will receive an email letting you know the selection status of your application. Those teams selected will continue with the challenge consisting of the following events:

### **Event 1 – Project Development Challenge:**

1. STEM Engagement Report
2. Presentation and Demonstration Slides
3. Systems Engineering Paper
4. Proof of Life Video

Teams failing to submit any of these items will be removed from the challenge.

### **Event 2 – University of Central Florida Lunabotics Qualification Challenge**

1. This event is held at UCF’s Florida Space Institute’s Exolith Lab® in Orlando, Florida.
2. Here, the teams will put their designs to the test. The 10 highest-scoring teams from UCF’s Qualification Challenge will be invited to NASA’s On-Site Challenge at the Kennedy Space Center. Teams that do not reach the top 10 will also be invited to this event, but they will not be given the opportunity to run their robots.

### **Event 3 – NASA’s Lunabotics On-Site Challenge**

The 10 highest-scoring teams from the UCF Lunabotics Qualification Challenge will be invited to the Kennedy Space Center (KSC) to compete in the Artemis Arena located in the Astronauts Memorial Foundation’s Center for Space Education Building.

## 1.3 Lunabotics Regulations and Policies

First, read the Lunabotics Guidebook at (<https://www.nasa.gov/learning-resources/lunabotics-challenge/>).

### **Frequently Asked Questions / Ask for Help**

1. There will be no response to requests for information already contained in the Guidebook, to change a deadline or a rubric.
2. The team is responsible for monitoring the Lunabotics [Website](#) and the Lunabotics [Slack](#) for notices, updates, feedback requests, and responses to FAQs. The Guidebook and the FAQs shall be read together as one document.
3. The faculty advisor and/or team leads shall submit the FAQs. Email shall use an “.edu” domain address. This applies to the application process and communications with Lunabotics. We can only respond to “.edu” addresses.
4. Provide your school’s name, cite the relevant rule/paragraph number in the guidebook, your inquiry, and send it to [lunabotics@ucf.edu](mailto:lunabotics@ucf.edu). There will be no response to inquiries from any other source.

5. We understand the on-site events may conflict with final exams and /or your commencement ceremony. We can assist with proctoring exams on-site; please don't ask us to change dates or deadlines.

## 1.4 Roles and Responsibilities

It is the responsibility of the Chief Judge and Project Manager to ensure the integrity of the challenge as to the interpretation and enforcement of the rules and rubrics in the Guidebook. The goal is to apply the content of the Guidebook equally to the participants without passion or prejudice. The Lead Judges are responsible for creating the rules and rubrics and judging the deliverables received from the teams for their events. In matters associated with the overall Lunabotics Challenge, the Chief Judge and Project Manager's decision shall prevail.

## 1.5 Code of Conduct

Lunabotics is a National Aeronautics and Space Administration (NASA) Artemis Student Challenge and is held in a positive and safe environment. Students and faculty shall conduct themselves with integrity as to the spirit and intent of the rules, rubrics, and regulations. 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 not following the directions of the Lunabotics staff may be assessed penalty points or may be disqualified from a competition run or the entire Challenge. The Lunabotics Staff have the authority to act in this manner.

## 1.6 Appeals

All scoring decisions are final. If an appeal is warranted, the advisor or the student team leader shall submit the appeal in writing for consideration to the Chief Judge / Project Manager within 30 minutes of the posting of score(s) in question. The final decision of the Chief Judge / Project Manager shall prevail.

## 1.7 Participant Waiver

Each team will receive a waiver packet which must be filled out by all team members and sent to [lunabotics@ucf.edu](mailto:lunabotics@ucf.edu) in a single pdf. Separate pdf's from every team member will not be accepted.

## 1.8 Social Media

Keep up to date on Florida Space Institute activities and announcements on [Instagram](#), [Facebook](#), [X](#), and [LinkedIn](#).

## 1.9 Media Advisory

All participants and visitors to Lunabotics at the Kennedy Space Center or to the Lunabotics Qualification Challenge at the University of Central Florida (UCF) give permission to be photographed /videotaped for potential use in future media products, unconditionally releasing UCF and its representatives from any claims and demands.

## 1.10 Mentor/Protégé Teams

1. NASA collaborates with space agencies around the globe on many programs, including the International Space Station, Earth observation, and the Artemis missions headed to the Moon and Mars. Building and nurturing an eligible, diverse, and inclusive workforce is imperative to the future success of NASA and to our Nation. Veteran schools are encouraged to mentor and collaborate with first-time schools or schools classified as Minority Serving Institutions (MSIs). This is a means for teams to take advantage of the economies of scale as to costs, resources and overall experience. NASA will make the award to the mentor school. The distribution of work, costs, awards, etc., is an arrangement between the schools. As an example, awards to winning mentor / protégé teams would read as follows: "Grand Lakes University" in collaboration with "Faber College".
2. Decades of research by organizational scientists, psychologists, sociologists, economists, and demographers show that socially diverse groups (that is, those with a diversity of age, race, ethnicity, gender, and sexual orientation) are more innovative than homogeneous groups:
3. MSI Capability Gateway – <https://beta.nasa.gov/learning-resources/minority-university-research-educationproject/the-minority-serving-institution-msi-exchange/>
4. Scientific American – <https://www.scientificamerican.com/article/how-diversity-makes-us-smarter/>

## 1.11 Why the Moon

With NASA's Artemis campaign, we are exploring the Moon for scientific discovery and technological advancement and to learn how to live and work on another world as we prepare for human missions to Mars. We will collaborate with

commercial and international partners and establish the first long-term presence on the Moon. NASA will land the first woman and first person of color on the Moon, using innovative technologies to explore more of the lunar surface than ever before. The agency will use what we learn on the Moon to prepare for humanity's next giant leap – sending astronauts to Mars (<https://www.nasa.gov/humans-in-space/artemis/#missions>).

## 1.12 The Lunabotics Awards

**STEM Engagement Report** – (1st - \$1,000, 2nd - \$500, 3rd - \$500) best inspiration to study STEM-related topics in their community to include collaboration with middle school students and present a high number of quality activities to a large and wide range of audiences.

**Presentations and Demonstrations** – (1st - \$2,000, 2nd - \$1,000, 3rd - \$500) present intent and technical outcome of their design project. Allows the students to develop their public speaking skills.

**First Steps Award** – Best Presentation by a First-Year Team.

**Systems Engineering Paper** – (1st - \$2,000, 2nd - \$1,000, 3rd - \$500) best application of the NASA Systems Engineering process used to design, build, test, and evaluate their robot.

**Systems Engineering Nova Award for Stellar Systems Engineering by a First Year Team** – awarded to the team(s) who perform exceptional systems engineering in their College/University's first year in the Lunabotics Challenge as demonstrated in their systems engineering paper.

**Systems Engineering Leaps & Bounds Award** - for significant improvement over the previous year(s) in the team's application of systems engineering to develop their robot system.

**Lunabotics Innovation Award** – for the best design based on creative construction, innovative technology, and overall architecture.

### **Lunabotics Efficient Use of Communications Power Award**

**The Caterpillar Autonomy Award** – (1st - \$2,000, 2nd - \$1,250, 3rd - \$750, 4th - \$500, 5th - \$250, 6th - \$250) awarded by Caterpillar for successfully completing the activities autonomously.

**The Lunabotics Construction Award** – (1st - \$2,000, 2nd - \$1,000, 3rd - \$500) awarded to the teams that score the most points during the berm building operations in the Artemis Arena.

**The Grand Prize, The Lunabotics Artemis Award** – (\$5,000) The winning team shall submit the required items, complete all the events, and score the most points, a cumulative of the scores.

### The Points:

- |                                     |           |
|-------------------------------------|-----------|
| 1. STEM Engagement Report           | 15 Points |
| 2. Systems Engineering Paper        | 25 Points |
| 3. Presentations and Demonstrations | 15 Points |
| 4. Robotic Construction             | 25 Points |

Note: This list is not all-inclusive; some are not awarded every year and are subject to change without notice.

## 1.13 Eligibility

### 1. The schools shall:

Be an accredited Institution.

Enroll one (1) team per school only.

Be a post-high school, vocational/technical school, college, university, etc.

Be in the United States, its Commonwealths, territories, and or possessions.

### 2. The students shall:

Be 18 years old at registration.

Be currently enrolled and in good standing with their school.  
Be from the same school as their team.  
Participate in one team.

3. The Teams shall:

Have its own working robot(s).  
Have at least two (2) undergraduate students.  
The number of students on the team is at the school's discretion.  
Students who have graduated in the same semester/quarter as this challenge are eligible to be on the team.

4. The Faculty / Advisor (F/A) shall:

Supervise the team as to the spirit and intent of the Guidebook.  
Be employed by the institution and authorized to represent it. Cannot be a part of the team.

5. For the on-site event at UCF:

The person responsible for checking in with the team shall be 21 years old, employed by the institution, authorized to represent the institution, and remain on-site with the team until the team departs the challenge.

### 1.14 Alignment with National Standards in Engineering and Space

Lunabotics provides students an opportunity to apply the NASA Systems Engineering process in designing a prototype robot capable of performing the proposed construction operations on a simulated Lunar regolith surface. Encouraging innovation in student designs increases the potential of identifying clever solutions to the many challenges inherent in future Artemis Lunar missions. Students will develop a deeper understanding and enhance their communication, collaboration, inquiry, problem-solving, and flexibility skills, which will benefit them throughout their academic and professional lives.

The skills students develop in Lunabotics apply to other high-technology industries that rely on systems engineering principles. These industries will create a workforce posed to lead a new space-based economy and add to the economic strength of our nation. Lunabotics aligns with the Accreditation Board for Engineering and Technology (ABET) criteria outlined below:

Criteria 3. Student Outcomes: For baccalaureate degree programs, these student outcomes must include, but are not limited to, the following learned capabilities:

1. an ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly defined engineering technology activities;
2. an ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies;
3. an ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes;
4. an ability to design systems, components, or processes for broadly defined engineering technology problems appropriate to program educational objectives;
5. an ability to function effectively as a member or leader on a technical team;
6. an ability to identify, analyze, and solve broadly-defined engineering technology problems;
7. an ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature;
8. an understanding of the need for and an ability to engage in self-directed continuing professional development;
9. an understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity;
10. a knowledge of the impact of engineering technology solutions in a societal and global context; and;

11. a commitment to quality, timeliness, and continuous improvement.

### 1.15 Minority Serving Institutions Program

For More Information on MSIs, visit the [Department of Education Office of Postsecondary Education - Programs](#).

Veteran schools are encouraged to collaborate with schools classified as Minority Serving Institutions (MSIs). Building and nurturing an eligible, diverse, and inclusive workforce is imperative to the future success of NASA and to our Nation. This is a means for teams to take advantage of the economies of scale as to costs, resources and overall experience. The distribution of work, costs, awards, etc. is an arrangement between the schools. As an example, awards to winning mentor / protégé teams would read as follows: “Grand Lakes University” in collaboration with “Faber College”.

Decades of research by organizational scientists, psychologists, sociologists, economists, and demographers show that socially diverse groups (that is, those with a diversity of age, race, ethnicity, gender, and sexual orientation) are more innovative than homogeneous groups:

Being around people who are different from us makes us more creative, more diligent, and harder working. See Scientific American “How Diversity Makes Us Smarter” at <https://www.scientificamerican.com/article/how-diversity-makes-us-smarter/>

### 1.16 Applying on the STEM Gateway Website

Please see the [NASA Lunabotics Guidebook](#) for information on this.

## **SECTION 2: TECHNICAL**

### 2.1 RoboPits

The RoboPits this year will be located on the UCF Main Campus, approximately 10 minutes away from the competition arena. Use of the robopits at UCF is limited to assembly and disassembly of rover, electronic modifications, and code modifications. Teams may not cut metal, weld, or conduct any other modifications that could create a potentially unsafe environment in the robopit. Drilling into your rover is permitted. We recommend that your rover is built before you come to the competition! The pit boss has final say on whether an activity is unsafe.

### 2.2 Check-in and Set-up

1. The Pit Boss will assign your pit, explain the inspection process, signing up for runs, and other protocols. If things get hectic, be professional.
2. Your team will be required to provide two contact phone numbers in case the team needs to be reached at any point during the competition and cannot be found. These numbers will not be shared with anyone and will be deleted at the end of the competition.
3. Your pit measures 8’x10’ with two chairs, one table, and two power outlets. Pits have power strips provided. Do not daisy chain power strips.
4. Each team will keep their team and equipment contained within their assigned pit and keep the walkways/hallways clear and unobstructed.
5. Vacuums are provided and are for shared use by all teams as needed. Return vacuums to the designated area.
6. Notify the Pit Boss about any safety concerns or vacuums that need cleaning.

### 2.3 Transportation

Teams are responsible for transportation of students and their rover from the Robopit to the Exolith® Lab for their competition run. Further details will come at a later date, but expect to move from the pit to the Exolith® Lab at least 90 minutes before your competition run to allow for 10-15 minutes of transportation time and a final inspection.

### 2.4 Team Spirit

You are responsible for creating your pit identification sign. Be mindful of safety guidelines and keep it fun! Your sign should be under 6 feet tall, and you can use LED light strings. Please note that UCF Fire/Safety may ask you to remove



it if it doesn't comply with their regulations. Get creative with a team cheer or chant and in decorating your team shirts. Use your imagination to make your team stand out

## 2.5 Safety (robot) and Communication (comm) Inspection

1. The inspection stations will be identified.
2. The robot will have to pass the safety inspection first before moving forward.
3. After the inspection is conducted, no modifications to the rover will be permitted until after the competition attempt.

## 2.6 Preparing for the Competition Attempt

The teams will be brought to the safety inspection approximately 30-45 minutes before the scheduled transportation time to ensure a smooth flow. Once teams arrive at the Exolith® Lab facility, up to four (4) students will go to the personal protective equipment (PPE) prep area to don the PPE gear they will be wearing in the regolith bin. Following a final inspection, the escort will take the team to the arena, where arena escorts will take over. If the team is not ready or cannot be located, the competition run time will be given to another team that is ready.

## 2.7 Clean-up and Check-out

The RoboPit is expected to be neat each night, with nothing outside of the pit boundaries. Unplug all items before leaving for the night. Keep the RoboPit and the surrounding area neat and generally clean; use the provided vacuums as necessary. You are encouraged to bring floor coverings/mats to facilitate this cleaning. Each team will leave their RoboPit as they found it. Teams are required to clean their pit and the area around it. Teams will request a RoboPit inspection from the RoboPit Chief prior to departure.

## 2.8 Stop Work Order (SWO)

Lunabotics staff are authorized to issue an SWO to a team regarding any suspected safety issue. The team will immediately stop all activity. The Faculty Advisor must meet with the Pit Boss to resolve the issue. The SWO will remain in effect until the Pit Boss has ruled on the issue. The Pit Boss decision shall prevail.

## 2.9 Waste Accumulation Protocol

Teams will comply with Federal and UCF hazardous and controlled waste program requirements. Regulation requires that you coordinate with the RoboPit Chief before disposing of the representative items listed below (specially marked containers will be provided):

Waste Accumulation and Disposal Protocol Batteries (Alkaline, Lithium, Ni-Cd). Spray Paint. Oily wipes/IPA solvent wipes. Spray Foam. Solder Waste. Spray Adhesives. Acetone wipes. WD40. PVC cement – brushes, wipes, and cans. PB Blaster. PVC primer – brushes, wipes, cans. Silicone Spray. Super Glue (cyanoacrylates). Oil Cans. Epoxy Tubes. 3 in 1 oil. Aerosol Cans. Any as required by regulations.

## 2.10 Safety in the RoboPits and UCF Arena (participants and other carbon-based life forms)

Lunabotics personnel (Pit Boss, Arena Chief, etc.) are authorized to rule on any safety and health issues. You are responsible for using the correct Personal Protective Equipment (PPE) for the situation. Do not wear ties, loose clothing, jewelry, hanging key chains, or similar when near or working on moving or rotating machinery to avoid the potential risk of being drawn into rotating parts. Only break-away lanyards are permitted. Use the right tool for the right job, wear gloves/gauntlets to de-energize robots and equipment as needed, bring jack-stands to support your robot instead of folding chairs, and wire strippers should be utilized instead of knives. etc. Bring your own LED lighting for your pit. Address any safety concerns to the RoboPit Chief immediately.

## 2.11 Personal Protective Equipment (PPE)

UCF will provide goggles, N-95 masks, bunny suits, rubber gloves and booties for use in the UCF Arena. The teams are responsible for providing all other OSHA, ANSI, etc., or equivalent required PPE.

## 2.12 Regolith Simulant – LHS-2E

1. Is a crushed Anorthosite and Basalt aggregate with a natural particle size distribution similar to lunar soil.
2. It is alkaline and may cause skin and eye irritation.

3. If you are allergic to talcum powder, it is a good indication that you may be allergic to the LHS-2E. Participants are required to don Personal Protective Equipment (PPE) before coming into contact with the LHS-2E.
4. LHS-2E contains a small percentage of crystalline silica, which is a respiratory nuisance. Respiratory protection shall be used.
5. All PPE must be ANSI-approved, UL-Listed, CE EN166 rated, AS/NZS certified, or CSA rated, as applicable. The following describes the common PPE that you are required to wear.

### 2.13 Respirators

1. OSHA1926.1153 – Respirable Crystalline Silica, 29 CFR 1910.1053. Permissible exposure limit (PEL). The employer shall ensure that no employee is exposed to an airborne concentration of respirable crystalline silica in excess of 50 µg/m<sup>3</sup>, calculated as an 8-hour TWA.
2. The Respiratory Protection standard, paragraph 29 CFR 1910.134(g)(1)(i)(A), states that respirators shall not be worn when facial hair comes between the sealing surface of the facepiece and the face or that interferes with valve function. Facial hair is allowed as long as it does not protrude under the respirator seal or extend far enough to interfere with the device’s valve function.
3. OSHA – has not exempted any workers for religious reasons; however, we recognize that if such a situation should arise, there are respiratory protection alternatives, such as loose-fitting hoods or helmets that will accommodate facial hair.
4. OSHA – workers cannot sign a waiver to be exempted from the stated requirements. A release or waiver is not possible for employees. That being said, when a(n) employer is looking to accommodate a religious practice, they may have to explore respiratory protection alternatives like helmets or loose-fitting hoods.
5. Most N95 respirators are manufactured for use in construction and other industrial-type jobs that expose workers to dust and small particles. They are regulated by the National Personal Protective Technology Laboratory (NPPTL) in the National Institute for Occupational Safety and Health (NIOSH), which is part of the Centers for Disease Control and Prevention (CDC). NIOSH-approved N95 Particulate Filtering Facepiece Respirators are required in the UCF Arena.
6. There are very few options, but the best choice would be for the individual to purchase a hooded-powered air purifying respirator (PAPR) – especially if they intend to stay in a career that requires the occasional use of PPE. These items shall be provided by the institutions for their participants if required.

### 2.14 Eye/Face Protection

1. Protective eyewear must be worn in the individual pits and UCF Arena.
2. It is also a good practice and principle to wear eye protection in the following situations:
  - Any area posted with signs requiring the use of eye protection.
  - When performing any work on the robot.
  - When there is a risk of flying particles or chemical exposure (such as splashes, splatters, and sprays).
  - Several forms of eye/face protection are available to provide protection from related hazards, including safety glasses with side shields, goggles, face shields, and face masks.
  - Safety Glasses and protective eyewear are designed to provide a shield around the entire eye to protect against hazards such as splashes of liquids, burns from steam, compressed air, and flying wood or metal debris. To prevent injury, all individuals in the pit area, the practice field area, and the arena must wear safety glasses or protective eyewear that is ANSI-approved,
  - Reflective lenses are prohibited; your eyes must be clearly visible to others. Accommodations will be made for participants that require tinted safety glasses.
  - Prescription Glasses: If you wear prescription glasses that do not have a marked safety rating, you must wear rated safety goggles over them to achieve adequate protection. If you wear marked safety-rated glasses, you may use ANSI-approved
  - Safety-rated glasses, side shields, and frames can be identified by markings stating the standard that they are rated to (ex. Z87.1).

### 2.15 Hand Protection

Hand protection protects against heat, electrical, chemical, laceration, and mechanical hazards. Use proper gloves and mechanical tool guards for the application. Selected the correct one to use for each activity.

## 2.16 Hearing Protection

Provide and use hearing protection devices, such as earplugs, where there are unsafe sound levels.

## 2.17 Foot Protection

Participants must wear shoes that completely cover the entire foot. Shoes must be substantial and have closed toes and heels to protect against foot injuries, regardless of work location. Flip-flops, sandals, mules, lightweight slippers, etc., are unacceptable when working on or near the robot. Safety shoes or toe guards are appropriate for areas where heavy objects can fall on your foot.

## 2.18 Clothing Allowed

Shirts/tops that cover the upper torso. Long pants that cover the wearer to the ankle. Completely enclosed shoes that cover the instep of the foot, preferably leather, which can be wiped clean. Baseball caps and other headgear as long as they are kept far enough back on the head so that vision is not impaired and do not interfere with protective eyewear.

## 2.19 Clothing Not Allowed

Hair must not impede vision or come in contact with the work. Hair must be kept away from the eyes. Long hair must be tied back. Hair longer than 6 inches from the nape of the neck must also be pinned up (use of hair nets or hats is acceptable). Flowing garments and neckwear such as ties and scarves that hang loose. Caps worn low over the eyes so as to impede vision. Cropped shirts, plunging necklines, spaghetti straps, or ripped shirts. Ripped jeans, shorts, capris, or skirts. Loose or flowing tops with wide/bell sleeves, outerwear such as coats or shawls. Sandals, open-toe, open-back, or open weave shoes, and shoes with holes in the top or sides that will expose the skin to regolith or retain regolith.

## 2.20 Spectators

Should follow the same rules as participants. If substantial close-toed shoes are not available, they may enter the pit area as long as they remain in the pit aisles. Spectators who do not meet the footwear requirement for participants, as described above, are not allowed inside individual team pits or in any locations where robots are being worked on.

## 2.21 Personal Protective Equipment (PPE) DONN / DOFF

1. Personal protective equipment (PPE) is an important element to help ensure participants are protected from hazards in the work area. The PPE Attendant will ensure that participants are provided with the correct PPE for the task they are performing. The following describes the common PPE that you are required to wear.
2. Participant PPE - includes N-95 Filtering Facepiece, full body protective suits with hood and booties, and nitrile gloves when entering the UCF Arena.
3. Judges/Regolith Assistants PPE - inside the arena during robot operation includes full face Respirator with P100 filters or full-face powered air purifying respirator (PAPR), full body protective suits with hood and booties, rubber boots, and nitrile gloves.

## 2.22 Donning Protocol

### **1. Participant**

- Select the appropriate size Tyvek coverall suit and put it on over shoes
- Select appropriate gloves and don them, overlapping the Tyvek suit.
- Tape gloves to the Tyvek coveralls overlap to ensure skin is not exposed.
- Tape may also be applied above the ankles and waist to contain excess Tyvek coverall material.
- Place N-95 filtering face piece over nose and mouth. Adjust the nose bridge to obtain a comfortable fit and prevent eye protection fogging.
- NOTE: Without exception, proper use of such masks and/or respirators shall require a clean-shaven face as determined by the Competition Staff.
- Place dust goggles over eyes and cover head with Tyvek suit hood.

### **2. Judges / Assistants**

- Full-face negative pressure respirator with P-100 filters or full-face powered air purifying respirator (PAPR) and cover head with Tyvek suit hood.

- Don rubber boots over Tyvek booties if working in the regolith pit.

## 2.23 Doffing Protocol in the UCF Arena After completion of the Robot Run

Please keep your Tyvek suit, boot covers, and N95 mask for your 2<sup>nd</sup> run. We will only be giving out one of each.

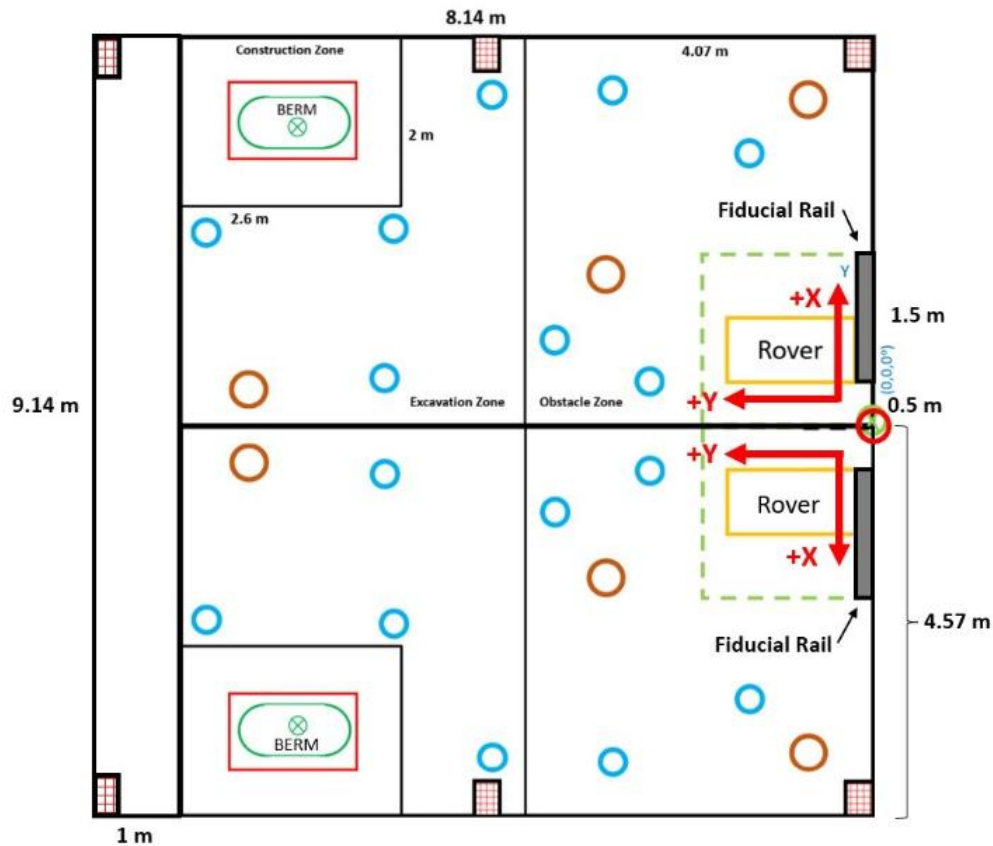
# SECTION 3: UCF ARENA SPECIFICATIONS AND PROTOCOL

## 3.1 UCF Arena Specifications

1. The Regolith Bin at UCF is filled with Lunar Highlands Simulant (LHS-2E) from Space Resource Technologies.
2. The arena area measures ~10 m long and ~10m wide.



3. The UCF arena contains ~90 cm depth of LHS-2E.
4. Larger rocks may also be mixed in with the LHS-2E in a random manner (gravel is ~2cm in diameter).
5. **Obstacle Zone** - the 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 excavation zone.
6. **Boulder Obstacles** - there will be at least three (3) obstacles placed on top of the arena surface within the obstacle zone area before each competition attempt is made. The placement of the obstacles will be randomly selected before the start of the competition. Each obstacle may have a diameter of approximately 30 cm to 40 cm and will have random heights. There may be boulders in the excavation zone, these will not exceed the dimensions of any in the obstacle zone.
7. **Crater Obstacles** - there will be at least three (3) craters of varying depth and width, being no wider or deeper than 40 - 50 cm in the obstacle zone.



**Figure 1: UCF Arena Layout**

### 3.2 UCF Arena Protocol

1. Once competition runs begin, the UCF 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 UCF 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 UCF Arena.
5. The UCF Arena is defined as all areas surrounding the regolith bin, including the staging area, mission control, and regolith bin deck.
6. For Arena operations, the currently active competing team members are defined as the team members attired in PPE 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 UCF Arena.
8. Team members placing the robot in the Competition Arena will don PPE in the Exolith staging area.
9. When properly attired, they and Mission Control teammates will be escorted to the UCF Arena entrance.
10. The Arena Chief will grant access to UCF Arena staging area when ready.
11. Student cell phones, cameras, tablets, and other restricted electronics devices brought into the UCF 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 in PPE 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. Assume there are positive and negative obstacles. Assume you cannot drive over the obstacles.
18. When complete or directed by Arena personnel, the team members will promptly exit the Arena.
19. Only the team members in PPE 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. Photos may be permitted during this time at the discretion of the Arena Chief. Photos are limited to the construction zone and berm construction. It may be that only the final berm configuration may be photographed. Photos, if permitted, shall be taken by a single designated individual using a single device (i.e. cell phone, tablet, or camera) retrieved from the Arena Chief's station. Any photos taken shall not be shared, posted, or transmitted in any way while the team members are in the UCF Arena. Violation of this rule may result in team disqualification.
21. When the competition run has ended, the team members in PPE shall promptly retrieve their robot and equipment from the Arena and proceed to the HEPA station.
22. At the HEPA station, team members shall:
  1. Vacuum excess LHS-2E from their robot.
  2. Place rover on egress platform to be lowered out of the bin.
23. Remember, the UCF 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.

## **SECTION 4: ROBOTS AND ROBOTIC OPERATIONS**

### 4.1 Robots

1. 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.
2. Students on the team shall perform 100% of this project (including design, construction, and 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). Components (i.e. electronic, mechanical, etc.) are not required to be space qualified for atmospheric, electromagnetic, thermal, or Lunar environments.

### 4.2 Robot Requirements

1. Volumetric dimensions - robot(s) shall be contained within a payload envelope measuring 1.50 m length x 0.75 m width x 0.75 m height. The orientation of these dimensions may be chosen by the team. It may deploy or expand beyond the envelop after the start of each attempt but shall not exceed 1.75 m in additional height (which is 2.5 m above the surface of the regolith). 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.
2. Robots will be inspected for the volumetric dimensions in the stowed configuration during the Safety Inspection. A "jig" frame will be placed over the rover for volume constraint verification. No modifications or team robot interaction is permitted during this verification.
  - Robot Mass - a maximum mass of 80kg. Subsystems/equipment on the robot that are used to transmit commands / data and video to the telerobotic operators are counted toward the mass limit.
  - 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.
3. 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. Multiple robot systems are allowed but the total mass of the whole system shall comply with the mass given in this rule. The commercial cost of delivering payloads to the Moon is about \$1.2 Million per kg (estimate). This competition aims to simulate a Lunar mission where a robot is delivered to the Moon. This corresponds to an approximate mission cost of \$72 Million. Lower masses will result in lower mission costs so this competition rewards teams that have a lower robot mass.
4. External robot antennas are required to reduce potential interference problems.
5. Robots shall have a minimum of four (4) lifting points, safe for human hands and clearly marked (ISO 7000-1368) for students and staff to use. Teams are responsible for placement and removal of their construction robot onto the

regolith 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.

6. 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.
7. The robot can run either by telerobotic (remote control) or in autonomous operations and cannot have any touch sensors to sense and avoid obstacles.
8. Reference Points / Reference Arrows - 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, Z axes, dimensions correspond to the typical payload volume available on today's Lunar landers).
  - The team must declare the robot orientation by length (arrow 1) and width (arrow 2) to the inspection judge. Reference Point (arrow 3) - must mark the forward direction of the mining robot in the starting position configuration (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.
  - The judges will use this reference point and arrow to orient the mining 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 if multiple arrows do not conflict.

### 4.3 E-STOP Button

1. Also known more formally as an emergency brake, emergency stop (E-stop), emergency off (EMO), kill switch, or emergency power off (EPO), is a safety mechanism used to shut off machinery in an emergency, when it cannot be shut down in the usual manner.
2. OSHA and relevant standards such as IEC 60204-1 state that an e-stop must be readily accessible to the operator. Additionally, it should be unobstructed—no collars or actuation restrictions—and easily accessible without having to reach over, under or around to actuate. Machine-building standards such as ANSI B11, B11-19 and National Fire Protection Agency (NFPA) 79 also address specifics in regard to safety devices such as an e-stop.
3. OSHA and relevant standards such as IEC 60204-1 further state that resetting of the e-stop alone shall not resume operation. A second deliberate action is needed, such as the pressing of a reset button. This could include twisting the mushroom button and allowing it to spring back up or pulling the button back up to reset. It cannot automatically reset.
4. The robot shall be equipped with an E-STOP button. An unmodified "Commercial Off-The-Shelf" (COTS) red button is required. Use sound engineering practices and principles in placing and securing the E-STOP button on your robot(s), failure to do so may 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.
5. 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
6. Disabling the E-STOP button without authorization from the Staff shall result in a safety disqualification.
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.
8. 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.

### 4.4 Power Meters / Data Loggers

1. 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. Shall be schematically located between the battery and kill switch, so the readings are not erased if the E-STOP button is activated. The devices shall be placed on the highest practical location on the robot and be easily visible.
2. 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.

## 4.5 Battery Protocol

1. This for the Lithium-Ion / Nic-Cad batteries used in your robots.
2. Batteries must be attended while charging. Chargers shall be unplugged overnight.
3. Battery containers must be designed for safely storing, charging, and transporting lithium-ion batteries, or approved equivalent.
4. Batteries must be stored in upright containers; batteries cannot be in contact with each other.
5. Batteries that have been dropped must be inspected for damage and replaced as needed.
6. Do not store batteries that are hot to the touch after charging.
7. If a battery continues to feel hot after charging, if possible, remove from the building and place outside and notify UCF Fire as a non-emergency issue.
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. 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. Closed pneumatic systems are allowed if the gas is supplied by the robot itself. Pneumatic systems are permitted if the gas is supplied by the robot and self-contained.
9. The rules are intended for robots to show an off-world plausible system functionality, but the components do not have to be traceable to an off-world qualified component version. Examples of allowable components are: Sealed Lead-Acid (SLA) or Nickel Metal Hydride (NiMH) batteries; composite materials; rubber or plastic parts; actively fan cooled electronics; motors with brushes; infrared sensors, inertial measurement units, and proximity detectors and/or Hall Effect sensors, but proceed at your own risk since LHS-2E & BP-1 regolith simulant is very dusty and abrasive
10. Teams may use honeycomb structures as long as they are strong enough to be safe and the edges sealed to prevent dust intrusion, a wheel with a large honeycomb structures that is open on both sides is allowed as long as the edges are not so sharp that they would be a cutting hazard.
11. Teams may not use GPS, rubber pneumatic tires; air/foam filled tires; open or closed cell foam, ultrasonic proximity sensors; or hydraulics because NASA does not anticipate the use of these on an off-world mission. This will not pass inspection.

## 4.6 Robotic Operations

1. The robot cannot be anchored to the sand prior to the beginning of the proof of life demonstration.
2. At the start of the competition run, the mining robot may not occupy any location outside the defined starting position in the regolith arena.
3. The robot must operate within the regolith 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.
4. The robot may not use any process that causes the physical or chemical properties of the regolith simulant to be changed or otherwise endangers the uniformity between competition attempts. The mining robot may not penetrate the regolith simulant surface with more force than the weight of the mining robot before the start of each competition attempt.
5. No ordnance, projectile, far-reaching mechanism, etc. may be used. The mining robot must move on the regolith simulant 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. Tape, clamps, or rods pushed into the regolith 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.
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.



## SECTION 5: SCORING, CONSTRUCTION, NAVIGATION

### 5.1 Scoring

1. UCF & KSC – The berm construction scores from each run will be added together for the final score (final score will be cumulative, not the highest of the two attempts, not an average of the two attempts).
2. KSC Only – The teams with the first, second, and third most construction points will receive up to 25, 20, and 15 points, respectively towards the grand prize. Teams not winning first, second, or third place in the construction category can still earn one bonus point towards the grand prize for every 0.2 cubic meters of berm constructed up to a maximum of ten points.
3. These are the overall scoring elements and their approximate weightings:

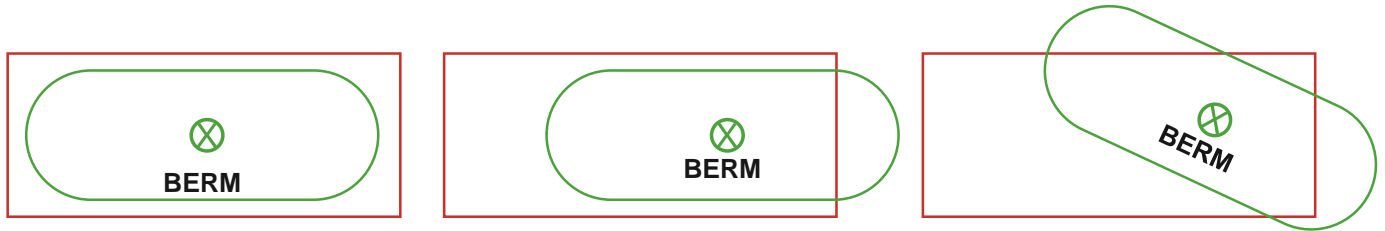
Scoring Element	Approximate Weight
Construction – Berm Productivity Normalized for Robot Mass (BP Mass)	30%
Construction – Berm Productivity Normalized for Energy Consumption (BP Energy)	20%
Autonomy	30%
Camera Bandwidth Use	10%
Dust Tolerant (Design)	5%
Dust Operation	5%

### 5.2 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 the berm volume within the target berm location will be counted. The team will earn construction points for each cubic cm of berm constructed above grade per minute per each kg of the robot’s mass. Only the portions of the constructed berm within the target area for berm placement will be counted. The target area has perimeter dimensions of 2.2 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 the berm volume within the target berm location will be counted. The team will earn construction points for each cubic cm of berm constructed above grade per minute per each w\*hr of energy consumed. The electrical energy consumed must be displayed by an (commercial off the shelf or “COTS”) electronic data logger and verified by a judge.
4. **Camera bandwidth Use** - During each competition attempt, the team will be scored on camera usage as follows: 0 cameras = 120, 1 camera = 60, 2 cameras = 0 points.
5. **Dust Tolerant Design** - During each competition attempt a team can earn up to 60 points for dust tolerant design features on the construction robot. Teams are encouraged to point out dust tolerant and dust free features to the judges during setup. The judges will allocate these points based on an inspection and performance during the competition run. The points for dust-tolerant design are as follows:
  - Drive train and components enclosed/protected: 20 points
  - Active dust control (brushing, electrostatics, etc.): 20 points
  - Custom dust sealing features (bellows, seals, etc.): 20 points
6. **Dust Free Operation** - During each competition attempt, a team can earn up to 60 points for dust free operation. The judges will allocate these points based on actual performance during the attempts. If the construction robot has exposed mechanisms where dust could accumulate during a lunar mission and degrade the performance or

lifetime of the mechanisms, then fewer Construction points will be earned in this category. If the construction robot raises a substantial amount of airborne dust or projects it due to its operations, fewer construction points will be earned in this category. Ideally, the construction robot will operate in a clean manner without dust projection, and all mechanisms and moving parts will be protected from dust intrusion. All decisions by the judges regarding dust tolerance and dust projection are final. The points for dust-free operation are as follows:

- Driving without dusting up regolith (10 points)
- Digging without dusting up regolith (40 points)
- Transferring regolith without dumping the regolith on your own robot (10 points)



	KSC	UCF
Berm Size	2.0m x 0.7m	1.3m x 0.7m
Target Berm Area	2.2m x 0.9m	1.5m x 0.9m

**Figure 4: Artemis/UCF Arena Layout 2 - Berm Positioning**

(Note 1: only the green actual berm volume inside the red box will count towards the berm volume measurement)

### 5.3 Construction Points Calculator

Example actuals based on a 30-minute run at KSC (UCF runs are based on 15-minute runs).

#### Construction Points Calculator – UCF Arena

Construction Category Elements	Units	Specific Points	Example Actuals	Example Points
1. <b>Pass All Inspections (Comm/Vehicle).</b>	Pass = Run / 0=Default		1	<b>Allowed to Run</b>
2. <b>Berm Construction Productivity – Normalized for Robot Mass (BCP Mass)</b> – A volumetric scan before and after the run will be performed. Only the berm volume within the target berm location will be counted. The team will earn construction points for each cubic cm of berm constructed above grade per minute per each kg of the robot’s mass.	cm <sup>3</sup> berm / min / kg robot mass	4.4	77551 cm <sup>3</sup> / 15 min run / 66 kg  <b>78.33</b>	<b>344.6</b>

<p><b>3. Berm Construction Productivity – Normalized for Energy (BCP Energy)</b> - A volumetric scan before and after the run will be performed. Only the berm volume within the target berm location will be counted. The team will earn construction points for each cubic cm of berm constructed above grade per each w*hr of energy consumed. The electrical energy consumed must be displayed by an (commercial off the shelf or “COTS”) electronic data logger and verified by a judge.</p>	<p>cm<sup>3</sup> berm / min /wathour</p>	<p>1.5</p>	<p>77551 cm<sup>3</sup> / 15 min run / 36 whr  <b>143.6</b></p>	<p><b>215.4</b></p>
<p><b>4. Camera Bandwidth Use</b> – During each competition attempt, the team will be scored on camera usage as follows: 0 cameras = 120, 1 camera = 60, 2 cameras = 0 points.</p>	<p># cameras</p>	<p>120, 60, 0</p>	<p>1</p>	<p><b>60</b></p>
<p><b>5. Dust Tolerant Design</b> – see description</p>				<p><b>60</b></p>
<p><b>6. Dust Free Operation</b> – see description</p>				<p><b>51</b></p>
<p><b>7. Autonomy</b> – See Construction Points – Autonomy</p>	<p>task</p>	<p>150, 200, 350, 450, or 600</p>	<p>150.00</p>	<p><b>150.00</b></p>
<p><b>8. Total Points</b></p>				<p><b>901</b></p>

## 5.4 Construction Protocol

1. The robot will be inspected before each competition attempt. 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 regolith simulants for the berm from inside the starting area, obstacle zone, or construction zone. All regolith simulants 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 regolith simulant to be changed or otherwise compromises the uniformity between attempts.
15. Bulldozing (i.e. pushing a pile of dirt/rocks) with a bladed dozer-type of rover is considered an acceptable excavation and regolith simulant transfer technique for the Lunabotics challenge. In this case, the robot would push material from the excavation zone into the berm area to create the berm. All regolith simulant material must be pushed in a pile from the excavation zone into and through the construction zone to the berm. Regolith simulant may be skimmed from the construction zone, but only if it is part of the operation of pushing it from the excavation zone into the berm (it may not be intentionally collected in the construction zone). The bulldozing pushing operation shall not start inside the construction zone – each bulldozing attempt shall start in 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.

## 5.5 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.

## 5.6 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” during any attempts at autonomy points. 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 (there are no walls in off-world locations, and teams shall operate as closely as possible in that scenario of operations). 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.

## 5.7 Fiducials

*Coming soon!*

# SECTION 6: MISSION CONTROL CENTER AND AUTONOMOUS OPERATIONS

## 6.1 Mission Control Center (MCC)

Teams will control or autonomously operate their robot from the MCC to simulate operations of a Lunar In-Situ Resource Utilization (ISRU) construction mission. 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 the MCC rules in the Lunabotics guidebook and ensure they are interpreted and enforced equally for all teams.

### 6.1.1 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 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 UCF Arena teammates during the setup period, which is only permitted using equipment provided by 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 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 Lunabotics staff may be assessed penalty points, disqualified from a competition run, or disqualified from the entire Lunabotics Challenge.

#### **6.1.2 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 UCF 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 UCF Arena. This radio will be returned 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.

#### **6.1.3 Mission Operations**

1. Teams are allowed 15 minutes per competition run under nominal conditions.
2. Telerobotic operators will have access to two situational awareness cameras in the construction area in the UCF Arena via monitors provided in the MCC. The use of these cameras will result in a point deduction. 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.
4. 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 should:
  - 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.
5. 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 NASA situational awareness cameras, if in use, is permitted during autonomy attempts.

#### 6.1.4 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 Comm: 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 UCF 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.

#### 6.1.5 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 if the robot was actively dumping material prior to the expiration of the competition timer. If the rover is loaded with regolith and not in the berm zone, it may be necessary to active it once more to unload the regolith prior to egress.
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 UCF 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.

## 6.2 Autonomous Operations

During each competition attempt, the team will earn up to 500 Construction points for autonomous operation. As Mission Control Judges (MCJ) 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 UCF runs and runs at KSC. This means that teams that do not make the top 10 and move to KSC may still be eligible for the Caterpillar Autonomy Awards.

#### 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:

#### **6.2.1. Excavation & Dump Automation: 150 pts**

1. Teams are allowed to traverse to the Excavation Zone via remote control.
2. Once in the Excavation zone, they must indicate to the MCJ that they are going hands-free for the excavation attempt.

3. The robot must execute machine control commands itself during the excavation task.
4. The robot must demonstrate the ability to excavate, transport, and place. Hands-free operation must begin before the robot engages the regolith to begin the excavation process.
5. Teams must continue in hands-free mode to transport regolith after excavation to the construction zone.
6. 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. MCJ may engage the arena judges for confirmation if camera angle/performance does not allow confirmation in Mission Control.
7. A complete cycle of digging, transporting, and placing regolith in the berm construction location must be completed in hands-free mode.
8. This level of automation will require teams to master the lower-level machine control of their robot platform associated with excavation and dumping. In addition, teams will need to master localization in the excavation and construction zones as well as path planning to align and place regolith at the designated berm construction location.

### **6.2.2 Excavation & Dump Automation - Full Run: 300 pts**

1. Teams are allowed to traverse to the Excavation Zone via remote control.
2. Once in the Excavation zone, they must indicate to the MCJ that they are going hands-free for the excavation attempt.
3. The robot must execute machine control commands itself during the excavation task.
4. The robot must demonstrate the ability to excavate, transport, and place. Hands-free operation must begin before the robot engages the regolith to begin the excavation process.
5. Teams must continue in hands-free mode to transport regolith after excavation to the construction zone.
6. 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. MCJ may engage the arena judges for confirmation if camera angle/performance does not allow confirmation in Mission Control.
7. The robot must execute a minimum of three excavation, travel, dump, and return to excavation cycles to be eligible for this level of autonomy.
8. The robot must be in hands-free mode at all times in the excavation and construction zones for the entire attempt. A team is allowed to revert to remote control for travel only between the excavation and construction zone one time and will incur a 50-point penalty for remote control.
9. This level of automation will require teams to master the lower-level machine control of their robot platform associated with excavation and dumping. In addition, teams will need to master localization in the excavation and construction zones as well as path planning to align and place regolith at the designated berm construction location. In addition, it will demonstrate the ability to do this over the entire run and adapt to changes in the arena over the course of excavation and dump cycles.

### **6.2.3 Travel Automation: 200 pts**

Teams may begin with remote control and move the robot within the starting zone only to “lock” in their localization solution. The teams must then 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. The robot must start in the starting zone and remain hands-free until any part of the robot has crossed into the excavation zone. This level of automation will require the team to master the following:

1. Localization across the entire competition arena.
2. Object detection and location relative to the robot.
3. Navigational planning based on location and obstacles/traversable area.
4. 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 excavation zone. The teams should not architect a “Point and traverse” approach for this automation step.
5. If the robot comes in contact with a rock or drives across a crater in the obstacle zone, as determined by the MCJ/Arena judges, a 35-point reduction will be applied.



6. For maximum points, the attempt must be made at the start of the run when first leaving the starting zone. In order 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. If multiple attempts are made, this penalty will only be assessed one time to the successful attempt.
7. If attempting excavation and dump automation in coordination with travel automation, the robot must remain in “hands-free” control during travel and excavation.
  - Example: Robot crosses the obstacle course in remote control before the attempt, hits an obstacle, and drives across a crater during the attempt. 200 points – 50 – 35= 115 points.

#### 6.2.4 Full Autonomy: 600 pts

1. The robot must be in hands-free control for the entirety of the competition run, completing two or more cycles of excavation and placement at the berm construction location of regolith. Berm construction points, as determined by the volumetric scan, must be achieved for this level of autonomy.
2. If the robot comes in contact with a rock or drives across a crater, as determined by the MCJ/Arena judges, a 35-point reduction will be applied. This is only true in the obstacle zone. The robot is allowed to move rocks and fill in craters in the excavation zone.
3. 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 hits an obstacle and drives across a crater during the attempt. 600 points – 35 = 565 points.

#### 6.2.5 Autonomous Operations Scoring

Allowable Combinations	Excavation & Dump	Travel	Excavation & Dump – Full Cycle	Full Autonomy	Total
Ext: 1	150	-	-	-	150
Ext: 2	-	200	-	-	200
Ext: 3	-	-	300	-	300
Ext: 4	150	200	-	-	350
Ext: 5	-	200	300	-	500
Ext: 6	-	-	-	600	600

**Autonomous Score Sheet**

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 cannot be combined with Excavation & Dump – Full Cycle. Excavation & Dump and/or Travel automation points will not be combined with Full Autonomy.

## SECTION 7: COMMUNICATIONS

*Coming soon!*

## SECTION 8: UCF ON-SITE WEEK INFORMATION

*Will be released 1-2 months before the competition*